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SURVEY PAPER

The connections between citizenship education and mathematics education

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Abstract
The connections between citizenship education and mathematics education have been the focus of theoretical development and attention by educators interested in issues of justice, equity, power, criticality, and citizen engagement with societal issues, across schools, universities, and adult education levels. In this survey article, we contribute to new knowledge in the field by identifying and describing three interconnected *layers of influence* on the praxis of teaching and learning: (1) perspectives from citizenship education and mathematics education (e.g., kinds of citizenship, critical thinking in mathematics education); (2) institutional factors (e.g., policy, curricula, implementation within education systems); and (3) emerging influences (e.g., changing skill demands, innovations from communities of practice). In exploring the connections between citizenship education and mathematics education, we go beyond extant theory development and point to influences such as global disruptions, societal changes, systemic structures at the national and local levels, messaging in the media, and the role of teachers and learners. The holistic analysis of these influences enables identification of tensions and dilemmas, and issues of identity, autonomy, adoption, and systemic change. Together these point to multiple implications for educators, policy makers, and researchers aiming to enable informed and engaged citizens.

Keywords Mathematical literacy · Numeracy · Mathematics curriculum · Statistical literacy · Criticality · Citizenship education

1 Introduction

The purpose of this survey article is to identify, describe and analyse the connections between citizenship education and mathematics education — providing insight into how the praxis of teaching and learning is influenced by systemic and socio-political factors. This discussion is taking place against the backdrop of significant disruptive phenomena that are impacting nearly all aspects of life on the planet — environmental, economic and societal. Such disruptions have been brought into stark relief by phenomena such as the COVID-19 pandemic in 2020–2022. Other disruptive phenomena, such as global warming, increased poverty, and unreliable food security, have been identified in the United Nations Sustainability Development Goals (SDGs) (United Nations General Assembly, 2015) — placing pressure on the economies, national security and social cohesion of nations. These challenges can only be addressed through international collaborative efforts that are dependent on a critical and responsible citizenship towards which mathematics education can make important contributions (Maass et al., 2019a).

A discussion of how citizenship education connects to mathematics education must acknowledge the different forms of citizenship which exist across societies and forms of government (e.g., democratic, theocratic, authoritarian). Exploring the connection between citizenship education and mathematics education against all these different contexts, however, is beyond the scope of this article. Thus, we restrict our discussion to democratic societies. At the same time, we acknowledge that many of the issues discussed in this article, such as humanitarian concerns and challenges to personal freedom, are experienced in societies that are

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not considered democratic. Within the identified scope, we include in the notion of 'citizen' all those who reside within a nation, including young people, migrants and refugees. Further, we use 'mathematics' and 'mathematics education' in a broad way to encompass the learning of mathematics, statistics, numeracy, mathematical literacy, and related areas, across schools, academic institutions and other tertiary schemes, and adult education contexts (Gal et al., 2020).

Previous research into the connections between citizenship education and mathematics education has been conducted across three broad contexts: (a) civic and community life — being a member of society (e.g., Maass et al., 2019a; Ridgway, 2022); (b) completing everyday tasks that make use of mathematics (e.g., Sawatzki, 2017); and (c) the workplace (e.g., Straesser, 2015). In this survey article, we focus on the first of these contexts, recognising the essential role of informed, participatory and responsible citizenship in addressing the many challenges faced by societies (e.g., Gal & Geiger, 2022; Maass et al., 2019a). In particular, we explore the ways in which connections between citizenship education and mathematics education influence the praxis of teaching and learning mathematics. In this context, we take praxis as action informed by traditions in a field with moral, social and political consequences (see Kemmis et al., 2014; Kemmis & Smith, 2008). This encapsulates how both theoretical and practical developments shape what occurs within the praxis of teaching and learning — involving classroom environments, teachers and learners. While a significant body of scholarly work exists about the mathematics needed for both functional and critical citizenship, this is a large amorphous area that requires focused discussion which we organise through the following research questions.

> *What are the key influences on the connections between citizenship education and mathematics education?*
> *What are the implications of strengthening the connections between citizenship education and mathematics education for praxis?*

These questions provided direction for our survey of literature across multiple fields. Three interconnected layers of influence emerged from this survey, which we argue shape the connections between citizenship education and mathematics education and, in turn, the praxis of teaching and learning mathematics. While other researchers have linked citizenship, mathematics education and globalisation (e.g., Chronaki & Yolcu, 2021), this article contributes to new knowledge in the field by offering a cohesive view of the following influences: (i) perspectives from citizenship education and mathematics education; (ii) institutional factors; and (iii) emerging influences. The article concludes with a discussion of the implications for theory and practice of these three layers of influence.

2 Layer 1 — perspectives from citizenship education and mathematics education

A central focus of research into the connections between citizenship education and mathematics education is understanding how citizens can be equipped to function in society, including the mathematical/statistical capabilities needed for informed, participatory and responsible citizenship. In this section, we outline perspectives from both citizenship education and mathematics education in seeking to identify connections that have the potential to impact on the praxis of teaching and learning.

2.1 The nature of citizenship and citizenship education

The earliest approaches to citizenship education were associated with allegiance to the nation-state, achieved through a curriculum focused on selective histories and distinctive societal values (Tudball & Henderson, 2014). Such approaches required individuals, especially Indigenous and immigrant members of society, to surrender their commitment to other cultures and languages (Wong Fillmore, 2005). Thus, in the process of cultivating loyal citizens, democratic societies have sometimes marginalised ethnic, gender, linguistic, and socio-economic groups from their cultures and histories (Banks, 2004).

More recently, however, "national" approaches to citizenship education have been disrupted by the growth of globalisation, resulting in an increase in immigration and diversity within societies. This has seen citizenship education develop an increasingly global perspective, including the cultivation of tolerance and commitment to supporting cultural diversity, while also acknowledging the multitude of interconnected identities that require negotiation (Abu El-Haj & Bonet, 2011). Broadly considered, the aim of citizenship education is now to 'develop the knowledge, skills and capacities to be active and informed citizens, capable of participating in their own communities, the nation, and the wider world' (Tudball & Henderson, 2014, p. 10).

The connections between citizenship education and mathematics education are complex, as even within democratic societies there is debate about the different forms of citizenship (practiced and/or evolving), including global citizenship, cosmopolitanism, and critical citizenship (see for example, Gibson, 2020; Oxley & Morris, 2013; Pais & Costa, 2020; Ronnstrom & Roth, 2019). The interpretation of each of these perspectives on citizenship and how they are

enacted is subject to dominant political influences (Akkari & Maleq, 2018), for example, neoliberal, radical, and transformational (Estelles & Fischman, 2021). These perspectives influence the ways in which citizenship is embedded and enacted in societies, including within education programs, resulting in different *kinds* of citizenship. Westheimer and Kahne (2004), for example, writing from a North American context, have identified three kinds of citizens that emerge through efforts to educate for democracy — personally responsible, participatory and justice orientated.

Personally responsible citizens contribute to their communities by acting in ways that do not impact negatively on others, for example, by obeying laws and staying out of debt. They also contribute to society as volunteers in publicly minded enterprises, such as those supporting the less fortunate in society. Education for this type of citizen is focused on building character — emphasising attributes such as being hard working, honest and generous. Participatory citizens are those who are actively involved in civic affairs and the social life of a community. This kind of citizen is inclined to do more than just contribute to community endeavours by taking on supporting roles as they are aware of how government and community-based organisations work and understand the different ways available to participate and organise efforts to help others. While justice-oriented citizens share a commitment to improving the life circumstances of others, in the same way as personally responsible and participatory citizens, they also understand the connection between social, economic, and political forces and work to address injustices and inequities by focusing on a critical analysis of structural issues.

