Approccio Montessori, educazione ai concetti matematici e differenze di genere: come possono gli insegnanti rispondere all'ansia per la matematica?

Montessori approach, math education and gender differences: how can teachers manage pupils' math anxiety?

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ABSTRACT
Currently, research concerning anxiety and gender gap in mathematics has not yet provided an exhaustive illustration of the phenomenon, observed mostly through the neuropsychological lens. Since in the last twenty years studies in math education (and STEM in general) have shown how arithmetic skills are essential for being active citizens in the technological and digital society in which we live, finding an effective educational answer is fundamental for the future. The aim of the present study is to analyse the characteristics of the educational action of a Montessori teacher, crossing them with evidence obtained from psychology and neuroscience regarding the effects of math anxiety on learning.

Ad oggi la ricerca inerente l'ansia e il gap di genere in matematica non ha ancora fornito un'esaustiva illustrazione del fenomeno, osservato per lo più attraverso la lente neuropsicologica. Dal momento che nell'ultimo ventennio la ricerca in didattica della matematica (e delle STEM in generale) ha dimostrato come le competenze aritmetiche siano imprescindibili per essere cittadini attivi nella società, tecnologica e digitale, in cui viviamo, trovare una risposta educativa efficace risulta perciò fondamentale per il futuro. Il presente studio analizza quindi le caratteristiche dell'agire educativo di un insegnante secondo l'approccio Montessori, incrociandole con le evidenze ottenute dalla psicologia e dalle neuroscienze riguardo agli effetti dell'ansia matematica sull'apprendimento.

KEYWORDS
Gender Gap; Montessori; Mathematics Didactic; Inclusion; Mind, Brain and Education.
Gap Di Genere; Montessori; Didattica Della Matematica; Inclusione; Mind, Brain and Education.

* Il presente studio è stato realizzato congiuntamente dalle due autrici, tuttavia l'effettiva stesura del paragrafo 1 è attribuibile ad Alice Tovazzi, mentre quella paragrafo 2 è ascrivibile a Barbara Caprara. Le conclusioni rappresentano il risultato di un lavoro condiviso.

1. Gender differences and math anxiety in education

1.1. *Historical overview*

The interest in gender differences in mathematics raised in the 1950s, when researchers tried to understand why scientific disciplines seemed to attract more males than females, focusing on differences in achievements and interests. The numerous researches conducted since then have shown how the potential outcomes are equivalent in the two genders, thus discarding the hypothesis of a biological inequality and giving rise to new questions. Attention was hence paid to attitudes, perceptions and interests towards mathematics, in other words to the influence given by gender stereotypes. In particular, the existence of a vicious circle within different learning contexts has been hypothesized: conventional and immutable expectations and attributions on the part of parents and teachers would affect the acquisition of skills, with consequent discrepancies in the levels reached by male and female students (as can be seen from the results of the OECD PISA survey, for which the male advantage seems to unite students from all over the world). The results obtained from the PISA survey would confirm themselves stereotyped expectations, reinforcing the false idea of an innate gender difference (Hutchison et al., 2017).

In the 1970s was therefore supposed that one of the consequences of this phenomenon is represented by *math anxiety*, which has a higher prevalence in female students, hindering their scientific accomplishments. It was in those years that the Mathematical Anxiety Rating Scale was developed (Richardson & Suinn, 1972), but still in the successive decades in different educational environments persisted the idea that mathematics was destined to selected few students, in particular males, and that the failure to achieve satisfactory results from most of the female students was due to attitudes, laziness, or even their gender. In this second phase of the gender gap research, new evidence demonstrating how the female gender is directly correlated with the anxiety for mathematics has been obtained, underlying the negative repercussions on motivation and on levels of competence achieved by female students in all grades (Skagerlund et al., 2019).

1.2. *An educational perspective*

Math anxiety, defined as a state of discomfort and negative emotions during the performance of mathematical tasks (Ma & Xu, 2004), differs from *anxiety to test* for being experienced not only during assessments and for not being merely related to achievement worries. Anyway, both math and test anxiety cannot be differentiated from *general anxiety* until 6th grade: for this reason personal protective factors in the earlier school years consist in high levels of self-concept and resilience (Mammarella et al., 2018), while parents and teachers' stereotyped attributions, but also pressure given during lessons, represent a risk factor (Rubinsten et al., 2018). Pressure indeed seems to act like a stressor thus overloading working memory (Soltanlou et al., 2019): stressing situations are not favourable for learning, shifting students attention on the outcome and not on the process of the task, leading them to choose suboptimal strategies, but also affecting their motivation (Caviola et al., 2017). Moreover, according to the reciprocal theory for math anxiety, math anxiety can spring from a situation of low math achievement, in some cases due to a genetic predisposition (Wang et al., 2014), but it is the continuation of this kind of situation that maintain math anxiety, in a vicious circle (Carey et al.,

2016). The persistence of this situation can lead to a gradual alteration of the neural architecture, firstly limiting attention and inhibitory functions (depleting working memory resources), with consequent lower performances in complex math tasks, secondly with a reduction of grey matter volume in the intraparietal sulcus, lingual gyrus and cuneal cortex, portions crucial for math functions such as number processing and calculation (Hartwright et al., 2018), and thirdly changing the structure of the right amygdala, which processes negative emotions (Kucian et al., 2018).

