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ORIGINAL PAPER

From teaching for war to acknowledging vulnerability: a cartography of gender and mistake-handling in mathematics education

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Abstract
This paper looks at the impact of gender on the way mistakes are managed in mathematics education. If first describes the historical interweaving of error, mathematics and gender. Subsequently, using microsociology based on a feminist and socio-constructivist paradigm, it documents and analyses both practicing and trainee mathematics teachers' experiences of error. We identify the effects of hegemonic masculinity on contexts of mathematical teaching and learning. With respect to mistake-handling related experiences, this manifests as competitiveness and aggressiveness, which have significant ramifications for student participation, particularly in the case of women. In response, we propose metacognition-assisted solving of problems with a low floor and a high ceiling as means to move away from mathematics education for war towards the recognition of vulnerability.

Keywords Mathematics education · Mistake · Gender studies · Vulnerability · Cartographic approach

Mistakes are an inevitable part of any learning process. Errors, that is, mistakes which are not "easily corrected when pointed out", but instead "systematic, persistent and pervasive" (Brodie 2011, p. 223), are a key resource for enriching mathematics learning (Alvidrez, Louie and Tchoshanov 2022). While academics and professional associations in mathematics education share this consensus, in practice incorrect answers continue to be treated as something to avoid, and education systems stress the advantages of success and the disadvantages of failure (Zhuang and Conner 2022). This phenomenon is not unique to

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mathematics, but a negative view of error seems particularly widespread in this field. This prevalence may be related to the type of truth constructed in this branch of knowledge, as a logical proposition in mathematics has two, exclusive, truth values: true or false. Maria Tulis (2013) suggests that seeing responses in mathematics through the lens of this correct–incorrect binary may partially explain why maladaptive patterns in teacher responses to errors occur more often in mathematics than in other domains.

The exceptionality of mathematical knowledge has a long-standing presence in philosophical reflections on knowledge. Michel Foucault (1972), for example, exempted mathematics from his criticism of science in *The Archaeology of Knowledge*, a reflection of the reality that "postmodern challenges to truth and authority do not extend to mathematics in any clear way" (Damarin 2008, p. 115). For his part, Thomas Kuhn (2004) differentiated mathematical proofs from other forms of deduction, arguing that, in mathematics, in the case of disagreement, ultimately one party must always acknowledge having broken a universal rule.

In addition to its particularity as a form of knowledge, mathematical ability has acquired extraordinary status as compared to ability in other disciplines at both an international and interpersonal level (Gates and Vistro-Yu 2003). It has become a signifier of intellectual capacity not just of individuals, but nations. Resultantly, a mathematically capable population has come to be understood as a condition for achieving the technological and scientific advancement that has become an explicit national priority in many countries (Gayozzo 2022). Technical advancement has a significance beyond material improvement, as progress, a key tenant of the discourse of modernity, both promises and lionises control over the natural and social worlds. This may be a contributing factor in the collective aversion to failure that prevails around mathematics.

Specifically in relation to mathematics education, there has been a long-standing tendency for research to focus on identifying patterns in student and teacher errors, the ideas that generate them, and interventions to reduce them. This may also have contributed to the idea that error is synonymous with deficiency (Leron and Ejersbo 2021). It is also an indicator of the historic pervasiveness of cognitive psychology in research conducted in this field (Kilpatrick 1992). Suzanne Damarin (2008) has argued that the hegemony of this approach hindered alternative research, and that the biologistic and uncritical tone of questions and answers led to the effect that context can have on mathematics education being largely ignored.

Since the late 1970s, researchers have increasingly recognised the need to take into account the influence of social, cultural and economic factors on processes of construction, learning and teaching of mathematics (Gerdes 1991). Interest in mathematics and mathematics education from disciplines including sociology, anthropology and philosophy has led to an increasing volume of research from constructivist, critical and postmodernist approaches. This has displaced positivism and established the importance of context. The aim of many contemporary researchers is to understand outcomes and/or explore possibilities of deconstruction and emancipation, rather than "'predict' social phenomena by 'objectively' observing and measuring a 'reasonable' universe" (Stinson and Bullock 2012, p. 43). These developments have impacted research related to both gender and error.

With respect to research addressing mathematics, education and gender, the diverse post-cognitive approaches previously listed seek to offer sociological readings of masculinity in mathematics, and/or emphasise the desirability and possibility of transformation (Leder 2019). Research from this perspective has also made it possible to deconstruct untested assumptions about mathematics education, by asking questions such as: What is counted as mathematical knowledge and ability? Who is excluded from mathematics under such definitions? (Atweh and Cooper 1995).

This shift in priorities and interests is also evident in research on error and mathematics education. Since the 1970s, a behaviourist approach has given way to a constructivist view (Hoth, Larrain and Kaiser 2022). From this perspective, error is understood as a learning opportunity. This conceptualisation opens a space for the continuous and progressive improvement of the quality of students' mathematical knowledge (Groth and Bergner 2021). Error becomes a resource with which to deepen students' ways of understanding and doing, which are often not either entirely right or wrong, but on a spectrum (Leron and Ejersbo 2021). This shift has also occurred across the wider context of STEM education (Simpson and Maltese 2017). Relatedly, an increasing volume of research focuses on the sociocultural dimension of the experience of error. Rosella Santagata (2005), for example, reasons that classroom practices around error are highly impacted by cultural context. Sarah Lubienski (2002) argues that treating mathematical error as shameful and to be avoided reinforces social inequalities, as the social consequences of making mistakes tend to be more severe for marginalised groups.

This paper adopts a deconstructivist approach as a means of achieving insight, and facilitating transformation in the present. Informed by this approach and by personal experience, we had ample reason to support the argument that the negative view of error prevalent in mathematics education has a greater impact on the mathematical practice of girls and women. As a result, we chose to look at the role gender systems play when handling errors in this field. To do so, we analysed the presence and impact of values historically associated with hegemonic masculinity and gender–mathematics stereotypes in the experiences and discourses about error among both practicing and trainee mathematics teachers.

While we were keenly aware of disadvantage and exclusion, we did not assume that these were the only dynamics in play. Foucault (1980) and Rosi Braidotti (2002) observe that power dynamics are always complex and leave space for resistant and alternative practices. We sought to identify these and to strengthen them through deliberate intervention.

This included an experiment that we carried out in a math subject that is part of the Degree in Primary Education offered at the Vitoria-Gasteiz campus of the University of the Basque Country. We developed several classroom activities that focused on metacognition and included careful problem design. This enabled us to develop practices based on a more productive vision of errors. In the findings and discussion section of this article, we look at the effect of this experiment in terms of building more inclusive mathematics and mathematics education.

