***Resilience* in mathematics education research: A systematic review of empirical studies**

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Abstract

In recent years, the number of studies examining resilience in relation to mathematics teaching/learning (or mathematical resilience, according to some), increased significantly. This paper is a systematic review of 78 studies published between 2010 and 2021, and investigates (a) conceptualisations of mathematical resilience, (b) demographic characteristics of participants in the papers identified, and (c) factors that influence the development of mathematical resilience. Our analysis indicates that mathematical resilience is conceptualised in two ways: as the coexistence of disadvantage and high mathematical performance; and, as part of one's mathematical identity. Participants in related studies belong to one of the following categories: disadvantaged pupils; "typical" pupils; disadvantaged university STEM students; "typical" university students; prospective teachers; in-service teachers. Mathematical resilience is found to be influenced by both psychological and social/environmental factors. Finally, we discuss implications and how the field can move forward.

Keywords: mathematical resilience, education, systematic review, empirical studies, teaching/learning

Introduction

Resilience is, nowadays, a relatively common word in everyday language. Despite its literal association with elasticity of objects, when used to describe human behaviour, resilience encapsulates one's "capacity to recover quickly from difficulties" (Oxford Lexico[1]) or "the ability to be happy, successful, etc. again after something difficult or bad has happened" (Cambridge Dictionary[2]). In this paper we seek to unpack issues related to resilience and mathematics education, by examining the relevant literature published between 2010 and 2021 in a systematic manner. Exploratory in nature, this paper aims at providing an overview of the current state of the art, by identifying, analysing, and discussing what recent studies inform us (more information is presented subsequently, especially under Methodology). This topic is, we reckon, of high importance, especially when school mathematics is often associated with negative attitudes and anxiety (Buckley & Sullivan, 2021; OECD, 2013), as well as high drop-out rates (Lessard et al., 2009; Lundetræ, 2011). People who demonstrate mathematical resilience often have a higher sense of self-efficacy (Schweinle & Mims, 2009; Yeager & Dweck, 2012) and persist more in learning mathematics even when they experience challenging living conditions (Borman & Overman, 2004).

We begin this paper by looking at how research about resilience stemming from the field of psychology has influenced the work of researchers in education. Subsequently, we provide insight into the concept of mathematical resilience, present the research questions specific to this paper and how they have emerged, and illustrate our methodology. We proceed by presenting the main findings of our review, followed by discussion with implications and suggestions on how the field can move forward.

Resilience: from research in psychology to research in education

Historically, *resilience* entered the academic discourse of human development in the 1970s, through studies in psychology and psychiatry, regarding patients or children of patients with mental health issues (Lundholm & Plummer, 2010; Luthar et al., 2000). At first, scholars were driven by a shared belief that individuals exhibiting resilience in the face of adversity had remarkable characteristics and extraordinary coping mechanisms that made them stand out from those not coping as well. In fact, at that time resilient individuals were widely characterised, even by the American Psychological Association (Pines, 1975), as "the invulnerables". It took several years for scholars to conclude that resilience does not stem from special or exceptional qualities, "but from the everyday magic of ordinary, normative human resources in the minds, brains, and bodies of children, in their families and relationships, and in their communities" (Masten, 2001, p. 235). This understanding of resilience as something more than a personal characteristic or quality

[1] www.lexico.com/definition/resilience
[2] https://dictionary.cambridge.org/dictionary/english/resilience

(Masten & Wright, 2010) was reached through several waves of research (Allan et al., 2013; Lundholm & Plummer, 2010): During the first wave, researchers focused on exploring and understanding the personal characteristics of resilient individuals; during the second, the interactive processes underlying resilience became of central interest; and, the third emphasised (and still does) the designing and implementation of theory-driven interventions that would help individuals expand their resilience capacity and processes; while the recent, fourth wave, "is integrative, seeking to encompass rapid advances in the study of genes, neurobehavioral development and statistics for a better understanding of the complex processes that lead to resilience" (Masten & Wright, 2010, p. 214).