As written previously, another risk factor is represented by parents and teachers attributions: their educational role has a significant influence on girls and boys attitudes and believes towards math (Soni & Kumari, 2017). It has thus been revealed that anxious female teachers influence female pupils, and not male pupils (due to greater gender-based identification), increasing their anxiety levels towards the discipline (Beilock et al., 2010). Once the low expectations have been internalized and stereotyped self-attributions have been elaborated, students will be strongly influenced, with serious repercussions on future learning quality. These discoveries are particularly relevant in countries like Italy, where the female component in primary teaching exceeds 95% (OECD, 2017) and it is not possible to exclude a relationship between this percentage and the third last place occupied by Italy for gender equality in the mathematical learning of the entire OECD area. From the last PISA survey (2016) in fact, it emerges not only that 23.4% of Italian students do not reach the minimum levels of competence, but also how this percentage is mainly represented by female students, data also confirmed by the Invalsi surveys (2018).

2. The Montessori approach

2.1. *The pedagogical view*

Montessori (1870-1952) outlined an educational system aimed at the long human childhood (term used by the Doctor during the training courses she held between 1949 and 1952), in which different educational plans correspond to the individual's different development plans, from birth to adulthood. It is an educational offer that consists of an organic set of proposals, designed on the basis of a precise psychological theory and a philosophy of relations between man and the world. This system has been defined and is universally known as the "Montessori method" but it is understood that this is not just a method, since it «cannot be reduced to a collection of instructional techniques or curricular objectives or didactic materials» (Cossentino, 2005, p. 212).

The pedagogist did not intend, in fact, to indicate a prescriptive educational model, but wished to elaborate, on the basis of lived experiences and observations, an orientation aimed at the development of the human personality (Montessori, 1992). Consequently, in our opinion, the "method" can only be seen as an open and permeable proposal, applicable also in fields that differ from education.

Although the Montessori phenomenon is characterized by stability and consistency, it should be noted that the definition of the method remains today the object of different interpretations; educational practices can also vary considerably from context to context, from country to country. However, there remains a global agreement on the fact that at the basis of the current success and spread of the Montessori proposal are precisely its unchanging founding characteristics and in particular three peculiar and distinctive elements: «a comprehensive and stable method of Pedagogy the construction of classrooms as developmentally

prepared environments and a system of teacher training that places equal emphasis on the acquisition of highly complex technical expertise and the cultivation of a teaching disposition aimed emphatically toward following the child» (Whitescarver & Cossentino, 2007, p. 2).

At the centre of the method we firstly find a new vision of childhood, which considers the child as a proponent of its own development, being able to realize its human potential in a work of delicate construction of the personality through self-education. In an educational context, this translates into the fact that every child is welcomed in a prepared environment, where he or she is invited to work at his or her own pace, motivated to learn through the materials chosen on the basis of one's personal interest, in a process of individualized learning (Malm, 2008).

2.2. *Montessori teacher's portrait*

To carry out the role of interpreter of childhood, Montessori takes a very rigorous attitude and organizes her intuitions around a coherent system of techniques, procedures and materials organized into specific objectives and targets. All single individual elements are in fact closely connected to each other and they cannot be interpreted separately, without causing an alteration of the principles themselves, thus frustrating the educational work.

To fully understand the operational choices proposed within the Montessori schools, it is necessary to take as a fundamental instance the diversity of the child with respect to the adult, in timing, in rhythms and in learning modalities: the subject who learns must be put into the condition of being able to *build*, following their own internal needs, knowledge and skills. The school should therefore be able to effectively correspond to the psychological needs of children, favouring materials that allow active manipulation experiences, allowing the *hand* (irreplaceable organ in the path of knowledge) to bring the child closer to abstract speculation through a motor path. In order to guarantee freedom of choice and expression, it is therefore necessary to resort to indirect teaching, in which the scientifically organized environment, through specific materials (sensorial and non-sensorial), can facilitate the understanding of concepts, through a motor-oriented and respectful methodology of the freedom of the child with regards to the choice of the "what", of the "where" and of the "how long" to learn. The adult must have confidence in the spontaneous interest of the child, who, if placed in the right environment, scientifically prepared, can follow a completely internal development plan, spontaneously feeding his or her own interest to learn through work, construction and bringing to term the activities he or she started.