Mathematics and hegemonic masculinity

Modern values historically linked to hegemonic masculinity, including objectivity, power, progress, control, universality and competitiveness, permeate mathematics. While she is addressing science more generally, we would apply the insight of Evelyn Fox Keller (1985) to argue that this not only establishes what mathematics consists of and what it is done for, but also impacts the imaginary of who does mathematics:

> A science that advertises itself by the promise of a cool and objective remove from the object of study selects for those individuals for whom such a promise provides emotional comfort. Similarly, I suggest that a science that promises power and the exercise of dominion over nature selects for those individuals for whom power

and control are central concerns. And a science that conceives of the pursuit of knowledge as an adversarial process selects for those who tend to feel themselves in adversarial relation to their natural environment. (Fox Keller 1985, p. 24).

While scientific culture has evolved over time and science and mathematics are now open to wider participation, values and attributes including detachment, domination, and competition are still at the core of modern scientific ideology. Due to their alignment with hegemonic masculinity, they produce an archetype of the modern mathematician who is, resultantly, masculine, which makes mathematics a means by which masculinity can be performed. Sarah Hottinger (2016) provides support for this reading through her analysis and comparison of portraits of a woman and a man, both mathematicians from the seventeenth and eighteenth centuries, concluding that these images present femininity and the archetype of the mathematician as mutually exclusive.

We do wish to make it clear that historical links between mathematics subjectivity and hegemonic masculinity do not determine the mathematical identity of every individual in the present. As pointed out by Heather Mendick (2005), "that people whose bodies are socially marked as feminine do things that are socially marked as masculine and vice versa is not surprising". Nevertheless, the author reasons, being marked as a man or a woman "impacts on one's possibilities for acting …; not all positions are equally available to all people" (p. 246). When we describe participants in this research as "boys" and "girls", we do so with reference to hegemonic categories of enacting gender that impact, but do not determine, their identities. We explore ways of enhancing the possibilities for acting in mathematics of people whose bodies are not socially marked as masculine. By doing so, we seek to redress some of the harm caused by the ongoing often inappropriate assumption that gender is a natural or unproblematic system of categorisation.

Engagement and gender–mathematics stereotypes

As compared to the eighteenth century, women are now much more likely to participate in mathematics and science in most societies (Zouda 2018). Despite this, many stereotypical beliefs related to mathematics and gender persist, and these reproduce gendered biases in the educational community (Amurrio, Larrinaga, Usategui and Valle 2012).

Luis Bonino (2002) suggests that hegemonic masculinity, that is, the normativising configuration of social practices for men predominant in our patriarchal cultures, is embodied through a series of beliefs or mandates. These include heroic bellicosity, in which the prototypical figure is the hero whose mandate is to compete and win. The gendered socialisation of boys thus encourages them to take more risks. Moreover, in general, boys receive more support when developing their self-confidence, initiative, problem-solving skills, resilience, determination, competitiveness and capacity for risk-taking. Resultantly, making a mistake poses less of a threat to gender performance for boys than for girls.

The above dynamics are reflected in gendered engagement with mathematics. This emerges from a very young age, even before children acquire basic numeracy. Anna Günther-Hanssen, Anna Danielsson and Kristina Andersson (2020) reached this conclusion after observing the emergent science and mathematics work done by kindergarten students. Girls and boys tended to form their own groups in which they performed gendered routines. Boys' routines occupied much more physical and acoustic space than those of girls. As Judith Butler (1990) argues, repeated actions are key in shaping gender identity. For this reason, it is important to observe and intervene in routines that reinscribe the performance of gender and science.

As well as engagement, the perception of mathematical ability is also impacted by gender. When girls experience difficulty with mathematics, this is seen as a sign of their inability. In contrast, boys' failures are seen as a symptom of laziness or lack of maturity (Real-Ortega and Ursini 2010). Thus, unsurprisingly, girls themselves tend to attribute failure to their innate lack of intelligence or inability to understand mathematics. Boys, on the other hand, tend to blame failure on a poor relationship with the teacher or lack of support (Ursini, Ramírez, Rodríguez, Trigueros and Lozano 2010).

Microsociology as a window on error management in mathematics

Both authors of this paper are practicing mathematics teachers in higher education. This positioning allowed intimate access to mathematics classrooms, a privileged site from which to observe and experiment with error management. The approach we used to engage in systematic reflection from within was microsociological research. This involves analysing social processes that take place in everyday life, including the forms that class, gender and race are manifested in specific contexts and interactions (Castillo-Hernández 2017). We focused especially on the impact of values historically linked to hegemonic masculinity and gender–mathematics stereotypes on ways of managing, experiencing and inhabiting the error in mathematics. Using microsociology and inspired by a Foucauldian conception of power (Foucault 1980), we engaged with both social structures and social action to overcome the agency–structure duality. This had repercussions at a conceptual, pedagogical and methodological level.

Conceptually, the idea of the negotiated self became a core concept when defining gender, mathematics identity, cognition and learning. We understood gender as a set of "cultural meanings associated with behaviour, personality and expressions conventionally labelled as feminine or masculine" (Lindqvist, Sendén and Renström 2021, p. 334). Further, gendered traits and actions are placed in a hierarchy, with those defined as masculine generally being valued more highly (Reisner 2015). Understanding gender in this way enabled us to focus on how gendered power relations are reflected in and reproduced by classroom practices and discourses. It is also important to note that gender is dynamic, changing, intimate and spectrum-like (Esteban 2009), best conceived of as constructed performatively in constant interaction with one's environment (Butler 1990). Similarly, we consider that mathematics identity "encompasses a person's self-understanding … in the context of doing mathematics" (Martin 2006, p. 206), and "how others construct us in relation to mathematics" (p. 207). We understood identity as something one does, not something one is. By doing so, we aimed to underline its relational and dynamic nature (Chronaki 2013), as well as to widen the lens from the individual to address context, social groupings and power (Darragh 2016). In the same way, we approached cognitive development not as a static and predetermined process that precedes learning, but instead a dynamic process that is transformed by the context of each student (Vygotsky 1988). We understood learning as a process situated in social interaction, rather than the addition of information to an individual mind (Lave and Wenger 1991).

Over the research period, we adapted our pedagogical practices and materials in order to better reflect these theoretical understandings. In line with a socio-constructivist understanding of mathematical learning, we designed low-floor, high-ceiling mathematical problems and promoted the use of metacognitive tools for problem resolution. One of our objectives in doing this was to make engagement with the error in mathematics class more productive, especially for our women students.