From our perspective, the development of justice-oriented citizenship requires educational approaches that are genuinely transformative, as the focus must be on engendering the critical capabilities needed to address cultural, economic, and social problems (UNESCO, 2015), such as those generated by the disruptive phenomena faced by the world today. At the same time, the foundations needed to substantiate such a critical pedagogy remain underdeveloped and under theorised (e.g., Bamber et al., 2018). This means that educational institutions must commit to programs that support the development of critical global citizens with the capabilities needed to pursue structural inclusion, political efficacy, and civic action, both domestically and internationally. Currently, however, programs related to global citizenship tend to be embedded within social studies subjects in schools (Banks, 2017). This approach neglects possible contributions from other areas of the curriculum (e.g., mathematics) that can support critical approaches to citizenship which inform balanced judgement and prudent decision making.

We also see these *kinds* of citizenship as requiring varying degrees of commitment to individual or collective approaches to living within a society. In the former, a focus on the conduct of the individual (doing no wrong) is seen as an approach which promotes the health of society in itself. The latter locates the responsibility of the individual within society more broadly and requires a transformative perspective. These different orientations to citizenship connect with mathematics education in distinctly different ways.

2.2 Mathematics education and informed, responsible and critical citizenship

There have been attempts to connect mathematics citizenship education and mathematics education for more than five decades. An early attempt to do so is documented in the Crowther Report 15–18 (Ministry of Education, 1959) — developed to identify the mathematics needed by individuals in the UK to continue their participation in further and higher education. A key target of this initiative was to promote a mathematics/science capable citizenry to support economic development in post-war Britain. This report was followed up by Mathematics Counts (Cockcroft, 1982), some years later, in response to criticism of the mathematical readiness of workers for the workplace during the 1970s. Among a range of recommendations identified in this report was that citizens should acquire sufficient mathematical capability during schooling to participate in further and higher education, employment, and adult life generally — introducing the notion of being *numerate*. One of the key findings of the *Cockcroft* report was that ongoing changes in society resulted in greater mathematical demands on citizens, and that "basic skills" were no longer enough for an increasingly complex world. Building on this perspective, Steen (1999) argued that to thrive in an increasingly "data drenched world", citizens must be quantitatively literate. His description of quantitative literacy (2001) included seven capabilities: confidence with mathematics; appreciation of the nature and significance and history of mathematics; logical thinking and decision-making; solving everyday problems using mathematics; number sense and symbol sense; reasoning with data; and the ability to draw on mathematical knowledge and tools. It is noteworthy that this construction of quantitative literacy addresses affective aspects, such as confidence with mathematics, going beyond previous attempts to define the area which had typically focused on cognitive capabilities.

A significant development in mathematics educations since the 1980s is the important notion of being *critical*. Frankenstein (1983), for example, brought attention to the way in which critical theory (e.g., Freire, 1970) can provide insight into the mechanisms by which mathematics

enables the oppression and marginalisation of large groups of people, as well as how this might be changed. Consistent with this approach, Gutstein (2010, 2016) developed the idea of *critical mathematical thinking* based on his work with marginalised youth in under resourced urban schools in the USA. Parallel to these developments Skovsmose (1985, 1990, 2013, 2020) linked critical theory, mathematics education, and citizenship when formulating *Critical Mathematics Education* (CME), in which mathematics is seen to play a powerful role in the formatting of societies and associated inequities. Similarly, ideas such as ethnomathematics (e.g., D'Ambrosio, 1985, 1989; Zaslavsky, 1973) emerged from post-colonial Brazil with the aim of 'challenging eurocentrism in mathematics education' (Gerdes, 1997). While these different approaches are distinct, Ernest (2010) has summarised their principal ideas as:

> …aporism, applications, citizenship, competence, critical, democracy, dialogical, formatting power, globalisation, knowledge, mathemacy, mathematical archaeology, meaning, modelling, philosophy, political dimensions, project work, reflective, responsibility, society, social functions, technology, theoretical framework, uncertainty. These terms highlight the emphasis on both epistemological issues and social contexts and issues concerning mathematics, with a special emphasis on education and social critique/social justice. (p. 65).

Others have built upon these foundations to explore other dimensions of criticality in mathematics education including socio-political issues (Gutierrez, 2013); environmental challenges (Barwell, 2013); and the evaluation of mathematics/statistics-based reports in the media (Gal & Geiger, 2022).

From a critical perspective, understanding how mathematics can contribute to the formatting (see Skovsmose et al., 2023) of the messaging to citizens by governments, commercial entities, the media, and collectives of citizens themselves is a key capability. Such understanding is therefore fundamental for informed and responsible citizenship so that citizens are empowered to engage with the mathematics underpinning societal issues. Consistent with this view, Maass et al. (2019b) have argued that making connections between responsible and critical citizenship and mathematics education is vital if young people and adults are to be equipped to make the decisions needed to ensure a sustainable, equitable and peaceful world. This has implications for teaching and learning programs in mathematics and science, for example, the inclusion of topics which promote discussion about the ethical, social and cultural consequences of decisions based on mathematical/scientific evidence (Maass et al., 2019a). They note, however, that issues such as ethics, equity, and social justice, have not been prominent in discussions about mathematics or science education, despite the moral dilemmas that often accompany innovation.

Despite the limitations in teaching and learning practice reported by Maass et al. (2019a), there are current developments in mathematics education that seek to address the lack of attention to significant societal issues in mathematics education classrooms and bring about curriculum change, for example, an ICMI supported symposium on Mathematics Education and the Socio-Ecological (March 2023, https://www.mathunion.org/fileadmin/ICMI/Conferences/Socio%20Ecological/ICMI_Symposium-announcement.pdf). The impact of these developments, however, will be promoted or constrained by the *kinds* of citizens and citizenship — personally responsible, participatory or justice-oriented — societies and education systems wish to promote. How teachers and schools contribute to the development of desirable characteristics of citizenship is significantly influenced by institutional factors such as the decisions of policy makers, curriculum writers and the requirements of school systems. These represent our second layer of influence, which is discussed in the next section.

3 Layer 2 — institutional factors related to policy, curricula and implementation within education systems

In this section we identify, describe and exemplify the second layer of influence on the connections between citizenship education and mathematics education — institutional factors related to policy, curricula and implementation within education systems. These include policy perspectives on essential capabilities, and educational systems goals, curricula, and assessment.

Describing the connections between citizenship education, mathematics education, and the praxis of teaching and learning is a complex endeavour as these are informed and shaped by different, and sometimes competing, priorities aligned with the policy directions and requirements of governments and school systems, as well as the practical concerns of schools and schooling (see for example, Ball et al., 2011). How these perspectives are prioritised and balanced determines the way educational goals are set and initiatives implemented, either top-down or bottom-up.