It would be naïve to assume that resilience-related research is unproblematic. In fact, in their critical evaluation of the literature more than twenty years ago, Luthar et al. (2000) highlight various issues, many of which still exist. First, there seems to be little consensus among authors regarding conceptual and operational definitions of resilience (Ungar, 2010), while a variety of different models is used to talk about the processes underlying resilience (Nearchou et al., 2014). Also, the outcome of being resilient may range from returning to a stage of equilibrium to developing conditions of flourishing (Allan et al., 2013). Second, it is impossible to establish that participants in resilience studies experience comparable levels of adversity. There are no standard criteria in defining and measuring adverse conditions; in fact, any criteria quickly become outdated (Chung et al., 2017). Third, in acknowledging the multidimensional nature of resilience, we must accept that certain individuals show resilience in some domains, but not in others. Finally, as resilience may grow over time, in certain contexts, and under specific circumstances, it is possible that it may also decline, rendering the results of several studies, especially those of interventional programmes, unstable.

In educational research, following the lead of psychology, resilience is often defined as a process, capacity or outcome of successful adaptation during exposure to adversity or risk (Allan et al., 2013; Mansfield et al., 2016). Several recent studies (e.g. Nearchou et al., 2014; Scrine, 2021; Yamamoto et al., 2017), both with school children and university students, have established strong positive links between resilience and academic performance, mental health, self-efficacy, positive attitudes toward schooling, and engagement. Also, resilience appears to be a construct that can grow and be strengthened over time, as a result of an individual's interaction with various protective systems (Chung et al., 2017). For example, Bronfenbrenner's (1986) ecological systems theory views child development being affected by several interconnected systems, ranging from the microsystem (immediate family, friends, schools) to the macrosystem (cultural attitudes and ideologies), all shaped by the chronosystem (time-based dimension covering changes in context over time). In turn, Ungar (2013) talks about a social-ecological understanding of resilience, emphasising that social and physical ecologies play a vital role in positive developmental outcome when individuals undergo excessive stress. From this perspective, resilience is shown to be influenced by various factors such as, inter alia, quality of peer friendships (Doll et al., 2011), family environment (Nearchou et al., 2014), school characteristics and structures (Borman & Overman, 2004), and national culture and context (Miljević-Riđički et al., 2020).

Insights into mathematical resilience

Recently, educational research on resilience has approached the concept through the lenses of specific school subjects: language education (Nguyen et al., 2015), environmental education (Lundholm & Plummer, 2010), science/physics (Nehmeh & Kelly, 2018), sports and physical education (Montero-Carretero & Cervelló, 2020), religious studies (Miller, 2013), to name a few examples. As academics working in the fields of mathematics education and inclusive pedagogy, we are particularly interested in relationships between the concept of resilience and mathematics education. These have been examined for many years now. An initial search on Google Scholar for publications from 1970 until the first week of September 2021, with the terms "math*" and "resilien*", and also including at least one of the terms "teach*", "learn*", "student", "pupil" gave us 461 results[3]. Interestingly, while changing the time range, we observed that 123 papers were published between 1970 and 2009, while 338 papers were published between 2010 and September 2021. In other words, there are almost three times more papers published in the last 11 years than during the previous 39 years. This observation regarding an expanded international interest in this area sparked our curiosity in learning more about this type of resilience, *mathematical resilience*.

Despite the growing research interest, a consensus about a clear definition of mathematical resilience is still lacking. For instance, Schweinle and Mims (2009) talk about resistance to stereotype threat, such as mathematics learners being projected to low expectations because of their racial/ethnic background. For others, like Lee and Johnston-Wilder (2017), mathematical resilience shares many characteristics with other psychological constructs, such as self-efficacy, optimism, motivation, and confidence. In turn, Yeager and Dweck (2012) associate resilience with a growth mindset about one's intellectual abilities in mathematics. Put otherwise, learners "who believe (or are taught) that intellectual abilities are qualities that can be developed (as opposed to qualities that are fixed) tend to show higher achievement across challenging school transitions and greater course completion rates in challenging math courses" (p. 302). While we find these ideas very useful, we shall not attempt further to define mathematical resilience at this stage. On the contrary, the observed lack of definitional agreement upon this important notion led to the formulation of our first research question, concerned with mapping the relationship between mathematics and resilience in empirical studies. Also, as we can see in the definitions cited above, Schweinle and Mims (2009) refer to a specific marginalised group of learners and associate resilience with social constructs (e.g. racial stereotypes, expectations), while authors like Lee and Johnston-Wilder (2017) and Yeager and Dweck (2012) take a different perspective, approaching