Methodological framework, research design and method of analysis

In this paper, we analyse the connections between a restrictive view of error, values historically linked to hegemonic masculinity and gender–mathematics stereotypes, understood as a repertoire of norms that enable or constrain actions depending on one's social positioning. We also delve into the implications of the pedagogical transformations mentioned in the previous section, paying close attention to gender. By doing this, we seek to deconstruct mistake-handling practices linked with a negative view of error and explore more inclusive alternatives. The nuances of how this was carried out are described in the following subsections.

Overarching methodological framework

Our research process consisted of developing a cartography, described as follows by Braidotti (2002), a pioneer of this approach:

> A cartography is a theoretically-based and politically-informed reading of the present. A cartographic approach fulfils the function of providing both exegetical tools and creative theoretical alternatives. As such it responds to my two main requirements, namely to account for one's locations in terms both of space (geo-political or ecological dimension) and time (historical and genealogical dimension), and to provide alternative figurations or schemes of representation for these locations, in terms of power as restrictive (potestas) but also as empowering or affirmative (potentia). (p. 2)

A cartographic approach aligned with the theoretical and conceptual framework of the study in a number of ways. Firstly, it offered a good fit for the microsociological nature of the study, as it stressed the importance of paying close attention to micro-practices carried out on a daily basis, on the one hand, and of doing research from within and in connection with our environment, on the other. This provided a means to make the researcher's own political and historical positions explicit and recognise that the researcher is also a research subject. Moreover, cartographies are both critical and creative mapping practices (Cozza and Gherardi 2023), which match the deconstructive and transformative vision described in the introduction. Finally, Braidotti's (2002) characterisation of power offered a means to overcome the agency–structure duality. Cartography as a methodological approach inspired the research design, which is described next.

Research design and data collection

This article is based primarily on Uzuri's PhD thesis, carried out at the University of the Basque Country, a public university in Spain. This thesis examined the mathematical discourses, practices and experiences of both practicing and trainee mathematics teachers in order to gain insight into the ways in which gender is configured in mathematics education.

The PhD thesis was conducted simultaneously with designing and delivering the subject *Mathematics and its Teaching I* to students enrolled in the first year of their Degree in Primary Education programme, and much of the research was carried out in this space and time shared with mathematics students. While cartographies should not be based solely on human-centred research methods (Cozza and Gherardi 2023), we did make use of interviews and questionnaires to enrich and enhance the validity of our research. The inductive and open-ended nature of the research allowed it to be carried in two phases which are described below.

Phase 1: exploration

This phase was used to identify provisional research questions for the PhD. It involved in-depth interviews with an intentional selection of participants, all of whom were engaged with STEM education. Most interviewees, 12 out of 15, were women. This was a deliberate choice because while subjugation is not the basis for an ontology (Haraway 1991), a subaltern gender position can give rise to a more complex view than that of social privilege (Harding 1991). Apart from position, positioning is a key practice that provides the basis for knowledge (Haraway 1991). Therefore, we selected respondents who identified as feminists.

Clara, Ester, Haizea, Irene, Karmen, and Rosa (pseudonyms chosen by the researcher) participated in interviews in 2018. All six were science teachers and researchers linked to the University of the Basque Country. All had conducted research in the field of mathematics or used mathematics in techno-scientific fields. In this paper, we focus on testimony specific to error and error management. The interviews included questions about their reasons for pursuing a scientific career, as well as about their academic and professional experiences in science and science education. A second block of interviews, carried out at the end of 2020, involved a selection of students who had been enrolled in *Mathematics and its Teaching I.* These students were identified as having a genuine interest in topics related to gender inequality, as demonstrated in their interventions and work submitted. Five women (Ane, Eire, Ilargi, Malen and Naia), three men (Andoni, Amets and Eneko) and one non-binary person (Lola) took part (pseudonyms chosen by the participants). The interviews included questions about students' reasons for pursuing a Degree in Primary Education, their mathematics identities and their gendered experiences in mathematics education. Interviews allowed the study to "become-with" in connection with the participants (Cozza and Gherardi 2023), as these encounters provided new mappings that were key for the design of the second phase of the research.

Phase 2: in the classroom

Students enrolled in *Mathematics and its Teaching I* at the Vitoria-Gasteiz campus in the 2020–2021 academic year were key to the research. Most of these students ranged in age from 18 to 21. They included 78 girls (55%) and 64 boys (45%). While this distribution is normal for the Vitoria-Gasteiz campus, it is unusual, given that 82% of all primary school teachers in Spain are women (Instituto Nacional de Estadística 2021). The difference in this case is due the fact that this campus offers a specialisation in physical education: 87% of the men enrolled in *Mathematics and its Teaching I* stated that this was the specialisation they wished to pursue. It is difficult to determine the impact that this may have had on the overall results of the research, but a more even gender split did facilitate a comparison between the men and women enrolled.

Students were not taught as a single group, but separated into three classes. In two of these groups, classes were conducted in Basque, and in the third, in English. The student body was quite homogeneous in sociocultural terms. Identifying as a Caucasian Basque woman at an early stage of her academic career, Uzuri shared similarities, in terms of cultural identity and socioeconomic status, with a majority of the student body. Students were informed, both orally and in writing, about the research process and objectives at the beginning of the course. None of the research implements impacted on the grades students received, and participation was voluntary. Over the course of the semester, five instruments were used to generate data for the PhD, which are described next:

- Uzuri's field notes. Over the second semester of the 2020–2021 academic year, Uzuri kept a field diary which covered over 200 h of participant observation. As well as capturing events, the notes included the emotional reactions, subjectivities and discourses experienced and encountered over this period. In line with the cartographical approach of the study, this enabled her to turn her experiences as a mathematics teacher into an object of research, and to remain aware of her own subjectivity (Braidotti 2002). In addition, ongoing review of field notes made the research process more dynamic. To give an example of how this worked in practice, Uzuri documented a conversation between students in which a clear preference for men as mathematics teachers emerged. This had obvious relevance to both the thesis topic and the existing literature. In response, an additional data collection instrument, the questionnaire described in the following paragraph, was added to the research process.
- An open-ended questionnaire to collect descriptions of mathematics teachers. Students described mathematics teachers who had taught them at some point in their lives. In total, 56 first-year students described 147 teachers. However, as coding did not reach saturation, students from other years were invited to fill in the same questionnaire. This produced a total of 243 responses including 580 descriptions of mathematics teachers.
- An open-ended questionnaire to qualitatively assess the subject. Students gave their opinion on different aspects of the subject, including problem solving. A link to this questionnaire was sent to all students enrolled in the subject in the last week of course. This was in addition to the generic feedback questionnaire administered by the university. A total of 79 students completed the questionnaire.
- Mathematical autobiographies. In recognition of the importance of offering space and time to reflect on mathematical experiences identified in the first phase of the study, students wrote or recorded first-person accounts of their own experience of mathematics education and/or participation in mathematical contexts. A total of 62 students completed and submitted their autobiography.
- Examination. The examination was not intended to be part of the research, but as an assessment tool for the subject in which the research took place. However, the process of correcting the examination offered an opportunity to gather data on how many students had employed the methodology taught in class for problem solving. A total of 71 girls and 56 boys completed the examination.