If a top-down view is adopted, educational policy is the starting point for a cascading set of initiatives and processes (Ball et al., 2011). Educational policies and guidelines within curriculum documents aimed at fostering an informed and responsible citizenry, however, are themselves influenced by international developments (e.g., skills retraining due to

shifts in the global economy), global initiatives (e.g., UN Sustainable Development Goals; 21st century skills), and comparative studies (e.g., PISA, PIAAC). At the same time, educational policies and curriculum documents require enactment. This requires an understanding of how policies can be interpretated and translated by a range of diverse actors in school environments (e.g., principals, teachers, students, parents/guardians, school communities), and not simply implemented in a prescriptive fashion (Braun et al., 2010). When schools develop their own interpretation of policy, they draw on aspects of their culture, including situated opportunities and constraints — elaborating, limiting, or changing the scope of policy in the process of enactment. At the same time, for schools and teachers to enact policy and curricula in ways they perceive to be important for the development of informed and responsible citizenship, they must have the agency and autonomy necessary to adapt the requirements of policy makers and school systems — a bottom-up approach. Thus, the praxis of teaching and learning is subject to both top-down and bottom-up processes.

3.1 Educational policy and essential capabilities

The increasing demands of citizenship have been recognised by international bodies through reports such as the Key Competencies for Lifelong Learning (European Union, 2019) and the Global Sustainable Development Report (Messerli et al., 2019). The 17 Sustainable Development Goals (SDGs) (United Nations General Assembly, 2015) adopted by the United Nations recognises that global challenges such as poverty can only be addressed via strategies that address health, education and inequality, while at the same time, maintaining economic growth and responding to climate change. These reports recognise the role of science, mathematics and technology in understanding and responding to the identified social, environmental and economic challenges.

Rapid societal, economic, and technological change have inspired the development of a range of frameworks that identify and describe the capabilities required to meet 21st century demands, for example, *The* Partnership for 21st Century Skills (2002) and *Assessment and Teaching of 21st Century Skills* (Care et al., 2012). While these frameworks are distinct, they both include capabilities related to creativity, problem solving, critical thinking, and the use of technology to access information and for communication. Social and cultural capabilities are also seen as essential for full participation in society. While such frameworks do not make specific reference to mathematics, they are often referenced in curriculum documents as a way of connecting subject areas to the capabilities needed for full participation in society. For example, the Senior Secondary Curriculum within Queensland, Australia states that young Queenslanders in the 21st century need to be: innovators; entrepreneurs; lifelong learners; and responsible global citizens. These aspirations underpin the General Mathematics syllabus which refers to the need for critical thinking, creative thinking, communication, collaboration and teamwork, personal and social skills, and ICT skills in the 21st century (https://www.qcaa.qld.edu.au/senior/senior-subjects/general-subjects/21st-century-skills).

Other frameworks, however, refer to and define both mathematical and citizenship competence, separately and in relation to one another. For example, the Key Competencies for Lifelong Learning (European Union, 2019) – see exemplar descriptions in Table 1.

These statements include common elements such as the use of reasoning and problem solving within personal, civic,

Table 1 Key Competencies for Lifelong Learning (European Union, 2019) mathematical and citizenship competence

	Mathematics	Citizenship
Competence	…is the **ability to develop and apply mathematical thinking and insight in order to solve a range of problems in everyday situations**. Building on a sound mastery of numeracy, the emphasis is on process and activity, as well as knowledge. Mathematical competence involves, to different degrees, the ability and willingness to use mathematical modes of thought and presentation (formulas, models, constructs, graphs, charts). (p. 8)	… the **ability to act as responsible citizens and to fully participate in civic and social life**, based on understanding of social, economic, legal and political concepts and structures, as well as global developments and sustainability. (p.12)
Skills	…to apply basic mathematical principles and processes in everyday contexts at home and work (e.g., financial skills), and to follow and **assess chains of arguments**. An individual should be able to **reason mathematically, understand mathematical proof and communicate in mathematical language, use appropriate aids including statistical data and graphs, and understand the mathematical aspects of digitalisation**. (p. 8)	…the ability to engage effectively with others in common or public interest, including the sustainable development of society. This involves **critical thinking and integrated problem-solving skills**, as well as *skills to develop arguments* and constructive participation in community activities, as well as in decision-making at all levels, from local and national to the European and international level. This also involves the **ability to access, have a critical understanding of, and interact with both traditional and new forms of media** and understand the role and functions of media in democratic societies. (p.12)

social and work contexts (bolded). The identified capacities are seen as key to the critical thinking needed for the effective decision-making central to informed and responsible citizenship. Interestingly, the final bolded statement within the list of citizenship competencies refers to an evaluative capability in relation to the media within democratic societies, highlighting the increasing role of the media in influencing the views of society.

3.2 Implementation of systemic goals and curricula

Educational policies and curriculum documents require enactment and can be interpreted and implemented in different ways at national, regional and/or local (e.g., school/classroom) levels. When attempting to connect mathematics education with citizenship education, the challenges associated with implementation at each level needs to be considered.

A criticism of curricula internationally, is that they focus on only specific national ideologies, the maintenance of culture, and procedural aspects of citizenship, rather than taking a global cosmopolitan perspective (Fozdar & Martin, 2020). This is despite growing acknowledgement that globalisation and internationally shared challenges (e.g., UNSDGs, https://sdgs.un.org/) demand that curricula also address global engagement and responsibility. Maass et al. (2019b) have made a similar observation about education in mathematics and science, which has been principally focused on the development of concepts and skills in isolation from societal implications, despite the ethical and moral dilemmas often posed by discoveries in these disciplines. This creates the impression that curriculum developers see citizenship education as more suitable for "other subjects" (see for example, Banks, 2017).

There are, however, instances where systemic progress appears to have been made, even if these remain limited. Chong (2015), for example, found, in an analysis of the development of Global Citizenship Education (GCE) in the Hong Kong curriculum guidelines, that there has been an evolution from learning about rights and responsibilities to challenging injustice, discrimination, exclusion and inequality. Such examples of programs are particularly noteworthy as they have been effective despite the challenges associated with *intended*, planned, *enacted*, and *assessed* sequence for implementing curriculum (Remillard & Heck, 2014). These challenges are well documented, for example, Ball and Cohen (1996) point out that while the design and distribution of curriculum materials is one of the oldest strategies used to foster the implementation of curriculum objectives, success rates have been uneven. This is because such initiatives often fail to provide the relevant professional learning opportunities that target teachers use of materials, resulting in situations where the enacted and assessed curricula are different from what was intended or planned. The caveat to successful education programs related to rights and responsibilities and challenging injustice, discrimination, exclusion and inequality, whether in Hong Kong or other national systems, however, is the fragility of initiatives that have a focus on socio-political issues. This fragility is due to their susceptibility to changes in local civic circumstances, which can arise within any nation, or in fact, any education system.

To support the development of the decision-making capacity needed for informed and responsible citizenship, critical reasoning and thinking have been increasingly introduced into curricula. For example, the Ugandan Lower Secondary Mathematics Curriculum; Mathematics Syllabus (Ministry of Education and Sport, 2020), includes the learning objective, "young people will become positive contributors to society who understand how to design, make and critically evaluate products and processes to address needs" (p.7). In a more explicit example, *critical and creative thinking* is a General Capability within the Australian Curriculum, which must be addressed in all subject areas (ACARA, 2021). Increasing attention to critical reasoning and thinking can also be seen through inclusion in assessment frameworks such as PISA (OECD, 2022) and PIAAC (e.g., Tout et al., 2021). At the same time, questions remain as to whether such assessment frameworks influence national assessment practices in a significant fashion (see Graven et al., 2023).