[3] The asterisk (*) works as a placeholder for suffixes. For example, "math*" covers words such as the British English *maths*, the US English *math*, as well as *mathematics* and *mathematical*. Similarly, "resilien*" covers resilience, resiliency, and resilient.

resilience from a psychological point of view. Reflecting on these observations, our second question aims at capturing the variety of participants involved in related studies, while the third seeks to explore factors that appear to influence mathematical resilience. Specifically:

1. How is the relationship between resilience and mathematics understood in such studies? (in other words, how is mathematical resilience conceptualised?)
2. Which groups of participants are involved in these studies? (in other words, whose resilience is being examined?)
3. Which factors influence mathematical resilience?

In the following section, we present the methodological decisions taken for finding answers to these questions.

Methodology

We employed a systematic review methodology, focusing on international peer-reviewed literature. This kind of review adheres "closely to a set of scientific methods that explicitly aim to limit systematic error (bias), mainly by attempting to identify, appraise and synthesize all relevant studies (whichever design) in order to answer a particular question (or set of questions)" (Petticrew & Roberts, 2006, p. 9). Here, the following databases were used: APA PsycInfo, Education Research Complete, ERIC, and Web of Science. We searched for papers that included "math*" AND "resilien*" in their title, abstract, and/or keywords.

Inclusion/exclusion criteria

We developed a set of inclusion/exclusion criteria, in order to set the boundaries of our review (Petticrew & Roberts, 2006):

1. Subject area: The papers had to be concerned with issues of mathematics education and resilience, regardless of school level.
2. Source: The studies must have been published in peer-reviewed journals. We excluded book chapters and conference proceedings, which do not always undergo a peer-review process. Including only peer-reviewed journal papers served as an indirect measure of the "quality" of the work selected. Even though issues of quality and its measurement are quite controversial in academia, the process of peer-reviewing acts as a mechanism of assessing and preserving the trustworthiness of reporting scientific findings.
3. Time range: The studies were published between January 2010 and September 2021 (the latter being the last month in which the search for papers took place). As mentioned earlier, our pre-systematic search on Google Scholar pointed towards the year 2010 as critical in

the timeline of related research, since after that year the number of publications almost trebled.

4. Research methods: We focused on papers reporting empirical findings based on quantitative, qualitative, or mixed methods. At the same time, theoretical and review papers were excluded.
5. Language: For pragmatic reasons, papers had to be published in English.

Identification of papers

We followed an adapted version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009), as presented in Figure 1. Overall, 78 papers satisfying all inclusion criteria were identified, and therefore, considered for our analysis. They are presented at the end of the paper in a separate reference list.

[Insert Figure 1 about here]

Analysis

Because of the exploratory nature of our work, we decided from the beginning not to employ any predetermined coding scheme for the *critical appraisal* of studies (Petticrew & Roberts, 2006). Instead, we generated codes by treating the research articles as qualitative data, in a combination of theory- and data-driven thematic analysis (Miles & Huberman, 1994). Specifically, the three research questions served as themes. Each article was critically appraised against those themes, codes were identified, and later, combined into categories (sub-themes). Such an approach is common among systematic reviews (see, for example, Matengu et al., 2021; Sigvardsson, 2017; Xenofontos et al., 2021). Firstly, we randomly selected 15 papers, which we coded independently. In qualitative investigations, this number is generally considered sufficient for data saturation (Guest et al., 2006; Xenofontos, 2018). Secondly, we met and discussed similarities/differences of our two schemes, and agreed on a common scheme. Thirdly, we randomly selected 10 more papers and coded them independently, to examine the extent to which our common scheme would be sufficient or whether new codes were necessary. Subsequently, relevant adaptations were made. Finally, we divided the remaining papers between us and completed the coding process. We were in continuous communication during the whole coding process, so that any ambiguous or controversial issues regarding the coding scheme would be quickly resolved.

