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The aim of this paper is to investigate the potential power of mathematics in a socially difficult environment, as a high-security prison. More, we ask whether mathematics can enhance social skills (ethic skills, in particular), not only in prisoners: we present a mathematical experimentation involving prisoners, as those who, by means of mathematics, first learn ethic skills and then teach ethic skills to people from outside the prison, with a methodology we call "Mathem-Ethics". The theoretical framework we work with is Horizontal Teaching, which provides a way to learn for both learners and teachers. We briefly discuss some results of the experimentation, in terms of its efficacy on people from inside and outside the prison.

Keywords: Mathematics education, ethics, social change, horizontal teaching.

Introduction.

"Mathematics is bad for society", said Arvid, an 11 years old student, in a challenging tone (Ryan et al., 2021). What Arvid was brave to say, is perhaps, shared by many students of different ages. As Wright (2019) highlighted, quite often mathematics is reduced to a set of rules and procedures to memorize and apply (OFSTED, 2012; Foster, 2013), resulting in many children (and adults) continuing to exhibit alienation from mathematics (Nardi & Steward, 2003). Nowadays education aims more and more towards functional mathematical literacy, that refers to the capacity of creating and applying mathematical knowledge when required in real life (Jablonka, 2003), and many efforts are taken from researchers and teachers to enhance mathematical skills in students that are useful for developing citizens able to solve real life problems that require mathematical literacy. But still, it is a common idea among students that these mathematical skills are only technical, and are not useful in social life. If mathematics is not bad for society, at least it is seen as useless for society, not connected to ethics and not useful to contribute to a life change. "Discussions about the connections between mathematics and democracy amongst the general populace have not been explicitly well rehearsed, other than to either assume that mathematics has nothing to do with anything political, being neutral in form and practice, so it has nothing to do with democracy, which is something political; or that it is implicitly democratic." (Swanson, & Appelbaum, 2012, p.1). However, mathematical literacy is relevant to both social and economic needs and to an individual's participation in today's democratic society (Jablonka, 2003; Skovsmose, 2007). If there are those who think mathematics is a tool to obtain social training in obedience, an industrial trainer (Ernest, 2019), Swanson and Appelbaum ask whether disobedience to the evocative power of mathematics could be itself a democratic action. Democratic teaching practices may have a positive influence on students' learning outcomes in the mathematics classroom. This may be because successful democratic teaching and learning is conceived as situations where "individuals are able to think for themselves, judge independently, and discriminate between good and bad information" (Dewey as in Orrill, 2001, p. xiv). Therefore, there is a need to rethink teaching, taking into account the social dimension. Both Vithal (1999) and Aguilar and Zavaleta (2012) pointed to the need for empirical studies to experiment with existing theoretical ideas on the connection between mathematics

education and democracy. Daher (2019), for instance, presents a study to assess four democratic practices (freedom, equality, engagement and justice) in the mathematics classroom. If mathematics education can be used to develop citizens' skills to sustain a democratic society (Aguilar and Zavaleta, 2012), it should be even more important to develop it in a context where the students are prisoners. This has not been investigated so much and it is the focus of this paper. Several mathematical activities with students that are inmates have been successfully carried out in Swedish prisons (Helenius and Ahl, 2017; Ahl and Helenius, 2020). The authors highlight that successful mathematics education in prison can play a role in producing identity change increasing opportunities for re-entry in the society. In this paper we present a project, called *Vietato non toccare (Don't not touch)*, carried out in a high-school in a high-security prison in Sicily (Italy). This project aimed to enhance mathematical skills in inmate students through a laboratorial approach, in order to improve motivation of students and their sense of self-efficacy, i.e. confidence of success in handling a problem (Bandura, 1997). More, we aimed to use mathematical education for ethical purposes, with a methodology that we call *Mathem-Ethics*, experimenting with a way to use mathematics to achieve a change of life. We call Mathem-Ethics a methodology to teach/learn mathematics, giving precise ethical meanings to mathematical concepts. It is possible to design mathem-ethical activities, with the precise target of enhancing both mathematical and social skills. Our research questions are: "Is it possible for inmate adults to acquire ethical skills by means of a mathem-ethical path that will help them with a real life change?" (RQ_1), "Is it possible to enhance social skills in people by means of a mathem-ethic path in prison?" (RQ_2). In this paper, we first present the theoretical framework as the basis of our activity, Horizontal Teaching. Afterwards, we briefly describe the whole project and the methodology. Then we present the mathem-ethic path that was carried out. We end with some discussion and conclusions regarding the efficacy of the experimentation for those involved.

Theoretical framework.