While multiple initiatives related to the development of critical citizenship capabilities through policy initiatives and curriculum change can be identified in the literature, this is an area where the implementation of instructional programs in classrooms and administration of relevant assessment remains challenging (see for example, Geiger et al., 2015). This may be related to attempts to adopt a top-down approach without fully considering the affordances and constraints associated with making changes to the praxis of teaching and learning. Such constraints include the need for teachers to adopt unfamiliar roles and identities when discussing issues such as ethics, equity, and social justice in mathematics classrooms. This may be seen by some students as problematic in a subject where answers are often seen as unambiguous (right or wrong) and free from subjective judgement (Ernest, 2010). Further, topics identified for critical discussion may not align with the concerns/values/beliefs of a local community — potentially creating conflict with stakeholders and dire consequences for teachers. This can play out through extreme reactions, such as banning of books and/or specific topics (e.g., the Holocaust) or certain theories (e.g., Critical Race Theory in the USA).

It is now commonplace for education systems around the world to include a rhetoric that supports the development of

critical democratic participation in pursuit of a more equitable and just society within curriculum documents. Yet, in practice, the focus of teaching and assessment is on the knowledge needed for individual decision making in pursuit of personal gain (e.g., best buys or not being caught out by false advertising of products) — a situation that represents a misalignment of stated curriculum goals and educational practice (see Graven et al., 2023). Such misalignments send mixed messages to teachers who wish to attend to connections between mathematics education and citizenship issues. In this situation, teachers find themselves navigating a complex terrain in which the aspiration of *justice-oriented* approaches to teaching and learning is constrained by institutional factors, in this case assessment policy and practice, to approaches only likely to support a *personally responsible* kind of citizenship.

Despite the frustrating reality of such misalignments, and the constraints these place on teaching for critical democratic participation, and hence justice-oriented citizenship, institutional structures — policy, curriculum and the requirements of school systems — are under constant pressure to address significant influences within areas of their responsibility. These include influences associated with cultural and societal change, expanding and new media, visibility of and reliance on increasingly sophisticated forms of mathematics, and communities of practice with a focus on critical citizenship. These emerging influences are discussed in the next section devoted to Layer 3.

4 Layer 3: emerging influences

In this section, we examine emerging influences that have implications for the connections between citizenship education and mathematics education. As these influences are ever-changing, we provide four selective examples: (i) impacts of cultural/societal change; (ii) expanding information and media channels; (iii) increasingly sophisticated use of mathematics and statistics; and (iv) innovations from communities of practice (Sect. 4.1 to 4.4). These are examples, identified through our survey of the literature, of influences that emerge independently from other layers and tend to develop rapidly — creating additional new demands on citizens that require urgent responses. Each of these influences heighten the need for greater attention to critical aspects of citizenship, influencing the praxis of teaching and learning accordingly.

4.1 Impacts of cultural/societal change

We have set this article against the backdrop of significant environmental, economic, and societal disruption. The impact of disruptive phenomena has given rise to wide ranging initiatives and movements that aim to address associated challenges through cultural/social change. As an exhaustive coverage of such initiatives and movements are beyond the scope of this article, we restrict ourselves to two that have attracted significant attention in recent times – sustainability as an environmental concern and activist movements related to injustices/inequalities in society.

4.1.1 Addressing the challenge of sustainability

The United Nations' Sustainable Development Goals (SDGs) focus on a range of issues that require urgent attention, including the impact of urbanisation on natural environments, food and water security, improved health and living conditions, and reducing or eliminating inequity and poverty. This development signifies a need for educational policy and practice to prioritise an understanding of issues associated with the SDGs and the capability of young people and adults to interpret the mathematical and statistical information used to measure change. As Wolff (2020) argues, societies are aware of the current and future impacts of COVID-19, but this disruption is accompanied by many other crises, such as climate change, which must also be understood and monitored. Hence, there is a need to consider which issues should be the focus of sustainability education and what teaching and learning approaches are most effective in promoting behaviours that support sustainability (Valero, 2023).

Studies in *civic statistics*, related to key societal topics (not only SDGs, but also related topics such as employment and crime), indicate that revision of curricula and instructional approaches are needed to address the intricate capabilities and dispositions needed to meet current and future challenges (Ridgway, 2022). Such changes also require that issues related to sustainability are included in assessment programs (including high-stakes examinations) if initiatives in this area are to be valued by teachers, students and the school community more broadly. Without an alignment between curriculum and assessment, the enactment of educational initiatives related to sustainability at classroom level is unlikely (see Sect. 3.2). To be effective, educational efforts within mathematics education, aimed at preparing learners to understand and respond to issues related to sustainability, must go beyond localised curriculum innovation and connect to global efforts. An example of such global effort is the World Bank's 'pillars of action' program (World Bank, 2022), which focuses on learning and education at institutional and national levels.

At the same time, Valero (2018) cautions against the development of programs concerned with understanding, designing, and improving teaching and learning alone, as

this can contribute to mathematical subjectification — a form of governing individuals and communities to maintain western profit driven perspectives of nationality and citizenship. Such programs must also bring learners into an understanding of the cultural politics of mathematics education including an appreciation of the ethical and spiritual consequences of mathematics informed decision making. (e.g., Gutiérrez, 2013, 2022).

4.1.2 Impact of activist movements

The role of activism in democratic societies has a long history of initiating social and cultural change, especially in relation to the marginalisation and de-humanisation of groups within societies. Two recent examples — the Me Too and the Black Lives Matter (BLM) movements — began in the USA spreading to protest action in other countries. These movements spread quickly due to information and data sharing that included vivid images and video, which exposed the systemic dehumanisation of women and Black members of societies.

Critical Race Theory (CRT) takes specific issue with ongoing systemic racism ingrained in systems (including in mathematics education) and the perpetuated myth that racism ended with the civil rights movement. We note, however, that across 32 states in the USA there has been a backlash from conservative members of society to a broad range of reforms beyond critical race theory, including LGBTQ+rights and the oppression of religious minorities (including the denial of the Holocaust) (Friedman & Johnson, 2022). The banning of materials and topics aimed at informing communities about such issues infringe on student and teachers' democratic rights to access such material and signal a marginalisation of student identities based on race, gender, religion and sexuality. This has implications for student mathematical identities that intersect with their social identities (Valoyes-Chávez & Darragh, 2022).

In post-colonial countries, movements (including mass protests) to decolonise education are gaining momentum (Alvares & Faruqi, 2014). The foci of curricula decolonisation movements include mathematics and science education in schools (e.g., Parra & Valero, 2021; Mudaly, 2018; Keane et al., 2017) and in higher education (Khoza & Biyela, 2020). Discussions about decolonisation in these contexts include debates about the issue of language in higher education. A significant concern is the dominant use of colonisers' language for education in formerly colonised countries (Lin & Martin, 2005), including its exclusive use in higher education in sub-Saharan African countries (Brocke-Utne, 2017).

While teachers of mathematics and statistics understand the importance of preparing learners for informed, participatory and responsible citizenship, they may have reservations about acting autonomously to address societal issues which can be seen as controversial — such as those previously outlined (Bansilal et al., 2022). This can be due to institutional pressures, a sense that relevant issues are disconnected from official curricula, or perceived limitations in their instructional capability when relating mathematics to societal concerns. Further, assessment programs can restrict attention to citizenship issues, focusing teaching on discipline specific capabilities rather than the broader goals of education. Consequently, teachers may be concerned about devoting time to topics that will not be assessed. This means that if mathematics education and citizenship education are to be connected, selected civic related topics must be carefully selected and aligned with planned curriculum and assessment programs (Wassner & Proemmel, 2022).