Andrea's field notes

For this article, the second author contributed field notes based on her own experience as a researcher working in the field addressed by the PhD. Andrea identifies as a Latina woman, mathematician, and established researcher. She is based in Chile and is currently researching topics related to gender studies in STEM. Her contribution to the data pool used in this paper was a collection of anecdotes in which she included stories and reflections on the mathematics–error–gender trinomial. In line with the cartographical approach already described (Braidotti 2002), the decision made by both authors to include their own subjectivity as part of the findings was intentional (Reznik, Massarani and Calabrese-Barton 2023).

Method of analysis

Datasets are not neutral and their meaning is not self-evident. Every time a researcher decides what to observe, ask or record, they are engaging in interpretation (D'Ignazio and Klein 2020). For this project, one of the most important phases of the interpretive process was the formal analysis of the data. This involved categorisation using thematic analysis and outlining relationships between emergent categories (Braun and Clarke 2006).

To analyse the interviews with scientists and students, preliminary coding based on the interview questions was conducted to organise the data. The next step consisted of a move from description to interpretation, making sense of patterns in the responses. On the basis of the patterns observed, in the case of the interviews with scientists, the data were restructured around seven themes, and in the case of the interviews with students, six themes.

For the descriptions of mathematics educators, emergent categories were identified over the course of a first reading. Using a modified version of the system developed by Berinderjeet Kaur, Phong Koay, Jamilah Yusof, Zaitun Taha and Khoon Wong (1999), these categories were classified in four blocks: personal characteristics (e.g. tendency towards anger), pedagogy (e.g. dynamics based on reward and punishment), relationships (e.g. ridicule) and repercussions (e.g. discomfort). Once a stable set of categories was established, relative frequencies with which they were mentioned in the descriptions were recorded.

The results from these analytic processes were used to assist the analysis of the mathematical autobiographies and the field diary. Rather than analysing these datasets inductively, excerpts relevant to the emergent themes from the earlier phase of research were identified. In the case of the subject evaluation questionnaire, items related to these themes (e.g. problem solving) were analysed inductively.

For the PhD thesis, four overarching themes that tied in with the overall research objective (i.e. to understand how gender is configured in mathematics education) were established. One of these was gender in experiences related to mistake-handling in mathematics. As mistake-handling was not a predetermined area of interest, but instead emerged during analysis, it was not present in data collected using every implement and not all participants spoke to the issue.

This paper extends the analysis of this theme beyond the PhD. Specifically, additional work included the in-depth analysis of the experiences of error recounted by participants. This analysis was guided by Sara Ahmed's (2006) phenomenology, and an understanding of identity as action. Within this approach, gendered aspects of mistake-handling in mathematics are understood as products of the repetition of certain norms, conventions, demands and prohibitions, rather than originary. This exposes "the sedimentation of history in the repetition of bodily action" (p. 553). Repetitions produce what Ahmed calls a *corporeal horizon*: a space for action that brings certain objects (including physical objects, but also objects of thought, feeling and judgement) within our reach while placing others beyond it (Ahmed 2019). This concept of *proximity* proved invaluable when defining gendered dynamics of mistake-handling, particularly in relation to the notion of *proximity* being *inherited*. The notion that the *repeated performance* of the labour required to reproduce gender norms conceals the effort involved—and thereby reinforces the perception of these norms as natural—was also a key theoretical precept (Ahmed 2006).

Gender and mistake-handling in mathematics

Learning a certain scientific discipline "is not merely a matter of acquiring knowledge" (Brickhouse 2001, p. 286), but also "a process of coming to *be*, of forging identities in activity in the world" (Lave 1992, p. 3). Doing mathematics, then, is necessarily tied to the performance of a mathematical identity. The particular social and historic context of mathematics have inscribed hegemonic masculinity onto the performance of it, especially with respect to mistake-handling. We focus on how this is reflected across different mathematics contexts in the following subsections.

Mechanisation, competitiveness and speed tests

Mechanisation or memorisation of basic calculations, for example, the times tables, is a widespread practice in mathematics education, especially at a basic level. The logic behind this is that a capacity to perform rote calculations leads to an ability to understand these operations as objects (i.e. as overall units) rather than as processes (i.e. as a succession of actions; Dörfler 1991). This shift from process to object is essential to the mental storage, processing and manipulation of mathematical knowledge (Tall 1993). Applying mechanised concepts is advantageous, as it demands less conscious effort and focus can be redirected to more complex mathematics.

While memorising some mathematical facts does have pedagogical value, it also entails some risk. First, memorisation and speed drills are among the most commonly used tools to promote this type of learning. These techniques can give students the impression that mathematics is *only* a set of methods and rules (Boaler 2016), and that being good at mathematics is about remembering and executing those methods and rules quickly (GenTIC 2017). Moreover, dynamics of competitiveness and shame can encourage students to hide errors, as when errors are made in the context of these activities, they are frequently corrected without giving students the opportunity to reconsider their reasoning or to explore the conceptual understandings behind their answers. This is associated with the development of negative emotions around sharing one's thinking in class (Steuer, Rosentritt-Brunn and Dresel 2013). Learning math facts through memorisation also "pushes students onto a procedural pathway that works against their development of a mathematical mindset", as deep understanding is often not available (Boaler 2016, p. 72). Concerningly, Sarah Wellberg (2024) identified a strong correlation between teachers holding a rules-based conception of mathematics and the belief that not all students are capable of succeeding in the subject. This can potentially lead to exclusionary dynamics. However, there are alternative means through which students can mechanise certain operations. In fact, Maragerete Delazer, Anja Ischebeck, Frank Domahs, Laura Zamarian, Florian Koppelsaetter, Christian

Siedentopf, Liane Kaufmann, Thomas Benke and Stephan Felber (2005) studied students learning math facts in two ways: through conceptual learning and through memorisation. These researchers found that students who learned through strategic approaches outperformed those who relied on memorisation, demonstrating equal speed in solving test questions and greater ability to transfer their knowledge to new problems.

