Is Mathematics Education Worthy?
From Mathematics for Critical Citizenship to Productivity Growth

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Public discourse concerning STEM has an increasing influence on mathematics education, yet the exact role that mathematics plays in STEM is hard to define. I compare STEM to numeracy to investigate how mathematics is repositioned in these two discourses. Each is analysed in terms of rhetorics that argue for the worth of mathematics education. While numeracy viewed mathematics as worthy for critical citizenship, STEM argues that mathematics has worth due to its support of the innovation required for productivity growth. Analysis of the rhetorics is argued to support the mathematics education research community response to changes in public and policy discourses regarding mathematics.

The way that mathematics education is discussed in public discourse has shifted significantly in recent years. In the Australian context, the term numeracy is falling out of favour while STEM (science, technology, engineering, and mathematics) gains prominence in government publications (Australian Council for Educational Research [ACER] & Stephens, 2009; Department of Education and Training, 2016). Many authors argue that the pedagogical implications of STEM are not well defined, and the links between the STEM disciplines are not self-evident (van Driel & Clarke, 2016). Rather than trying to define STEM, or explicate the links between STEM disciplines, I take a different approach. Numeracy and STEM are posited to be rhetorical discourses in Australia. By tracking the shift from a rhetoric of numeracy to a rhetoric of STEM, it is hoped that the way this shift repositions mathematics education can be investigated, which may assist the field of mathematics education research when considering responses to STEM rhetoric.

The use of the term "rhetoric" in this paper comes from the work of Sutton-Smith (1997), who defines rhetoric as a "persuasive discourse, or an implicit narrative… [designed] to persuade others of the veracity and worthwhileness of their beliefs" (p. 8). In the context of mathematics education, rhetorics of mathematics education can be seen as discourses that argue for and provide validity to the teaching of mathematics. Sutton-Smith (1997) described seven rhetorics applied to "play" in different times and places. Within each rhetoric, the nature of play was different, and his work enabled shifts in rhetoric to be identified. Sutton-Smith (1997) was able to identify each rhetoric by identifying different ways that discourses presented play as being worthy. I begin my analysis by identifying different arguments for the worth and validity of mathematics education present in mathematics education discourse. Two research questions guide this study: (1) How do the numeracy and STEM discourses argue for the worth of mathematics education? and (2) Has there been a shift in the way that the worthiness of mathematics education is articulated as discourse shifts from a numeracy discourse to a STEM discourse?

Government texts are used as examples of numeracy and STEM discourse. Analysis involves locating arguments for the worth of mathematics education within government texts. A brief summary of the development of STEM within economic discourse is presented. This then informs analysis of policy documents, in which I seek to identify the rhetorics of which mathematics education numeracy and STEM are representative.

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Literature Review

Sutton-Smith (1997) argued that rhetorics can be hard to identify because they are often expressed implicitly. The form of rhetorical analysis that he employed built on the work of literary theorist, Kenneth Burke (1969). Burke argued that rhetoric attempts to bring about change in people. Rhetorical analysis, as a form of discourse analysis, begins by identifying elements of a text which are persuasive. These persuasive elements can then be analysed in order to identify how the worth of the subject of the discourse is being articulated. Mathematics education rhetorics in text, for example, will try to persuade readers to value mathematics education, and will express implicit beliefs regarding why mathematics education is a worthy endeavour. Direct articulations of these arguments are rare, but Skovsmose's (1994) framework for a philosophy of mathematics education directly articulates arguments for the worth of mathematics education. Reviewing Skovsmose's work, six distinct mathematics education rhetorics can be identified, and are summarised in Table 1. Of the six rhetorics identified, only four were present after the numeracy and STEM texts were analysed. Hence, detailed description of last two rhetorics in Table 1 – which are not part of the analysis– has been omitted due to space constraints.