4.2 Expanding information and media channels

Current realities, recent changes, and projected developments on a range of key civic, cultural, economic, technological, and environmental topics are reported to the public via a variety of information sources, including media channels — both established and emerging (Ridgway, 2022). News media (i.e., whether in print, digital, or broadcast formats) have traditionally been considered the primary vehicle through which most citizens are informed of current events, including key social and economic matters. There are, however, many new digital channels for reporting the news, such as on official websites, radio broadcasts, blogs, podcasts, and postings on social networks (Apuke & Omar, 2021). Many official statistics agencies, for example, have formal social network channels and release quantitative news to the public via Facebook or Twitter/X.

The volume of news available to citizens has rapidly increased during the 21st century, and, at-the-same-time, the range of paths through which people encounter, identify, and consume news, including incidental exposure and recommender systems on social platforms, is also expanding (Schäfer, 2023). Consequently, the role of mathematical and statistical thinking and reasoning in the critical interpretation of reports in the mass and social media has been a focus of enquiry across a range of domains, such as mathematical literacy, adult numeracy, and statistical literacy (Jablonka, 2003). This enquiry has led to the identification of new demands on citizens' mathematical/statistical knowledge. For example, Gal and Geiger (2022) conducted a content analysis of a large sample of media items from four countries regarding the COVID-19 pandemic. From this research they argued that the breadth and depth of the mathematical and statistical products knowledge needed to critically evaluate mathematical and statistical information is much

broader than what is typically expected in many curricula. Complementary studies have led to theory development about the citizenship-related constructs such as *data literacy*, *information literacy or news literacy*. These include mathematical and statistical components but also draw on ideas and concepts well beyond these two disciplines (Cui et al., 2023).

Other authors also point to the increased need for capabilities and dispositions needed to think critically. Duncan et al. (2018), for example, identify thinking critically about the quality or adequacy of quantitative arguments (e.g., about results of modeling related to global warming), permissible inferences from the analysis of data, and the quality of evidence as key capabilities for informed and responsible citizenship. Skovsmose (2020) adds to this discussion by outlining the ways in which reports in the media are formatted, that is, shaped in support of particular positions or arguments. This perspective highlights the need for criticality when engaging with the news, especially in the context of the rapid emergence of phenomenon such as *fake news* and the proliferation of *misinformation* (Carmi et al., 2020), within sources beyond traditional news media, such as on social networks (Apuke & Omar, 2021). The issue is amplified by 'news channels' that are biased towards particular agendas, resulting in the spread of misinformation. A recent illustration of the issue of bias in the media is the lawsuit against traditional news channel Fox News for spreading misinformation about the manufacturer of voting machines to cast doubt on the credibility of the outcome of the national presidential election in the USA. Such developments point to the need for criticality to have a central role in data and information literacy, even when applied to seemingly trusted sources of news. Recent systematic literature reviews, however, indicate that data and information literacy are still emerging educational fields that are based on limited empirical studies and lack agreement about the conceptualisation of key learning goals (Cui et al., 2023; Ghodoosi et al., 2023.

4.3 Increasingly sophisticated use of mathematics and statistics

Information and news about societal, environmental, and economic issues are reported to the public, both local and global, through the use of increasingly sophisticated mathematics and statistics, for example, the logarithmic scales associated with "flattening the curve" and the R or reproductive number. The demands placed on citizens by such news requires a rethinking of the mathematical/statistical/digital knowledge, capabilities, dispositions, and practices needed for informed, active and responsible citizenship. These are exemplified below under three distinct but related areas.

4.3.1 Complex mathematical and statistical information and arguments regarding global disruptions

The last decade has witnessed the rapid emergence and/or intensification of disruptive phenomena, such as the COVID-19 pandemic, global warming and environmental changes, wars, waves of refugees and migration, and disruption of food supply chains and energy markets. These have received focused attention by authorities and the media, with implications for policy priorities and public expenditure, all of which impact the lives of citizens and society at large. As Gal and Geiger (2022) have pointed out, information in the media about the prevalence, progression, and severity of such disruptions, and predictions about their anticipated progress and impacts, require an understanding of a wide range of statistical and mathematical products (StaMPs). These include the need to: understand comparative information; interpret communication about risk and predictions from statistical and mathematical models; and activate blended knowledge. These and other aspects of disruptive events require mathematical and statistical capabilities that go beyond current content in typical mathematics curricula internationally. This raises the question of how citizens can acquire the capacity to evaluate the mathematical and statistical information now commonplace in public forums.

4.3.2 Impact of new digital resources and types of data

Citizens are increasingly faced with a world in which new forms of data are used by governments, corporations, and non-profit organisations (Ridgway, 2016). Within this context, the term 'data' should be viewed broadly, well beyond that of traditional statistical processes, such as surveys, as many new types of quantitative or quantifiable information and representations are now used. *Open data* () from diverse sources are also now accessible but the credibility and completeness of such sets are variable. There is also an urgent need to understand how *big data* () and *administrative data* () are used in decision-making processes by public and private organisations. How such data is used has implications for the agency of citizens in the practice of informed decision-making. The analysis and use of data is also shaped by technological advances. Such advances require increased levels of digitally enabled data literacy — empowering citizens with the ability to select relevant data sources, and to access, analyse, and compare the characteristics, strengths and weaknesses of mathematical and statistical data (Knight et al., 2022).

4.3.3 Algorithmic, computational and modeling-based systems in the public sphere

Citizens increasingly engage with, and are affected by, decision system technologies that are informed by the algorithmic processes employed in data science, machine learning, and/or models and applications based on artificial intelligence (AI). Algorithm-related technologies are developing rapidly and employed by commercial providers, public agencies, scientific organisations, and many industries. These technologies are used in a growing range of areas such as healthcare, transportation, education and college admissions, and risk assessment (Pessach & Shmueli, 2022). Citizen engagement with algorithmic systems in everyday life include recommender systems that profile users and suggest placement of advertisements or courses of action (e.g., products in online shopping, newsfeed options), screening processes for loan applications, and e-recruitment procedures for worker selection (Smythe et al., 2021). These systems, however, typically operate as 'black boxes', that is service recipients and/or operators are mostly (or generally?) unaware of the modelling or algorithmic processes operating under the hood and have no access to the underlying data and predictive logic.

The penetration of algorithmic systems into all walks of life raises concern about their impact on citizens' loss of privacy, financial and personal security, mental health, and well-being. This issue is exacerbated by *algorithmic bias*, that is, the possibility that, whether by intention or not, systems advantage or discriminate against specific social groups. Such outcomes can be due to their design, operation, or the underlying database on which the systems are trained (Pessach & Shmueli, 2022). Hence, users need not only be aware of and understand the logic and intended benefits underlying the use of algorithmic systems, but also their potential ethical ramifications at societal, organisational, and personal levels.