Mechanisation was a recurring theme in our research data across different instruments. Mechanisation processes recounted by participants often involved speed tests and/or competitive environments. For example, in his mathematical autobiography, Gorka recalled speed tests as a regular activity in class: "The teacher would ask us to calculate a sum or whatever, and the first one to get it right would get to leave class first for recess." Beñat, in his mathematical autobiography, recounted broadly positive memories, stating that he was one of the best mathematics students in primary school, as well as "fairly quick in the task of completing 60 operations in 60 s". However, we found more consistent evidence of these practices causing discomfort in relation to mathematics learning, especially for women. For instance, in her interview, Nahia shared the following: "When we started doing mental arithmetic and exams, which consisted of doing I don't know how many calculations in ten minutes, it started to make me feel panicky". In her mathematical autobiography, Maier also had negative memories from her primary education mathematics classes because of speed tests: "They would give us a sheet with the multiplication tables, and then they would say, 'Ready, set, go!'. The first one to finish would shout 'Done!', and the rest of us had to stop as well". In these mechanisation processes, error tended to have a restrictive character, which sometimes made it a source of shame and/or something to be hidden. For example, in his interview, Eneko talked about having felt ashamed to admit that he didn't know the multiplication tables: "Everybody knew the multiplication tables and I still didn't … At home, I would cry and say that I didn't want to go to school the next day".

Anxiety derived from speed drills was more often mentioned by girls both in interviews and mathematical autobiographies. The existing literature also suggests that the effects of speed drills as a pedagogical tool are gendered (Boaler 2016). When memorising basic calculations as mathematical facts, the brain stores them in working memory. Under stress, working memory can freeze up, making it difficult to access the mathematical facts stored there. This is more common in girls and is related to mathematics anxiety (Beilock 2011). Thus, in competitive environments where error has a restrictive character, girls tend to perform worse than boys and tend to perceive more pressure (Örs, Palomino and Peyrache 2013). However, this is not the case in non-competitive environments (Jurajda and Münich 2011).

Observing these gendered dynamics does not imply any naturalisation of them: "Bodies are … shaped by contact with objects and others, with 'what' is near enough to be reached … What gets near is both shaped by what bodies do and in turn affects what bodies can do" (Ahmed 2006, p. 552). This *proximity* to certain objects (i.e. values, attitudes, aspirations, etc.) and not others is socially *inherited* (Ahmed 2006). In the case described above, this means that the doing of gender has an effect on the reachability of competitiveness as an attitude when doing mathematics, and, at the same time, this reachability affects the doing of gender. Beñat (man student), Nahia, and Maier's (women students) excerpts illustrate different levels of reachability of competitiveness and, hence, different engagements with it.

Competitive classroom culture that values achievement over understanding also tends to (re)produce other dynamics that can produce negative outcomes, such as subjecting students to ridicule for making a mistake (Burton 2004). For this reason, in the next section we discuss the punishment of error.

Aggression and ridicule

Punishing error is a practice more widespread in mathematics than in other disciplines. Although authors including Tulis (2013) suggest that this could be due to the greater weight of the right–wrong binomial inherent in the discipline itself, microsociological observation of the way that error is punished suggests that it is also due to dynamics characteristic of hegemonic masculinity, including aggressiveness, competitiveness and the exercise of authority.

We found a large number of examples of aggressive attitudes in the management of error in mathematics. For example, when asked about her time as a PhD student, Ester recounted that when a doctoral student presented their work, the rest of the students would be hard on them: "When you showed any weakness or shortcoming, they gave you a hard time". Irene reported that the university where she did her thesis held two types of seminars: one was attended only by students, while the other was also attended by supervisors. She recalled that while the former were relaxed, in the seminars attended by supervisors, both supervisors and PhD students would aggressively question whoever was presenting their work: "You were torn apart by the teachers and also by your fellows, because they wanted the teachers to notice them". When asked in an interview to describe her academic career, Haizea also remembered a tendency to put pressure on students when they gave presentations. She did her thesis at a research centre, and explained that she used to feel particularly uncomfortable with the aggressive attitudes of the lead researcher: "They really liked to play the boss in group meetings. They made us uncomfortable, demanded results, pressured us…" Andere, when documenting her primary school experience in her mathematical autobiography, reported the aggressive response of a mathematics teacher to a mistake she made: "I did a multiplication wrong, and they started shouting at me. I got really stressed, I felt humiliated, and it made me afraid of math lessons". In several of the testimonies, along with aggressiveness, ridicule emerged as another way to punish errors. For example, in a written description of one of his secondary education mathematics teachers, one student reported "If we said something wrong or made a mistake, she laughed at us." Also in their written description of a teacher, another student remembered "If you asked him a question, he would ridicule you in front of the whole class". When asked about her relationship with her thesis supervisor in an interview, Irene reported that he ridiculed his doctoral students: "He might question you, question you, question you, question you, question you, up to the point that you weren't even sure of your own name anymore".

In some cases, the mathematicians and scientists interviewed reported questioning and confronting these attitudes. For example, when asked to reflect about her relationships with her fellow students and superiors as a doctoral student, Haizea said that she once reproached the aggressive behaviour of the lead researcher of her group. His response highlights the legitimacy enjoyed by these practices: "He would say that it was for our own good: 'Well, it's like that in the real world, it's so you get used to it.'" In her field notes, Andrea documented her experience in a focus group about mathematics education. Two university professors, both men, reiterated the idea of aggressiveness being a legitimate practice in mathematics: "They treated men PhD students with overtones of violence that they related to teaching in order to go to war … They perceived mathematics as a field bearing some resemblance to a war zone: sacrifice, competition, hostility, not showing vulnerability…" Perhaps representing the other side of the same coin, when asked about her time as a PhD candidate during interview, Ester reported that she and other women were excluded from debates: "If you presented something [in a conference or seminar], the responses from the so-called experts were kind of paternalistic. I kept seeing that again and again". Irene, in response to the same question in her own interview, shared that, at a conference, a prestigious researcher asked every PhD candidate a question except her, the only woman: "I felt really bad, because I felt like I didn't even… he didn't even let me fail on my own".