The material used in the Montessori approach is called *development material* as it does not present itself a simple didactic material in the hands of the teacher who offers help during his or her work, but guides the child in his or her *self-education*. Its use, in fact, allows the child who explores and knows the reality to become aware of his or her errors, through the mechanism of self-correction, and to acquire independently different concepts explored, moving from concreteness to abstraction. Different materials, presented by the teacher in a gradual order, concern the classic thematic areas of learning, such as the development of knowledge related to the five senses, the concepts of mathematical thinking, the rules of linguistics and disciplines such as geography, history and science dealt with in an interdisciplinary perspective.

In summary, a Montessori teacher has numerous tasks: on one hand he or she must know well the materials and how to present them at the right time of the child's

development, while using a few but precise words *"le parole tue sien conte"* (be your words few) said Montessori citing Dante, on the other hand he or she should monitor and keep the educational environment tidy, while observing each child in free interaction with materials and the environment. In doing this, the teacher must be very careful to provide help that supports the pupil's autonomous path, without suppressing his or her free expression nor replacing it: "The teacher does nothing but help him at the beginning to find his way through so many different things and to learn their precise use, that is, she begins him to an orderly and active life in the environment; but then she leaves him free in the choice and execution of the work". (Montessori 1999, p. 69) In this regard, we believe it is important to better clarify the fundamental characteristics of the three-period lesson, a modality which is useful for the teacher in order to explain precisely how the materials of development are managed, and which differs from the classic frontal lessons centred on the adult rather than on the child. For Montessori, the lesson must have three fundamental characteristics. The first is brevity, in fact the teacher must be as concise as possible in his or her explanation, succeeding at the same time in getting the message to the child in the correct way; he or she must therefore be clear and concise. "Perfection consists in the search for the necessary and sufficient minimum" (Montessori, 1999, p. 117). The second is simplicity, that is, the teacher must use simple words in order to reach the child as directly as possible; they must "represent the exact truth" (Montessori, 1999, p. 118). The third and final characteristic is objectivity, i.e. the teacher must place himself or herself as objectively as possible in front of the child during the explanation; "The teacher's personality disappears, and only the object remains in evidence, on which she wishes to focus the attention of the child" (Montessori, 1999, p. 118).

Conclusions

Although the scientific community has made great efforts over the past 60 years to define mathematical anxiety (Dowker et al., 2016), highlighting a constant decreasing incidence in learning contexts, the reduction of the gender gap in scientific disciplines presents a fragmented patchwork on the planet and, in addition, in no country is the diminution sufficient to compensate this gap (Hutchison et al., 2017). Hence, promoting processes of teaching-learning that enhance confidence, resilience, self-esteem and self-efficacy, but also experiences of high success in math is fundamental in order to avoid high rates of math-anxious pupils. The Montessori approach represents thus an optimal solution, especially for first grades, when the vicious circle of math anxiety begins: Montessori defines precisely the teacher as a director, because she or he mainly plays the role of the class observer, tending not to teach in first person, but rather to direct the children in their physiological and psychic development, favouring contacts with the materials. The teacher must not transmit concepts to the students, but on the contrary must guide them in their growth by intervening as little as possible. The teacher's fundamental tasks in Montessori schools, as well as careful observation, are the management of the classroom environment (which must always appear neat and clean, in order to facilitate the free choice of materials by children) and the presentation of materials themselves, which should take place according to some particular form of lessons: the individual one, in which the teacher sits on the right of the single child; the three-period lesson, which is dedicated to sensory materials; the great lesson, that involves everyone and aims to intrigue and stimulate the students' imagination; the key lesson and the complementary lesson of

details. A teacher understands if he or she has operated in the best way, as he or she observes that children are able to work focused and interested even when he or she is not present. The role of the teacher as a director, therefore, given the tasks that must be carried out, can be compared to what the therapist carries out within the relationship that he or she creates with patients, as he or she must not tend to impose the own will to others, but rather to enhance individuality and autonomy (Opera Nazionale Montessori, 1993). It is consequently difficult for a Montessori teacher to transfer to the pupils his or her own attributions, expectations and believes, avoiding stereotypes often subconsciously transmitted in classrooms.

We would finally underline how the global diffusion of Montessori realities is linked to the topicality of this proposal, which is more and more often object of scientific studies that, from various points of view, confirm its validity and allow us to affirm that: «Modern research in psychology suggests the Montessori system is much more suited to how children learn and develop than the traditional system» (Lillard, 2005, p. 3). It is precisely from these considerations that it was decided to consider the Montessori proposal and make it the object of a still ongoing study, finalizing the research to aspects related to the understanding of basic mathematical concepts with particular attention to the relationship between math learning and anxiety in girls and boys.

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