While *computational thinking* is now viewed as an element of mathematical literacy, with regulators responsible for maintenance of fair practices in this area. (e.g., PISA, 2021; OECD, 2018), we argue that there is a gap between the presence of hidden models and computational logic within algorithmic systems and the way mathematical modelling is represented in mathematics education research and curriculum documents. This gap means that citizens are generally unaware of how algorithmic models impact on their everyday lives, including both benefits and risks. As a consequence, inequities and injustices that can emerge when citizens engage with such models, may not be brought to the attention of regulators responsible for maintenance of fair practices in this area.

4.4 Innovation from communities of practice

The emerging influences outlined in the preceding discussion require the generation of new theory and innovative practices. A range of organisations have formed around this goal, who, in turn, influence the connections between citizenship education and mathematics education by taking the bottom-up approach (described in Sect. 2). The work of these organisations encompasses new theoretical perspectives, curriculum reform, the design of teaching guidelines or classroom activities, and assessment materials. Some of these organisations, often identifying as communities, work at an international level, while others focus their efforts within one country, cultural context, or locality. Three illustrative examples for such communities of practice and their innovations are presented below.

Example 1 The Mathematics Education and Society (MES) community.

This international community has a focus on ideas related to the role of mathematics in society. MES members are interested in ethnomathematics, critical mathematics, social justice, and other topics that touch on mathematics and citizenship issues. These are built on localised mathematical wisdom that prepare future citizens to engage with topics of importance to communities and/or cultural groups (see Sect. 2). Members of this community communicate via email lists and internet websites, organise dedicated conferences, lead topic study groups at international conferences, and work on joint publications. While some of the activities and publications of MES members are dedicated to the development of theory and critical scholarly reflection, some publications and presentations describe ongoing projects and initiatives in a range of educational contexts. This includes exploring the ramifications for teacher preparation and professional development (e.g., Penteado & Skovsmose, 2022).

Example 2 Educators for quantitative literacy (QL) and quantitative reasoning (QR).

The last decade has seen the development of a network of educators who teach QR and QL topics (see for example, Foley, 2023). This group predominantly consists of educators in community colleges in the USA, who serve learners pursuing college degrees in non-mathematical areas and who have limited backgrounds in mathematics. These learners typically avoid mathematically rigorous courses and tend to hold negative views of mathematics and statistics, with the consequence of high dropout rates. Educators who teach QR and QL have developed dedicated curricula

and teaching methods that embed a range of topics related to citizenship issues, to motivate students, reduce dropout rates, and reinforce the connection of mathematical and statistical topics to social justice, gender equality, and other citizenship issues (Karaali & Khadjavi, 2021). Like those associated with the MES community, educators in the QR/QL network interact with the support of professional organisations (e.g., the National Numeracy Network, the Mathematical Association of America), hold regional and national conferences, and encourage joint discussions and exchange of educational products and ideas.

Example 3 Local initiatives focused on socio-ecological topics.

Presentations at a recent symposium on socio-ecological issues, organised under the auspices of the International Commission on Mathematical Instruction (ICMI, 2023), and a recent keynote by Coles (2023) at the Psychology of Mathematics Education (PME-46) conference, have highlighted initiatives by mathematics educators working with local communities in countries such as Brazil, Canada, Mexico, the Philippines, and the UK, on a range of projects. These initiatives revolve around issues such as pollution, water quality, loss of biodiversity, and other topics, and highlight the need for adults and pupils alike to develop awareness of disruptions, and related data, which affect their lives and prospects, and are the basis for local action. The work of this group of mathematics educators/researchers exploring such issues has been acknowledged by ICMI, who have announced a Study Conference devoted to the role of mathematics in addressing socio-ecological issues. This community has a focus on how to foster practical community-based approaches to addressing socio-ecological issues and theory generation.

While space limits discussion to three examples of the many communities that address issues that relate to the connection between citizenship education and mathematics education, these serve to illustrate simple yet powerful ideas. Educational work in mathematics and statistics education that connects with societal issues emerges in many contexts due to the ideas, perspectives, and energies of *individuals*, who are not governed by formal curricula or the demands of education systems. This stance can lead to the emergence of communities of practice devoted to specific themes of research or practical endeavour. These communities may even view themselves as "anti-establishment" — operating against the traditional abstract or procedural view of mathematics and statistics. Such developments imply a need to attend not just to teachers and learners' mathematical knowledge but also to their beliefs and to the value they place on the topics being taught or learned.

These emerging influences impact on institutional structures (policy curriculum, requirements of school systems), as flagged at the end of the previous section, and bring new ideas into perspectives on citizenship education and mathematics education, which informs the decisions of institutional structures (discussed earlier). This interconnectedness means that the adoption of holistic approaches, rather than only focusing on individual elements of Layers, is key to bringing about change that leads to greater focus on justice-oriented citizenship and the collective good.

5 Contributions of the articles in this special issue

This special issue of *ZDM—Mathematics Education* includes seven papers that together make substantial contributions regarding the layers of influence on the connections between citizenship education and mathematics education. The Issue highlights implications for teaching mathematics at multiple levels and contexts of education, spanning both formal and informal education systems.

The historical link between political developments and education systems is emphasised by Rosa et al. (2023). In this discussion, the authors raised questions about the influence of nationality, power, identity, and decolonisation. Their study, conducted in a Brazilian community, demonstrated how an ethnomodelling approach contributed to the development of mathematical content and supported students in making decisions about local and global problems.

Adopting a theoretical perspective on inclusive mathematics education, Skovsmose et al. (2023) reflect on the process and outcomes of several published projects involving mathematics learners from countries such as Brazil, Denmark, and South Africa aimed at developing an understanding of tolerance in relation to difference. They highlight the need to develop tolerance of 'differences' (e.g., national identity, economic, cultural or living conditions) though attention to shared concerns as part of mathematics education.

Taking a different perspective on student learning, Makar et al. (2023) examined Australian primary students' citizenship development through a data science approach, investigating civic problems through analysis of non-standard or messy data. In this study, they used a framework, generated from critical citizenship education literature, to analyse classroom videos. This analysis revealed how a complex data investigation in citizenship education was achieved through meaningful curriculum integration. The investigation also revealed a gap between data science skills and those developed in the mathematics curriculum.

In a study of how to support mathematics and science teachers as they attempt to implement intercultural learning, Sorge et al. (2023) discuss a professional development course involving teachers from six European countries. The findings of the study indicate that the course strengthened teachers' self-efficacy beliefs and was linked with teaching practices related to cultural diversity.

Goos et al. (2023) report on an investigation of adult numeracy provision in Ireland. Using interviews with adult education providers, adult numeracy tutors, and adult learners, the study identified themes that connect adult numeracy with a human rights conception of citizenship — seen as a right to access to and participate in economic, social, and community life. The study includes discussion of the barriers to participation in adult numeracy classes.

Drawing on a study of curriculum change within their own institution, Foley et al. (2023) examine issues associated with teaching college-level Quantitative Reasoning courses which aim to develop key practical and intellectual skills for citizenship. Based on interviews with instructors in the United States, the study shows that most instructors view critical thinking as a central goal of the QR course and as supporting citizenship education.

Finally, Graven et al. (2023) analyse the alignment of citizenship objectives in national curriculum documents against the type of items included in national school exit assessments for Grade 12 learners of Mathematical Literacy in South African high schools. Comparing item content across multiple exam years, the study shows shifts away from topics related to critical citizenship toward items orientated to life preparation. Findings of this study also indicate a movement away from open-ended questions towards closed 'check figure calculation is valid' type questions.