The experiences recounted by Haizea and Andrea in the previous paragraph suggest that the punishment of error may contain within it the intention to teach students how to perform confidence. Burton (2004) defines confidence as "one's efficacy to act within a social setting" (p. 360). It would seem that, in settings related to mathematics, efficacy implies performing hegemonically masculine traits, particularly aggressiveness. This is perhaps to be expected, as characteristics conventionally identified with leadership and competence tend to be historically masculine traits in wider society, despite leadership ability often being presented as gender neutral. Even where effective, leadership outside this traditional model may not be recognised (Cooper 2019). Moreover, Andrea's, Ester's and Irene's testimony indicates that the allegory of preparation for war is sometimes only applied with reference to men. Ahmed's (2006) idea of *inheriting* the *proximity* of objects is particularly applicable in this case, as men students seem to *inherit* the reachability of confidence performed through aggressiveness. This said, Haizea's and Andrea's excerpts illustrate the pressure to reproduce aggressive ways of performing confidence, which signals that "it is not automatic that we reproduce what we inherit" (Ahmed 2006, p. 555).

Overall, the excerpts cited in this subsection show that handling mistakes through punishment "makes some bodies feel in place, or at home, and not others" (Ahmed 2006, p. 563). Paraphrasing Fox Keller (1985), when confronted with the possibility of making a mistake in the context of mathematics, those who feel out of place when navigating historically masculine traits such as aggressiveness or competitiveness walk "a path bounded on one side by inauthenticity and on the other by subversion" (p. 174). In the next subsection, we engage with the idea of risk. This is followed by a section in which we focus on subversion, and subversive opportunities available in the context of error management.

Risk

When Irene was asked in an interview how a feminist perspective had changed her way of doing and teaching mathematics, she mentioned that it caused her to notice gendered attitudes to risk in the mathematics classroom: "Who interacts? The boys. Why? Because the boys speak up. Even if it's bullshit, they don't care. Because they think they know. Not all of them, obviously, but a lot of boys". Haizea shared similar feelings when talking about the weekly meetings held at the research centre where she did her doctoral thesis: "We undervalued our work a lot, we radiated a deep insecurity. And then the guys would turn up and give a shitty presentation, saying, 'I've done this, and I think this is super interesting because this and that…'".

The above citations suggest that girls have a bigger aversion to risk, and this aversion carries consequences. Elisabeth Cadoche and Anne de Montarlot (2021) identify placing excessive demands on oneself, disproportionate effort, work overload and, resultantly, anxiety and stress. This is perceptible in Haizea's fragment, and the following excerpt from Uzuri's field notes is another example: "Rigour is a shield, a huge source of protection, but every time a mistake slips through a crack, I feel very fragile". Another response to fear of failure is paralysis: faced with the risk of doing something wrong, no attempt is made at all (Cadoche and Montarlot 2021). Nahia, an interviewee who was aware of this phenomenon, shared the following when asked to reflect about how gender had impacted her experiences as a mathematics student: “Girls, when it comes to doing something, either we do it well or we don’t do it at all”. In her mathematical autobiography, Alba also shared that, faced with the risk of saying the wrong thing in the large group, she preferred not to participate: “I only participate when I am sure that what I am going to say is right, because I am afraid to participate if there is a chance that what I will say is wrong”. Markel, a man student, reported a very different experience in his mathematical autobiography: “I am a very bad mathematics student, but I try to improve, and I study a lot … I always try to participate as much as possible, so that I can learn from the teachers’ corrections”. The contrast between Alba’s and Markel’s testimonies is in line with research, including a paper by Zack Estes (2003), that suggest that paralysis is more common in girls than in boys. Estes (2003) asked women and men to rearrange a series of computer images. When giving an answer was optional, men’s results were better as women left a significant number of questions unanswered. When the same test was given, but providing an answer to every question was compulsory, the scores were equivalent. This showed that the original test demonstrated men’s confidence more than their ability.

Ahmed (2006) argues that “history ‘happens’ in the very repetition of gestures, which is what gives bodies their dispositions or tendencies” (p. 553). In the material analysed, we found some *gestures* whose repetition may explain the gendered inhabiting of risk described in the preceding paragraphs. These *gestures*, described below, were linked with gender–mathematics stereotypes.

When reflecting on her time as a secondary mathematics student during interview, Eire pointed that the expectations placed on students’ academic performance were gendered: “With adolescents, it was more easily accepted when a boy was lazy. If he passed his subjects, he was left alone, whereas there were, perhaps, more demands placed on girls”. Rachel Simmons (2009) likewise argues that, through reiterated performance, girls are taught from an early age that, in order to be taken into account and valued, they must be well-mannered and modest, respect rules and embody beauty and perfection; by way of contrast, boys are entitled to produce and dwell in disruption, which prepares them to inhabit imperfection.

Gendered inhabiting of risk could also be linked to gendered readings of boys’ and girls’ failures. For example, in her field notes, Uzuri compared the reactions of Asier (a man student) and Alba (a woman student) to their difficulties with problem solving. In both cases, students were expressing themselves during class time. While Asier complained that he couldn’t see the point in the activities and questioned the teacher’s approach to organising the class, Alba focused on her own limitations, saying she had always found mathematics difficult and had never been good at it. This coincides with findings by Sonia Ursini, Martha Ramírez, Claudia Rodríguez, María Trigueros and Dolores Lozano (2010), who assert that girls tend to attribute their own failures to their innate lack of intelligence, while boys are more likely to signal outside influences. This could be linked to the general tendency documented by Sigrid Blömeke and Gabriele Kaiser (2010) for teachers, parents and others to also assume that boys are more naturally gifted in mathematics than girls, and that girls have to work harder to be successful in mathematics.

The gendered readings and expectations described above lead us to conclude that making a mistake in mathematics has more serious negative implications for girls than boys. This means that, even when in the same context, making a mistake is a more substantial risk for women than their men peers. This insight offers a more compelling explanation to women’s observed aversion to risk than a recourse to biology. The repetition of a complex set of *gestures* serve to biologise girls’ and boys’ reactions to risk in mathematics: the signs of the work involved in reproducing gender–mathematics stereotypes disappear through the very repetition of that work, in the same way as, “if we work hard at something, then it seems effortless” (Ahmed 2006, p. 553), which ultimately produces a deceptive appearance of what is perceived as natural.

In conclusion, competitive environments, the management of error through punishment or ridicule and reproduction of gender–mathematics stereotypes produce heightened levels of fear and reduced motivation. They also contribute to the (re)production of stigma, as students with certain subjectivities are more vulnerable. In order to redress this reality, in the next section we show that the expression and management of vulnerability can encourage participation and confidence by all students. A shift from a restrictive to a productive management of error is key to achieving this. Below we propose a metacognitive approach to low-floor, high-ceiling problem solving as a means to make engaging productively with error more accessible.