Findings

Below we summarise findings related to the three research questions. Similarly to several recent systematic reviews (e.g. Dere & Ateş, 2021; Sigvardsson, 2017), in this section we present the outcomes of our analyses, keeping our interpretations, comments, and suggestions for the next section (Discussion). We use the terms *pupils* and *students* in British-English fashion: the former refers to school children, while the latter refers to students in higher education.

RQ1: How is mathematical resilience conceptualised?

In the papers identified, mathematical resilience is conceptualised in two congruent ways, as some papers embrace both.

Resilience as the coexistence of disadvantage and high mathematical performance

For 24 papers, mathematical resilience is demonstrated when learners with disadvantaged characteristics (e.g. low socioeconomic status, minoritised ethnic/racial background) score higher than expected in standardised tests of mathematical performance. In several papers, data from large-scale international studies such as the Trends in International Mathematics and Science Study - TIMSS (Alivernini et al., 2016; Frempong et al., 2016), the Programme for International Student Assessment – PISA (Cheung, 2017; Önder & Uyar 2018), or both (Chirkina et al., 2020) are taken as performance measures. Other studies use different standardised tools, such as tests developed by local authorities (Diamond et al., 2016; Fantuzzo et al., 2012) or other known scales (Ramakrishnan & Masten 2020; Tok & Unal 2020). Most of these studies are interested in identifying factors associated with resilience, typically to sketch the profiles of resilient learners. For example, in their work based on the South African 2011 TIMSS data, Frempong et al. (2016) concluded that "[a] typical resilient learner is a girl who does not speak the language of classroom instruction at home. This learner tends to not only value and like mathematics but also expressed confidence about her ability to learn mathematics" (p. 353). There is further discussion on associated factors as identified by studies subsequently, under the findings related to our third research question.

Resilience as part of one's mathematical identity

In most of the papers identified (n = 61), resilience was, implicitly or explicitly, approached as part of one's mathematical identity. We use the term *mathematical identity* to refer to how one sees themselves in relation to mathematics, "emerging from engagement in joint object-orientated and socio-culturally mediated 'activity'" (Black et al., 2010, p. 56). Some studies explore resilience as part of *pupils'* mathematical identity. For example, the teams of Boutin-Martinez et al. (2019), and Sparks et al. (2021), focus on how Latina/o secondary pupils' exhibition of resilience help them avoid school dropout or persist on developing an interest in pursuing STEM (science, technology, engineering, mathematics) studies at university, respectively. In a similar vein, from the perspective of university *students*, Leyva (2021) and Joseph et al. (2020) examine how Black women studying for STEM-related degrees draw on their own mathematical identities, express resilience and react to challenges in their respective academic disciplines, which are predominantly dominated by white men. A different example is the work of Xenofontos and Andrews (2020), who write about the mathematical resilience expressed by in-service primary *teachers*, in the framework of how teachers constructed their mathematical identity and self-efficacy beliefs.

RQ2: Whose resilience is examined?

Our second question was concerned with the groups of participants involved in studies linking mathematics and resilience. The papers identified can be categorised in six mutually exclusive clusters. That is to say that each study focused on a specific group of participants, as presented below.

Disadvantaged pupils

More than half of the studies identified focused on pupils experiencing some sort of disadvantage. Specifically, 41 out of the 78 papers were concerned with pupils satisfying various marginalising characteristics, such as having low socioeconomic background (Chirkina et al., 2020; Frempong et al., 2016; Holliday et al., 2014; Mota et al., 2016; Ramakrishnan & Masten, 2020), belonging to a minoritised racial/ethnic group (Boutin-Martinez et al., 2019; Diamond et al., 2016; Fantuzzo et al., 2012), having some kind of disability (Kritzer, 2012), or, being a child in foster care or adopted (Griffiths, 2012; Whitten & Weaver, 2010). Other studies examined resilience and mathematics in relation to pupils at the intersections of various marginalising variables. For example, in their work concerned with gender and race, Joseph et al. (2020) explored Black girls' mathematical experiences, while, similarly, Sparks et al. (2021) focused on the intersectionality of race/ethnicity, culture, and gender, from the perspective of Latina STEM pupils. Finally, Tok and Ünal (2020) were interested in children with *at least* one characteristic from a long list of disadvantaging factors including, inter alia, physical, emotional and/or sexual abuse, malnutrition, poverty, victims of natural disasters, and war.