Ethics or moral philosophy is defined as that branch of philosophy that involves systematizing, defending, and recommending concepts of right and wrong behaviour. Ethics is born, already with Socrates and many Greek philosophers, to answer questions of human morality by defining concepts such as good and evil, right and wrong, virtue and vice, justice and crime. It is a common opinion that social sciences, like literature, art, history, are didactically useful for ethics investigations in students. It is our opinion that mathematics too can be used to learn concepts useful for students' lives, in general, and to ethics, in particular. The theoretical framework we use to achieve ethical goals is based on Horizontal Teaching (HT) (Ferrarello et al., 2013). In teaching/learning environments, the actors are the one who teaches, the teacher, and the one who learns, the student. These two figures generally have distinct roles and, in traditional environments, the teacher transfers his/her knowledge to the student, we might say in a "vertical way", top-down. In HT, on the other hand, there is a teacher's awareness: the teacher is willing to challenge him/herself and expand his/her knowledge by entering the sphere of the student's knowledge. In fact, in HT, the two sets of knowledge, the one of the student and the one of the teacher, are placed at the same level and initially have an intersection (Figure 1a); the teacher must be able to enter into this intersection and expand it, so that the knowledge shared is greater than at the beginning of the process, expanding not only the student's knowledge, but also his/her own (Figure 1b). The expansion of the teacher's knowledge takes place not only in terms of content, but also with respect to the students' experiences, their interests, their learning styles. The expansion of students'

knowledge is not only about content, but also about the way they learn, contributing to enhance their mathematical literacy (Jablonka, 2003). So it is not only the student who absorbs from the teacher's knowledge but also the teacher expands his/her knowledge: this is the fundamental characteristic of Horizontal Teaching.

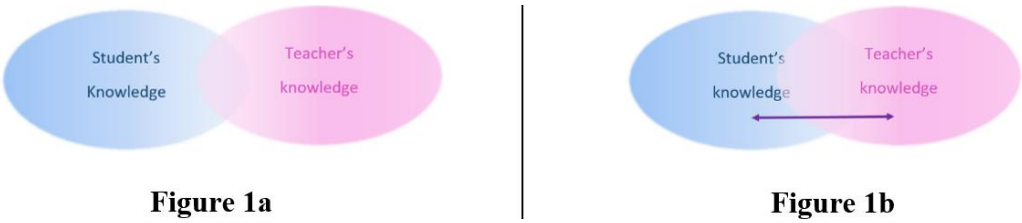

Figure 1a **Figure 1b**

Figure 1: Horizontal Teaching

In the HT model, learners are seen in relationship with themselves, but also with the other learners and the world, just as in Maheux & Roth (2011), where the authors describe a way of thinking about knowing, namely relationality, starting from the biological theory of cognition, (Maturana & Verden Zöller, 2008). Human beings are theorized as complex biological "learning systems" that coordinate with the co-emerging environment that they "bring forth" (Maturana & Varela, 1998) and in knowing mathematically, the learner and the knowledge are not independent entities. The novelty of HT, with respect to this model, is the role of the teacher, who becomes a learner too, sharing with the other learners (the students) their participation in creating a new world of knowledge.

Description of the project and Methodology.

Vietato non toccare (*Don't Not touch*), https://sites.google.com/view/dontnottouch/home, is a project conceived in 2017, when one of the authors won the *Italian Teacher Prize*, promoted from the Italian Ministry of Education. It was carried out with adult inmates in the high-security prison of Bicocca, within the high-school "K. Wojtyla" of Catania. It aimed to create an exhibition of mathematical objects in prison, and it consisted of three steps: 3D-printing of some objects, (Step 1); mathematical training of inmate students on the created objects (Step 2); guided tours of the exhibition (Step 3). The exhibition consisted of four sections (see Table 1).

Table 1: Sections of the exhibition

Section 1	**Not orientable surfaces**: Möbius strip; Klein Bottle.
Section 2	**Pantographs for geometric transformations**: Pantograph for homothethy; Pantograph for axial symmetry; Pantograph for central symmetry.
Section 3	**Conicographs**: Cone with conics' sections; Ellipsograph with antiparallelogram; Ellipsograph with rhombus; Hyperbolograph with rhombus; Parabolograph.
Section 4	**Archimedes' machines**: Parabolic mirror; Coclea; Lever.