Putting vulnerability at the centre

Framing mathematical error as shameful or as a behaviour to be punished or avoided reinforces the conception of error as a deficiency (Alvidrez, Louie and Tchoshanov 2022) and contributes to increased fear, experiences of failure, and demotivation among students (Tulis 2013). It also perpetuates social inequalities, given that the social consequences of making mistakes are often more severe for students from marginalised groups (Lubienski 2002). Consequently, teachers should transmit a positive (or at least non-negative) conception of error to students. In mathematics, activities frequently have one (and only one) correct answer (Ponte 2004). As a result, students are often confronted with a success–failure dichotomy. Katty Kay and Claire Shipman (2014) argue that strategic management of risk and failure can enable students to live more comfortably with imperfection and also diminish their fear of error. In this sense, the term *productive failure* (Savić, Gunter, Curtis and Paz-Pirela 2021) is used to emphasise the potential of error within processes of learning and discovery, as well as to acknowledge that difficulty with understanding concepts and failed attempts to resolve problems are intrinsic to mathematical practice and indispensable for the construction of mathematical knowledge.

While a discourse that reads error as a positive learning opportunity is valuable, it is not sufficient in itself, because beliefs are also shaped by our (mathematical) experiences (Stoehr 2017). Jo Boaler (2016) makes a number of suggestions in this area. She suggests that mathematical activities should (a) be susceptible to different approaches and forms of representation; (b) include a visual component, because this helps to activate more areas of the brain; and (c) be low floor and high ceiling, that is, easy to start solving, but challenging to finish.

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Approaches to error management in *Mathematics and its Teaching I*

As described in the methodology, over the course of the research Uzuri delivered the subject *Mathematics and its Teaching I* to students enrolled in a Degree in Primary Education. Among other content, the course included geometry and numeral systems. Figure 1 shows one example of a problem of a type that was used in both the final examination and as an activity in class. The problem is representative of both the geometry problems that were used in the subject and those addressing other areas of mathematics. It is the result of Uzuri's deliberate effort to apply Boaler's (2016) suggestions when designing mathematical problems for her students. It offers multiple possibilities in terms of representation and resolution. Moreover, for a problem to be considered low floor, high ceiling (easy to start solving, but challenging to finish), the particular group of learners has to be taken into account (NRICH 2013), and, over her years of experience delivering the subject, Uzuri saw that most students struggled with and got stuck with problems such as the one shown in Fig. 1 at some point. This led to designing a methodology that would assist students in the development of problem-solving strategies that would help lower the floor of the problems and make progress in the resolution process.

The three stages of this process of problem resolution were: understanding the problem, making a plan and carrying out the plan. These steps facilitated metacognitive awareness through self-questioning during mathematical activity. Particularly in the first and second phases, students were encouraged to use figures and colours, that is, to take maximum advantage of graphic representation.

In terms of applying the methodology, the first phase involves understanding the problem. In the specific case of the problem shown in Fig. 1, this means identifying the component geometric shapes. This represents a low floor, facilitating engagement and avoiding paralysis. The second phase consists of drawing up a plan for solving the problem. In the case of geometric problems, this means identifying combinations of the figures identified

The *lemniscate of Bernoulli* is an algebraic curve that has a shape similar to the symbol for infinity. The image below is a geometric object that resembles that lemniscate. The triangle ABC is equilateral, its' sides are $\sqrt{3}$ cm long, and the circles centered on D and E are 1 cm long. Carry out the following calculations:

a. The area of the lemniscate.

b. The perimeter of the lemniscate.

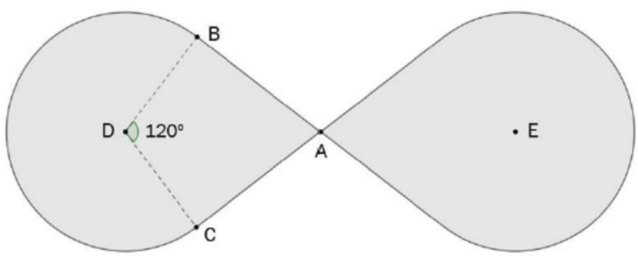

Fig. 1 Example of a geometrical problem

in the exploratory phase in order to calculate area and/or perimeter of the overall figure. This encourages experimentation with various possible means of resolution and also encourages students to think by using visual representation. In the third phase, students carry out their plans using the tools they have available. In the case of geometric problems, this means applying mathematical formulas for area and perimeter. These steps represent a relatively high ceiling in the context of the student group: the calculation of the area and/or perimeter of a complex surface. While the steps have been presented as a sequence, the process is not necessarily linear. If an error or obstacle is identified at any point, it is possible to redo the exploration and/or rework the plan. Thus, error becomes an integral part of the resolution process.

The methodology aims to implement insights drawn from a socio-constructivist understanding of mathematical learning, as low-floor, high-ceiling problem solving through a metacognitive approach can be understood as *scaffolding*, that is, "metacognitive, strategic, conceptual or procedural support" that seeks to allow [students] to participate in activities and to build skills that they would not be able to form if not helped (Trif 2015, p. 979). A specific aim was to provide the students with tools that would help them to orient their own attention, to plan and control their own problem-solving process.

Low-floor, high-ceiling problem solving through a metacognitive approach

To achieve full marks in the examination, students had to show their workings. However, it was made clear throughout the course that no points were awarded for following the specific methodology taught in class. Gender seemed to impact the choice to apply the methodology or not. This is shown in Table 1, which addresses the geometry problem in the 2020–2021 final examination and shows data disaggregated by gender for the use of different components of the methodology.

As can be seen in Table 1, women made greater use of all phases, followed the order presented in class to a greater extent and relied more often on the use of graphical representation and colour. None of the women students left the problem blank: even those who scored zero made an attempt to solve it. This was not the case for the men: seven students left the paper blank, i.e. 12,5%. This is significant, because the literature suggests that the tendency is rather the opposite: when facing the risk of making a mistake, girls are more likely than boys to avoid making an attempt (Estes 2003).

In terms of marks awarded for this geometry problem, women averaged 5,44/10 and men 4,66/10. This difference is consistent with the overall examination mark (women 6,04/10, men 5,15/10) and the final mark of the subject (women 6,43/10, men 5,32/10).