These articles provide new perspectives on the connection between citizenship education and mathematics education, engaging with issues across the layers of influence identified in this Special Issue.

6 Discussion & implications

In this article, we provided insight into the connection between citizenship education and mathematics education — identifying connections that cannot be addressed by attention to theoretical positions or to perspectives from practice alone. Thus, our analysis addresses the complex inter-related *layers of influence* on the connections between citizenship education and mathematics education that shape the praxis of teaching and learning, in contrast to previous research which has tended to adopt a mono-dimensional approach. We have structured the summary of our contributions to new knowledge via the research questions that provided direction for our study.

6.1 What are the key influences on the connections between citizenship education and mathematics education?

A key contribution to new knowledge, identified through our survey and in response to our first research question, is the identification and description of three interconnected layers of influence: (1) perspectives from citizenship education and mathematics education; (2) institutional factors related to policy/curricula/implementation within education systems; (3) and emerging influences. We have considered these holistically, a departure from previous research which has tended to treat them separately. Each layer influences the connections between citizenship education and mathematics education and in turn the praxis of teaching and learning in different ways. Layer 1 represents perspectives from research that inform both teacher education programs and school classrooms via ongoing professional learning. Layer 2 relates to institutional factors that catalyse both top-down and bottom-up processes that impact on classrooms, teachers and learners. Layer 3 represents rapidly emerging influences that create additional new demands on citizens that require urgent responses including, in particular, greater attention to critical aspects of citizenship. We capture the complexity of these three inter-related layers of influence, each involving multiple elements, in Fig. 1.

We found there was an emphasis on theory and theory development in scholarly discussions of the connections between citizenship education and mathematics education sketched in Layer 1. There were multiple additional influences, however, that work in different ways to impact on the connections between citizenship education and mathematics education and, in turn, the praxis of teaching and learning. Our review of the literature suggests that more attention is needed to Layer 2, especially to the views of educational policy makers about what constitutes the essential capabilities needed to accommodate the increasingly complex mathematical/statistical/digital demands of society. This perspective shapes what is required by school systems and what should be adopted by schools or other educational institutions. Policy makers' views on essential capabilities can be a reaction to a perception of civic and environmental changes, or other disruption, being experienced by society. These can be brought to the fore by international initiatives (e.g., UN SDGs) or activism related to addressing social issues (Layer 3). The influence of national educational goals and local educational systems within Layer 2 influence curriculum and assessment, as illustrated by Graven et

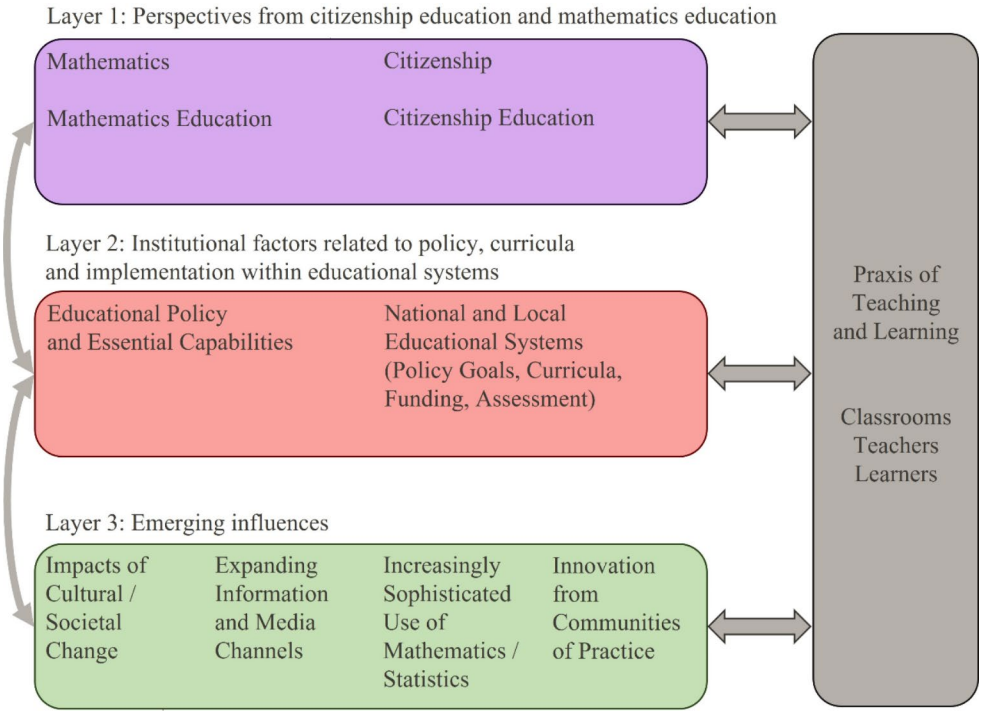

Fig. 1 Layers of influence on the praxis of teaching and learning related to mathematics education and citizenship education

al. (2023), and eventually affect the praxis of teaching and learning.

Our survey also identifies Layer 3, *Emerging Influences*, which comprises factors that have not previously been included in models of curriculum enactment (e.g., Remillard & Heck, 2014). This layer is related to ongoing discussion about the role of mathematics in power relations within society — reinforcing or challenging inequity and injustices — but goes well beyond it. This discussion has focused on the role of mathematics in emancipatory power (e.g., Ernest, 2010, Valero, 2018), criticality (Gutstein, 2016; Skovsmose, 1985), and the maintenance of democratic societies (Gibson, 2020; Skovsmose, 1990; D'Ambrosio, 1985). A central theme within this discussion relates to how mathematics can be used to support oppression and marginalisation by certain social actors, while also providing the ways in which these might be brought to light or addressed (e.g., Frankenstein, 1983). This theme is reflected in mathematics education and policy research being conducted by communities of practice, such as the MES and QL/QR communities (Layer 3), which respond to the issues emerging from social/cultural change (Layer 3). The efforts of these communities are aimed at challenging the status quo and/or existing programs set in place by the policies of government and/or the requirements of education systems (Level 2). The resulting generation of and advocacy for innovation can eventually influence the praxis of teaching and learning. Thus, emerging influences within Layer 3 must be considered when attempting to understand the impact of the connections between citizenship education and mathematics education on the praxis of teaching and learning.

6.2 What are the implications of strengthening the connections between citizenship education and mathematics education for praxis?

The rapid changes in society linked to disruptive phenomena mean that it is essential for citizens to comprehend and be capable of critiquing predictions and decisions provided by governments, experts and non-expert commentators. These predictions are communicated via increasingly sophisticated mathematics. This implies a need to rethink curriculum goals, with more focus on the teaching of statistics, and connecting mathematics with probability and especially risk. It also suggests that there should be greater emphasis on instruction that embodies the inter-relatedness of knowledge – including the connections between science, mathematics, economics, and studies of society. While we see such developments in curriculum as vital, Valero (2023), reminds us about the danger of mathematical subjectification, in which mathematics education can be a tool for maintaining western ideals of national prosperity at the expense of all else — including the health of the planet. This caution reminds us that the inclusion of overarching principles, related to the ethical and spiritual consequences of mathematics informed decision making, are imperatives in curriculum development.