"Typical" pupils

A smaller number of studies (n = 16) draws on data from relatively big samples of "typical" pupils, with no predetermined type of disadvantage. Nevertheless, in these studies, information about participants' mental state or psychological characteristics was collected, through questionnaires, tests, or other quantitative instruments. For example, Putwain et al. (2013) examined the extent to which test anxiety may mediate the links between resiliency and test performance. In a similar vein, Donolato et al. (2019) analysed relationships between pupils' working memory, negative affect (levels of anxiety, depressive symptoms), personal assets (self-concept, ego-resiliency), and mathematical literacy. In turn, Lee & Simpkins (2021) examined how high-school pupils develop ability self-concepts (such as self-efficacy) as a result of parental support, when teacher support was insufficient.

Disadvantaged university STEM students

Ten of the papers are concerned with university students with some sort of disadvantage, pursuing studies in STEM disciplines. These papers discuss how disadvantaging characteristics form barriers in these students' pursuit of studies or how they develop coping mechanisms and, despite low expectations from their environments, manage to navigate through challenges, thriving in university studies heavily based on mathematics. The ten studies focus on characteristics such as gender, sexuality, race, age, or combinations of these. For example, Di Bella & Crisp (2016) look at cisgender women's counter-stereotypical experiences in STEM disciplines, while Kersey & Voigt (2020) explore queer and transgender students' narratives of being subjected to lower expectations as a result of identifying as gender-nonconforming. McGee and Martin's (2011) work explored stereotype management among academically successful Black students. Other studies (e.g. Ryan & Fitzmaurice, 2017) investigate challenges mature students encounter in academia. Finally, some of the studies are concerned with intersectionality, such as gender and ethnicity, specifically from the perspectives of Black women (Leyva 2021; McGee & Bentley 2017).

"Typical" university students

Contrary to the previous category, three of the 78 studies focused on university students without any kind of disadvantage or marginalising characteristic. These three papers aimed at understanding factors that may enhance university students' mathematical experiences. Specifically, Gürefe & Akçakın (2018) focused on factors that help students studying STEM-related subjects develop persistence in mathematics. Similarly, Leung et al. (2020) were interested in supporting students majoring in non-STEM subjects while attending mathematics-related classes. Finally, the study of Neumann et al. (2020) presents an instrument measuring mathematical resilience of students majoring in mathematics, aiming at reducing dropout.

Prospective teachers

The authors of these three papers were particularly interested in the mathematical resilience exhibited by a specific group of undergraduate students: prospective teachers. For instance, Cutler (2020) examined how growth mindset principles, promoted through appropriately designed mathematics methods courses, may serve as protective assets, especially during periods of extreme stress, such as online teaching during the COVID-19 pandemic. Aiming at providing insight into how future teachers understand resilience, Lutovac (2019) analysed, in her study, two prospective mathematics teachers' narratives about how they managed personal incidents of failure in their subject of specialism. Finally, Sinicrope et al. (2015) sought to identify variables associated with academic performance, resilience, and a successful completion of a mathematics teacher education programme by prospective secondary teachers.