Table 1 Use of phases, graphical representation and colours in the examination

		Phases			Order	Graphical representation	Colours
		Identify shapes	Graphical resolution	Analytical resolution			
Women [71]	f_i	56	64	65	55	69	26
	%	79%	90%	92%	77%	97%	37%
Men [56]	f_i	19	35	43	21	41	2
	%	34%	63%	77%	38%	73%	4%

Thus, we cannot attribute gendered differences in results to the methodology. In any case, the use of performance to measure improvement in inclusivity is problematic, given that research shows that, among other issues, women continue to have a poorer self-conception of their ability in mathematics than men even when they achieve better results (Sáinz and Upadyaya 2006). For this reason, we chose to focus on participation in solving mathematical problems rather than on performance as a key indicator.

Student testimony supported the conclusion that the problem-solving methodology encouraged women students to participate. As described in the methodology section, all students enrolled in the subject were sent a link to a questionnaire which invited them to provide qualitative feedback. When providing feedback specific to the block "Solving mathematical problems", 28 of the 43 women who responded chose to mention that solving problems in stages had been useful. One girl reported "Before working with this means of problem solving, I had a hard time. Putting these strategies into practice has given me a different perspective". Another connected this method of solving problems to doing things calmly: "To do things calmly, this is the way it has to be. We shouldn't put the cart before the horse, we have to take it easy". Finally, this one student affirmed that phased problem solving helped her learn to connect ideas and become aware of the problem-solving process: "I found the problems valuable for learning to think, to learn to relate ideas, and to be able to understand what I was doing at any given moment". While women clearly benefited, it does not appear that the methodology (whose use was optional) was detrimental for boys in any way. Ten out of 25 boys chose to mention that the methodology had been useful when providing qualitative feedback on the subject. Three more wrote that while the methodology had not been of use to them, they recognised that it was useful for others.

The above observations suggest two conclusions. The first is that a metacognitive approach supports problem solving. While women students value this more highly and derive more benefit, their men classmates are not disadvantaged. The second conclusion is related to low-floor, high-ceiling problems, as establishing exploration as the initial approach to a problem makes getting started easier. While not all succeeded, almost every student (and every woman student) did attempt to solve every problem. Thus, solving low-floor, high-ceiling problems with metacognitive support appeared to make productive engagement with error more achievable, primarily by reducing the fear of making mistakes or failing. This seems to have dramatically reduced the rate of paralysis, which had a particularly favourable impact on girls' participation in mathematical problem solving.

Concluding thoughts and looking ahead

There is a growing body of research that conceptualises error as a learning opportunity (e.g. Hoth, Larrain and Kaser 2022) and suggests different practical means to realise this potential in the mathematics classroom (e.g. Leron and Ejersbo 2021). In parallel, many contemporary investigators offer sociological readings of masculinity in mathematics (e.g. Hottinger 2016) and/or explore transformation in mathematics education through feminism (Boaler 2016). However, there is little material that brings these areas together in order to address error management in mathematics from a gender perspective. The contribution of this paper is to discuss error, mathematics and gender together from a feminist and socio-constructivist perspective. This has enabled us to deconstruct mistake-handling in mathematics and identify opportunities to redress exclusionary gendered dynamics. One major conclusion is that adopting the constructivist idea of error as a learning opportunity is necessary, but not sufficient: a microsocial perspective is also essential in order to identify and address subtle dynamics of stigmatisation that (re)inscribe social stratifying factors including gender.

Our research shows that values historically associated with hegemonic masculinity, including competitiveness and aggressiveness, permeate mathematics classrooms even in contexts where official guidelines support an alternative approach. Specifically, these values are materialised in error management dynamics which feature punishment and promote avoidance. We have found that these dynamics had a different meaning and consequences for men and women, as did the risk of failure and making a mistake. This differential impact is due to the *inherited proximity* of historically masculine attributes for the former. It is also due to *gestures* linked to gender–mathematics stereotypes whose repetition conceals the work involved in reproducing gender norms. All of these factors contribute to the *orientation* of mathematical contexts towards the enactment of hegemonic masculinity.

This scenario is susceptible to transformation. We argue that the productive management of error in mathematics can help to combat gender inequality and encourage all students' participation. Concretely, we proposed low-floor, high-ceiling mathematical problems addressed using a metacognitive approach as a practical tool in this respect. Unlike mechanisation, this way of approaching mathematical activity makes the error an intrinsic part of mathematics. In some contexts, it can replace competitiveness and punishment of error with the management of vulnerability. Centring vulnerability is key because, as stated by Butler (2014), "without being able to think about vulnerability, we cannot think about resistance" (p. 18). Vulnerability should be rethought as a space for action, as a way to enact inclusion and enhance participation of all students in mathematics.

Our inclusion of respondents able to address different periods and roles in mathematics learning in combination with a complex set of research tools has allowed us to confirm that our conclusions are relevant across distinct mathematical contexts. Interviews with students and questionnaires provided insight into primary and secondary schooling, while interviews with women working as higher education mathematics or science teachers and professionals identified the persistence of these dynamics even at a tertiary level. Applying the concept of centring vulnerability beyond the classroom, we argue that illuminating the dark corners of error should also be formally established in mathematical research. Error and failure need to be recognised as valuable and relevant contributions to the productive process of advancing mathematical knowledge.

While this paper does make some contributions, it is not without limitations. A central issue is that the results are drawn from a research project in which error was not the central object, but one of the themes that emerged in the data interpretation phase. This means that the issue was not specifically targeted in the design of the research tools or process. As a result, some of the participants did not make contributions relevant to error management. This is especially regrettable in the case of Lola, who was the only non-binary participant. The absence of a more explicit questioning of the man–woman binary that could be anticipated given the theoretical underpinning of our conception of gender is partially due to the unfortunate absence of queer voices around this topic.

In response to this limitation, a natural continuation of this research, currently underway, is to delve further into the interactions between gender and error management in mathematics through data generation tools specifically designed for the topic in question. This will allow a deeper understanding of strategies of agency and resistance when dealing with restrictive views of error, further engagement with experiences that resist the gender binaries and greater space for voices speaking from other subjectivities. We hope to share the results of this in the near future.

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Author contribution This article is based on research conducted within the framework of the doctoral thesis authored by U.A.. Consequently, U.A. is responsible for the data collection and analysis. The interpretation phase was conducted, while U.A. was on a doctoral exchange placement mentored by A.V.. A.V. collaborated closely in the interpretative process, making substantial contributions in this area. A.V. was particularly interested in one of the themes that emerged during the interpretation phase: mistake-handling in mathematics. This topic became the focus of a thesis chapter and, subsequently, this article. This paper was formulated and structured jointly by both authors. U.A. took responsibility for producing the first draft of the article. Subsequently, both authors took turns revising and improving the paper. After several iterations, they agreed that it was ready for submission.

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