Most of the objects of the exhibition are mathematical machines (Bartolini Bussi & Maschietto, 2006). The authors led the training course for the inmate students (Step 2), to help them understand

the functioning of all the objects: 15 students were enrolled, just 3 became guides of the exhibition, because the others were moved to other prisons or got out of the prison. The training consisted of 20 meetings, held according to the methodology of the *Mathematics' Laboratory* (ML) (Anichini et al., 2004). In the ML, students are guided to discover and construct the concepts, supported by the teacher and their peers, in a collaborative and/or cooperative way. In fact, the ML is a set of activities carried out by students and teachers aimed at the construction of meanings of mathematical objects. In the ML, students do not study mathematics, but rather do mathematics, dealing with a problem, exploring, conjecturing, proving, applying. During the training (Step 2), every object was introduced by means of a problem, typically: "What does it do? And why?". The object was manipulated by students working together and under the guide of the teachers they developed an understanding of what the object does and why and they constructed the mathematical meaning lying within the mathematical object. At the same time, they were introduced to the ethical meaning of each section (see next paragraph). Learners are not only invited to touch, but rather they have to do it, in order to make visible and comprehensible the mysterious operating forces of mathematics, often remaining *unrevealed* (Roth & Maheux, 2015). Once the students finished the training course, they became guides of the exhibition and the gates of the prison were opened (Step 3). Visitors were students from school and university, teachers of all school grades, both mathematics teachers and not, university professors, both mathematics professors and not. Also the exhibition was organized as a mathematical laboratory: visitors were invited to touch the objects and manipulate them in order to understand their functioning. Together with the guides, visitors were assisted by the authors of the paper, who explained the ethical part of the various exhibition sections. Being in a high-security prison, we could not videotape the students or the visitors. We conducted a qualitative analysis, based on the spontaneous comments of students. They did not gain any kind of advantage in taking part in the project and they were not forced to write those comments. As for visitors, we administered a questionnaire with two questions. The first one differs according to whether the visitor was a student (question Q_S) or a teacher (question Q_T). Q_S: "Has your visit to the exhibition had or do you think it will have an *impact on the way you conceive mathematics*? (e.g. in relation to the social role that mathematics can play)"; Q_T: "Did your visit to the exhibition have or do you think it will have an *impact on the way you teach*? (e.g. with regard to methodologies, attitude towards students, topics etc.)". The second question was the same for both (Q_{ST}): "Did or do you think the visit will have an *impact on the way you behave in society*?"

The Mathem-Ethic path.

At the guided tours of the exhibition, all sections were presented according to their mathematical meanings and ethical meanings (Ferrarello et al., 2021) that we briefly describe here. Section 1- "Not-orientable surfaces: when *inside* and *outside* merge together": The objects we see every day have generally orientable surfaces, i.e. they have an inside and an outside, separated by a boundary, which we are forced to cross whenever we want to pass from inside to outside or vice versa. In life, we often classify things and people, by placing them inside or outside a certain set, with a very clear boundary. What we discovered, working with 'bad-by-definition' people in prison, is that, indeed, these boundaries are not as clear as we paint them, but rather blurred. Objects in this section were symbols of the meeting among people from inside (the prisoners) and from outside (the visitors) in

the neutral field of mathematics. Section 2 - "Pantographs for *transformations*: transform yourself by remaining true to yourself": In geometry, it is possible to transform a figure into another one, maintaining certain properties. A task of education should be to make students grow and evolve, by changing some things about them (transform yourself) and maintaining some of their features (remaining true to yourself). The school does not replace the students with new people, but rather transforms them. Objects of this section were symbols of the transformation of students and visitors. Section 3 - "Conicographs: Conditions for being in a *locus*". Conic sections are curves that can be described as geometric loci, i.e. we can describe a mathematical condition for a point, satisfied if and only if the point belongs to the curve. Being in a locus (a geometric one or, in a metaphor, in a real place) therefore depends on the conditions that one sets. Our behaviors (the conditions, in the mathematical metaphor) determine the effects on our life (the geometric locus, in the mathematical metaphor). If you really want to change the locus, then you have to start by changing the conditions. The ethical meaning of this section is the importance of self-determination to encourage students and visitors to own their own lives, taking them in hand and setting new conditions, to achieve new loci. Section 4 - "Archimedes' machines: Sicily, land of mathematics!". The place where the project has been carried out, Sicily, is often covered by prejudices associated with facts, people and ideas, which are not universal in Sicily: it is also the land of a millenary culture. Our exhibition is pleased to host a section of machines attributed to the Sicilian genius of Archimedes. In this section we want to remember Sicily for other facts, people, ideas and those that have contributed to our scientific culture: it is not only the land of mafia, but also the land of mathematics: like a person is not only a prisoner, but also, in this case, a guide of a mathematics exhibition (and much more).

Brief discussion and conclusions.