In-service teachers

Finally, five of the identified papers examined resilience and mathematics from the perspective of in-service teachers. Interestingly, these papers had different foci. Two of them were concerned with resilience exhibited by teachers in their own pedagogical practice. In particular, Bailey (2017) examined one teacher's commitment and challenges in fostering a problem-solving culture in the mathematics classroom. Similarly, focusing on newly qualified teachers in their first year of practice, Kelly et al. (2015) explored the challenges of teaching mathematics to pupils from economically disadvantaged backgrounds. Two other papers were interested in how teachers support the development of resilience in their pupils. For instance, the study of Pieronkiewicz and Szczygieł (2020) looked at how early years teachers, in collaboration with parents, can foster mathematical resilience in young children. In turn, Russo et al. (2020) analysed teachers' beliefs about the roles of struggle in the mathematics classroom and of growth mindsets in educational contexts, as well as teachers' willingness to embrace and support struggle, and build resilience in pupils. Lastly, the study by Xenofontos and Andrews (2020) identified resilience as a characteristic of teachers' self-efficacy in relation to their own mathematical competence.

RQ3: Which factors influence mathematical resilience?

Our third research question regarded the factors that influence mathematical resilience. Two clusters of factors were identified: the psychological and the social/environmental. It is worth mentioning that in some papers, components of both clusters were examined.

Psychological factors

Most of the articles identified (n=43) discussed the psychological factors that can influence mathematical resilience. Several studies focused on coping strategies (McGee 2011; McGee 2013;

Sparks et al., 2021; Leyva 2021). For example, McGee & Pearman (2015) focused on the internal processes and strategies that Black students developed in order to succeed academically while McGee & Bentley (2017) exploring the responses of Black women to structural racism, sexism and/or race-gender bias in STEM. Some studies used specific scales to measure participants' academic self-concept, self-regulation, self-efficacy, mathematics anxiety and ego-oriented (competitiveness) (Putwain et al., 2013; Kooken et al., 2016; Mammarella et al 2018; James et al., 2021; Oktay et al., 2021) while others focused on pupils' sense of belonging and attitudes to their school (Yilmaz Findik, 2016; Frempong et al., 2016; Donolato 2020; Lipscomb et al., 2021). Persistence was another factor discussed by some studies (Sinicrope et al., 2015; Kooken et al., 2016, Gürefe & Akçakin, 2018; Neumann et al., 2020).

Social/environmental factors

The authors of 31 articles focus on environmental factors that influence mathematical resilience. Several articles discuss the association of learning environments and teachers' teaching strategies or expectations with academic performance (Alivernini et al., 2016; Özberg et al., 2018; Chirkina et al., 2020). For example, the findings of Lee & Johnson-Wilder (2013) emphasise the link between strategies such as less teacher talk and more pupil talk, collaborative learning, and involving learning activities with resilience in learning mathematics. Some studies discussed peer collaboration or peer liking and interpersonal relationships at school, as factors that influence mathematical resilience (Langenkamp 2010; Mota et al., 2016; Cropp 2017; Liew et al., 2018) while other studies discussed parent education and engagement (Holiday et al., 2014; Frempong et al., 2016; James et al., 2021). For example, in their work Tok and Ünal (2020) found a significant difference between five-year-old children's resilience and their fathers education level. Lahdelma et al. (2021) focused on parents' temperament types in early adolescents' academic emotions in mathematics, while Whitten and Weaver (2010) focused on the quality of parent-child relationships.

Discussion

The previous section presented our findings, categorised under the three research questions that guide this systematic review. In this section, we "zoom out" from those specific questions, locate our findings within the broader area of (mathematical) resilience, and provide suggestions for further research. At the beginning of the paper, we summarised four waves of the wider field of resilience research in psychology (Allan et al., 2013; Lundholm & Plummer, 2010). Interestingly, the themes of those waves can be observed in the 2010-2021 research trends concerning mathematical resilience. Nevertheless, while in the general psychology research these waves appear sequentially over the span of 50 years, in mathematical resilience research the respective topics are explored simultaneously, "compressed" in a much shorter period. To sum up, research on mathematical resilience between 2010 and 2021 focuses on (a) the characteristics of mathematically resilient individuals (e.g. Boutin-Martinez et al., 2019; Frempong et al., 2016); (b) the processes through which psychological and/or social/environmental factors facilitate or prohibit the development of mathematical resilience (e.g. Chesmore et al., 2016; Tok & Ünal 2020); (c) the implementation of interventions to help learners expand their mathematical resilience capacities (e.g. Griffiths, 2012; Sparks et al., 2021); and, (d) the psychological components of mathematical resilience (e.g. Gürefe & Akçakin, 2018; Kooken et al., 2016).