At the same time, the complexity and inter-relatedness of layers of influence on connections between citizenship

education and mathematics education means that reform that promotes a mathematically/statistically/digitally capable and responsible citizenry requires attention to more than general policies or curricular guidelines regarding mathematics and citizenship education alone. Ultimately, it is teachers and lecturers in classrooms who make judgements about the relevance of different layers of influence on the praxis of teaching and learning. In doing so, they must strike a balance between the demands associated with different layers of influence and what they see as practicable in their circumstances (e.g., school or university resources and available time, needs of students). Teachers'/lecturers' judgements about their role in promoting critical and responsible citizenship will also be shaped by school expectations, their knowledge and expertise in relation to the connections between citizenship education and mathematics education, and their personal beliefs about topics that are appropriate for exploration in mathematics classes (e.g., degree of controversy).

The inter-relatedness of the layers of influence also generates inherent tensions and potential contradictions. For example, should a more "citizenship active" approach to promoting the connection between citizenship education and mathematics education be aimed at merely raising awareness of relevant issues or should it also lead to learner action? In this context, Frankenstein (1983) has argued that genuine engagement is needed to support change and a climate which amplifies the momentum of liberatory movements. Conversely, does inaction in relation to injustices identified using mathematics represent failure if the goal is to promote the connection between citizenship education and mathematics education?

Adopting a critical perspective when discussing mathematical material related to environmental/economic/social issues represents a challenge for many teachers (see, for example, Geiger, 2019), as approaches to mathematics/statistics instruction have most often been portrayed as neutral — separatable from personal values or ethics (Forgasz et al., 2015). Some have argued that this stance represents a world view focused on the dispassionate accumulation and consumerism by individuals (having) rather than ways of being contributing citizens, or on "objects rather than on people, feeling, empathy, caring, and being." (Ernest, 2010, p. 16). For example, Takker (2017) found that teachers saw contexts such as the difference between male and female wages as distractions from the mastery of the relevant calculations. On the other hand, teachers who believe that it is important to engage with emerging social issues may not feel sufficiently confident or prepared to engage learners with new content and/or teach via inquiry approaches that open debate about potentially sensitive issues (Bansilal et al., 2021). This issue is key, as it is teachers who are exposed to the highest level of risk when implementing change, compared to other stakeholders such as teacher educators and policy makers (e.g., Ernest, 2010). Such risk may be exacerbated if teachers are not equipped to engage with the notion of criticality within a rapidly changing world.

Engaging teachers with topics that address the connection between citizenship education and mathematics education requires reflection on relevant pedagogies across levels of education and about the factors that promote or prevent adoption of innovations by teachers. Pedagogies that support inquiry, critical thinking and reflection, and that emphasise greater contextualisation of instruction, may require the adoption of different socio-mathematical norms in classrooms (Makar et al., 2023). Despite years of promotion within reform-based movements, however, inquiry-based teaching is yet to gain broad acceptance. Teacher and system resistance to reform-based movements across the world are well known and represent one of the greatest challenges to the embedding of critical aspects of the connections between mathematics education and citizenship education.

Our analysis of relevant literature also highlights the need to pay attention to issues related to *learners*, a key perspective when designing programs for young adults or adult learners, as they will have developed their own views and beliefs about societal issues and the relevance of mathematics and statistics (Goos et al., 2023). Such views will dictate what and how discussion may play out in classrooms. These considerations give rise to questions such as: What is the role of learners' beliefs or their convictions in conversations about equity, diversity, and social justice? Do they view mathematics and statistics as reliable or informative tools for exploring these issues? Do they believe that mathematics is at all relevant to their expression of responsible citizenship? Questions of this type relate to affordances and constraints on learners' use of mathematics and statistics to critically evaluate claims, propositions, and arguments in the public domain, and engagement with needed civic action (Ridgway, 2022).

6.3 Final comments and implications

In concluding this article, we point again to the tensions which emerge when exploring the connections between citizenship education and mathematics education, raised by Frankenstein (1983) and still relevant today, 40 years later:

> In developing a critical pedagogy, we must consider both content and methods. Emancipatory content presented in a nonliberatory way reduces critical insights to empty words that cannot challenge students' taken-for-granted reality and cannot inspire commitment to radical change. Humanistic methods without critical

> content can make students "feel good," but cannot help them become subjects capable of using critical knowledge to transform their world. (p. 321)

Consistent with this view, we see that the connections between citizenship education and mathematics education must be addressed in meaningful ways, such as developing links to the United Nations SDGs or adapting curriculum to include discussion about disruptive phenomena or emerging social/cultural issues. This requires a balance between simplifying the socio-political complexity of problems and the focus applied to mathematically and statistically important issues. In achieving such a balance, the following questions require attention.

- Is the connection between citizenship education and mathematics education equally relevant to all students? If so, how might national and local educational systems address issues of curriculum development, instructional practices, assessment, and teacher preparation? If not, how might these systems cater for differential needs across grade levels and diverse students? (Layer 1)
- Where should the focus of innovation be on the connection between citizenship education and mathematics education (e.g., curricula level, teacher level)? One area that requires attention are the mismatches between policy related to the connections between citizenship education and mathematics education and the assessment that is developed and administered. (Layer 2)
- The issues raised in this article lead to significant questions for future research into citizenship education and the praxis of mathematics teaching and learning. For example, how might teachers be supported in promoting the *criticality* needed to engage with challenges inherent in addressing the ever-emerging influences on the connections between citizenship education and mathematics education? (Layer 3)

It is important to note, however, that attempting to address these questions through an emphasis on criticality requires different classroom tasks or activities and instructional approaches that may be seen by some as inaccessible to, or inappropriate for, under-achieving or diverse learners (e.g., Sabarwal et al., 2022). This represents a contradiction, as the inequity that may be addressed through a focus on the connection between citizenship education and mathematics education may be exacerbated by limiting certain students' opportunities to learn to think critically. Such an approach also neglects the plight of those Chronaki and Yolcu (2021) identify as "others" — those who do not benefit from preparation for citizenship, representing an often-invisible disadvantaged group in society.

The rapid pace of emerging influences on the connections between mathematics education and citizenship education, in our discussion of Layer 3, necessitates urgent revision of learning goals and teaching approaches. Such action is likely to be constrained, however, if educational innovations are initiated in a top-down fashion by large education systems. Mathematics education communities, educational policy makers and curriculum writers, must consider how to respond to the need for continuous and rapid change. We argue that this issue can only be addressed through research that investigates the potential of instructional schemes designed to embrace educational innovation and accommodate ongoing change. One promising approach is the 'agile education' perspective (Salza et al., 2019), which was inspired by proven approaches developed in other disciplines for agile software development and agile project management. This approach involves iterative cycles of design and trialling that are integrated at all levels of project development and are accompanied by full managerial support. Agile approaches have already shown promising outcomes in terms of both learning gains and learners' reactions, in the area of education for sustainability competencies (López-Alcarria et al., 2019). This suggested that agile approaches have potential for developing initiatives that can promote mathematical capabilities and dispositions linked with global sustainable development goals on the one hand, and the personally responsible, participatory and justice orientated views of 'citizenship' on the other.

The issues and questions discussed in this article point to challenges that researchers, practitioners, and educational decision makers must address. We hope that the ideas and challenges explored in this article will assist in focusing future directions for mathematically/statistically informed and empowered responsible citizenship, at all levels of education. Ultimately, however, future directions in research and practice must be informed by reflection on what *kind* of citizen societies wish to engender — individuals who believe it is enough to do no harm or those who take a critical view with the aim of improving the life opportunities of all members of society.

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