In this paragraph we briefly discuss the efficacy of the HT in the third step of the project: the guided tours of the exhibition, hosting people from outside the prison. In the following, we report in Italics some parts of the spontaneous comments from prisoners and answers from visitors. We underline where, as per the HT framework, students (blue set in Figure 1) can be also teachers (let us recall that visitors were teachers and students from outside), while teachers (pink set in Figure 1) are inmate students after becoming guides of the exhibition. In order to answer our first research question, RQ_1 ("Is it possible for inmates adults to acquire ethical skills by means of a mathem-ethic path to help them in a real life change?") we take into consideration the teachers' expansion, i.e. what the inmates, as guides of the exhibition, learned. We report some of their spontaneous comments. *This project brought into my life something unique and unimaginable. I didn't believe I could reach so much, and this makes me understand that also I have the skills and possibility to yearn for a future rich of occasions, and to give a turning point to my life*; and more. *This project involved a cultural change for us, but above all a personal one. At the beginning we were very enthusiastic but not very motivated, just because we gave limits to our potentialities, to our knowledge and intelligence. But by attending classes with commitment and passion we managed to get great results, making calculations, conjectures and evaluations. Until a few years ago, we would never have imagined debating on mathematical concepts. …* [We thank the teachers who succeeded] *to illuminate the way of our journey to a better future, believing from the beginning in*

us, teaching us that in life we must look beyond our expectations. But above all, thanks to mathematics, we know who we are and who we will be. Remembering that mathematics is not only made of numbers and sums, but also of much more! Thanks again for believing in us, and that we believed that the only thing you can't do in life is to divide by zero!. We underline that the inmates we worked with are all incriminated for mafia association (n. 416 bis of the Italian criminal code). Some of them are, by "family tradition" involved in crime and also did not have school education until they entered prison. Some, even if they are Italians, had difficulty also in speaking proper Italian, because they used to speak dialect. Moreover, inmates did not gain anything in taking part in the project. Little by little, they made *our* project *their* project and felt proud of being part of it. It is too early to see long term effects of this adventure, but for sure, from their word, we can say that a change already started. The 3 guides just finished high-school in prison and they are planning their future, even enrolling to university. In order to answer our second research question, RQ_2 ("Is it possible to enhance social skills in people by means of a mathem-ethic pathin prison?") we take into account the answers to the questionnaire by the visitors. As for Q_S, students visiting the exhibition expanded their knowledge seeing mathematics in a different way: they recognize that *it is possible to make mathematics also with a social role, a role of unity and education* because it can be a *tool for educating, growing, learning,* not *only for well-educated students,* but for all. *The myth of the social role entrusted mostly to social sciences has been dispelled*. As for Q_T, teachers visiting the exhibition had the opportunity to test the efficacy of the ML, whether they were math teachers or not. *Only those who play an active role in the learning process really learn: it is fundamental to let students having the pleasure of discovery. Asking the right questions, leaving space for silence, listening, observing together, providing tools, stimulating curiosity, are much more important activities than simply providing data and ready-made answers. Student as actors and not audience are happier and more effective* (from A. and P., not math-teachers that already work in a laboratorial way: the visit confirms their belief). We want to underline the position of N., a math teacher, who is revising his teaching practice, and he claims that the visit *has accelerated this revision process*. The teacher learned that *you cannot set a standard model to which the students must adapt, but the reverse process is needed: the teacher must adapt to the students.* Then all teachers benefit from visiting the exhibition expanding their knowledge in terms of teaching methodology. Let us move to Q_{ST}. Teacher P. wrote that *the way of behaving towards society has become more conscious*. The project *breaks down many commonplaces about prisons and prisoners* because the project shows that *the polarity of reality is a scam: true/false, good/bad, ignorant/knowledgeable, right/wrong, the polar view of reality is limiting, reductive, excluding* (target of Section 1 of the exhibition). Visitors (students and teachers) *discover wonderful people with a great desire for redemption*, and they found that *everyone needs to be recognized: trust, sincere appreciation, a smile, kindness, can help everyone grow much more than through disapproval and punishment* (target of Section 2 of the exhibition). Thanks to education, and also to math education *not always those who have committed a crime are bad people and can never change, [*they*] improve or try to take a new and better path* (target of Section 3 of the exhibition). Visitors *saw in their eyes* (the prisoners) *the desire to escape from a past that, now thanks to the experience made with the project, was "narrow"* (target of Section 4 of the exhibition). This led them *not to be prejudiced and do not judge too quickly, because the social, economic, cultural*

situation of each person varies according to the society in which they are born and grow up and they cannot choose that. While it is all of us who together can do something different and we can benefit from it all together! Visitors are inspired to do their best in a view of *I care*. A last consideration is the reciprocal relation amongst the people involved in the project. At every tour, the discourse always started with mathematics, and became more and more mathem-ethic. During the flow of the tour visitors and guides entered more and more into a confidential conversation. Usually, at the end, there was no more distinction between "inside people" and "outside people". One of the guides said that he *succeded to enter in to a relation with people, this was always my flaw*. The same happened to visitors. In the intersection of blue and pink sets (Figure 1), we find no difference between teachers and learners: a full Professor, visiting the exhibition, said "*I have had the pleasure of feeling ignorant in a singular place, where the last prove to be the first*". We hope that future mathem-ethics paths taken in prisons could open the doors to the development of social skills both in prisoners and in math educators. More to come!

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