A fundamental issue revealed by our systematic review is that many studies do not provide a clear working definition of mathematical resilience. We identified two approaches to its conceptualisation: resilience as the co-existence of disadvantage and high mathematical performance; and resilience as part of one's mathematical identity. In several cases among the reviewed papers, however, these conceptualisations are not explicitly addressed by colleagues; instead, they are inferred by the design of the study or the main findings. This issue corresponds to criticisms of general psychological research on resilience, arguing that the lack of consensus regarding conceptual/operational definitions, and the existence of a wide variety of different frameworks, complicate communication among researchers (Luthar et al., 2000; Neachrou et al., 2014; Ungar, 2010). Even though in some papers beyond the ones we included in our review, a few colleagues provide theorisations of mathematical resilience (see Lee & Johnston-Wilder, 2017; Schweinle & Mims, 2009; Yeager & Dweck; 2012), there does not seem to be convergence in their approaches. Future theoretical and empirical studies could focus explicitly on providing comprehensive frameworks through which mathematical resilience could be defined and operationalised.

A second point is an observed overemphasis on linking mathematical resilience to disadvantage, like low socio-economic status or minoritised ethnic background. Specifically, 51 out of the 78 studies are concerned with pupils or university students with disadvantaged characteristics. In psychology research, *resilience* is explicitly linked to *adversity*. But with no standard criteria in defining and measuring adverse conditions, much space is left for highly subjective interpretations (Chung et al., 2017). In mathematics education research, adversity has been mostly interpreted as disadvantage and marginalization – not surprisingly, sine resilience made a strong appearance after 2010, by which time the field was well-immersed into sociopolitical discussions, such as how school mathematics is associated with equity and social justice (Gutierrez, 2013; Xenofontos et al., 2021). Nevertheless, it is equally important to examine mathematical resilience from the perspective of psychological characteristics like depression, anxiety, growth mindset, and self-efficacy (Donolato et al., 2019; Lee & Simpkins, 2021; Yeager & Dweck; 2012). We thus encourage colleagues working in this area to start linking mathematical resilience with other socio-psychological constructs.

A third point revealed by our analysis is that research has, hitherto, taken a fragmented approach to examining mathematical resilience. Put otherwise, as indicated by the findings to our second research question, every study focuses exclusively on a specific group, like disadvantaged pupils, “typical” students in higher education, in-service teachers, and so on. Some studies adopt intersectional perspectives to define disadvantage (see, for example, Leyva, 2021; Sparks et al., 2021), yet resilience is not an incorrigible quality. In certain contexts, and under specific circumstances, it can grow or decline (Luthar et al., 2000). Future research could place more attention on examining several groups simultaneously, so that the similarities and differences of contexts and circumstances may be better understood. For example, a longitudinal project could focus on disadvantaged pupils’ narratives and follow up participants as they continue their higher education studies in STEM disciplines. Another idea is to explore the mathematical resilience exhibited by teachers, starting from when they are still studying (prospective teachers) and follow them through their transition to young professionals (in-service teachers). We are aware that longitudinal designs may be avoided as they are time-consuming, but cross-sectional approaches, we believe, could also be illuminative.

Finally, a key point emanating from our findings concerns the factors that impact the development of mathematical resilience. These factors, as presented earlier, can be clustered in two camps: *psychological* (cognitive and affective), and *social/environmental*. As observed in many of the studies reviewed (e.g. Alivernini et al., 2016; Chesmore et al., 2016; Rivera & Waxman, 2011; Suizzo et al., 2017), it is not always easy to distinguish between psychological and social factors, because the two broad clusters may interact. Also, our review indicates that researchers do not agree on the specific factors that should located within each camp. Future studies mapping these two territories, as well as an exploration of relationships within and across them, might contribute to a deeper understanding of the development of mathematical resilience.

In closing, we would like to report a reflective thought about our inclusion/exclusion criteria. We did not set any specific criterion regarding the methodological choices of the papers identified. Retrospectively, we ask ourselves whether the methodological preferences of the papers reviewed are, in any way, associated with our findings. Indeed, as every study is framed by specific boundaries, this could be examined in the future, either by us or colleagues interested in this area.

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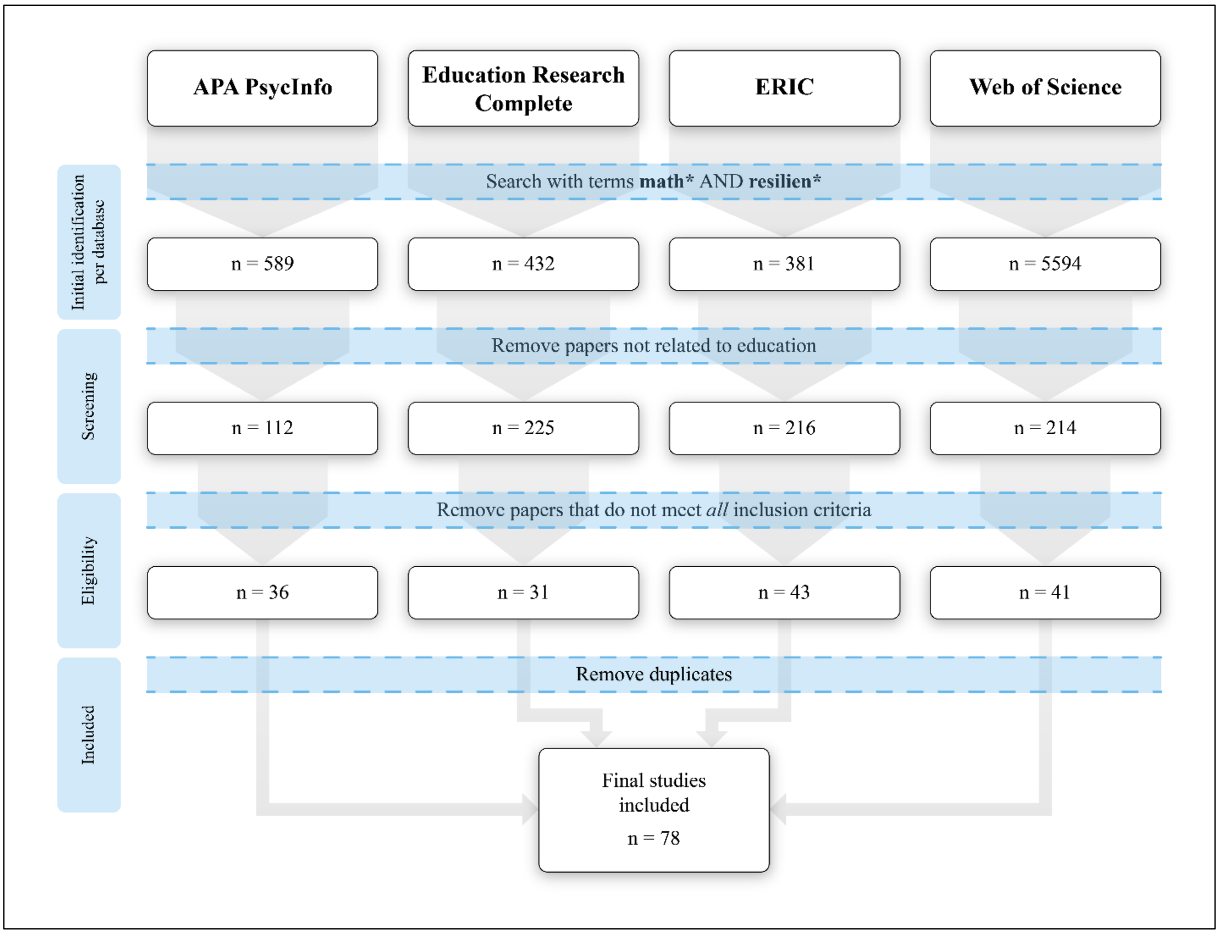

Figure 1: PRISMA flow diagram - the procedure of identification of relevant articles.