Table 1
Summary of Mathematics Education Rhetorics and their Positioning of Mathematics

Rhetoric	Worth of mathematics education	Positioning of mathematics with other subjects
Mathematics for critical citizenship	Essential to democratic participation	Positioned with literacy
Mathematics for human capital	Provides skills required for participation in the workforce	
Mathematics for technological progress	Underpins capacity for technological development	Positioned with science and technology
Mathematics for global competition	Provides advantage to nations that do it well	
Mathematics as a human right	Component of education for all	Positioned within the broad context of being educated
Mathematics for social equity	Provides access to the knowledge and skills of the privileged	

Skovsmose (1994) argued that some conceptions of education view mathematics as essential for critical citizenship (mathematics for critical citizenship). Without mathematics, people will not be able to participate in democracy effectively; hence, mathematics education is justified in terms of empowering citizens to be active and critical members of their societies. Within this discourse, mathematics is positioned alongside literacy as a basic prerequisite to civic competence. Skovsmose's (1994) second argument for mathematics education relates to human capital (mathematics for human capital). The economy requires workers who have a level of competence in mathematics. Hence, mathematics education is worthy because it fulfils the human capital needs of a society. Skovsmose's next argument connects mathematics and technology (mathematics for technological progress). In this discourse, mathematics is viewed as a foundational element of scientific and technological development. Mathematics is a means to an end; scientific and technological development are the end, so mathematics education is worthy because without it, science and technology cannot progress. Global competition (mathematics for global competition) has also been used to argue for the worthiness of mathematics education (Skovsmose, 1994). In this discourse, a nation's ability to educate its populace in mathematics is seen as providing a "competitive edge" globally. The identification of mathematics education rhetorics (Skovsmose, 1994) does not provide a comprehensive list of all mathematics education rhetorics. Given the constraints of this paper, the six rhetorics identified provide sufficient framing to enable analysis of numeracy and STEM discourses.

Economic Arguments for STEM and Mathematics Education

As STEM is the more current rhetoric that frames education policy that is considered in this study, a brief survey of the economics research literature that relates to STEM is presented. Quiggin (1999) outlines three economic models that have influenced education policy in Australia. Of these, Human Capital Theory (Becker, 2009) has become increasingly influential. Human Capital Theory argues for the economic value of education (as opposed to cultural value, for example), which is evident in the increased incomes of those with higher levels of education (Becker, 2009). Higher rates of pay are argued to increase an economy's productivity. More wealth can be generated per worker in a productive economy, which contributes to society's wellbeing (Conway, 2013). This line of argument has led economists to try to identify which industries have the most potential for productivity growth. For instance, Peri, Shih, and Sparber (2015), looked at how wage growth in major cities in the U.S. was affected by the proportion of the workforce that worked in STEM industries. They found that, "scientists and engineers are responsible for 50% of long-run U.S. productivity growth" (p. S226). This more recent trend in economic analyses that are concerned with addressing productivity growth has been arguing that disciplines that foster technological progress and research and development are more valuable than others (Office of the Chief Economist [OCE], 2015). STEM workers are the best positioned to drive innovation, and "the role of innovation in sustained economic growth cannot be overemphasised" (OCE, 2015, p. 138). This technological progress will enable productivity growth and lead to a better society with improved living conditions (Conway, 2013). Unlike early formulations of Human Capital Theory, recent economic discourse does not argue for the economic benefit of "education", but for the benefit of education only in areas deemed to have the greatest capacity to foster productivity growth – STEM. Mathematics education policy is likely to be affected by this economic discourse, which elevates mathematics education to a position of prominence within education but also makes mathematics education subservient to innovation and productivity growth.

Method

A range of documents have been analysed in order to identify which of the six rhetorics identified from Skovsmose's work are present in discourses of numeracy and STEM in the Australian context. The rhetorical analysis used involves identifying passages of the analysed texts that try to persuade the reader that mathematics education is worthy (Sutton-Smith, 1997). Skovsmose's (1994) work also highlights that the way in which mathematics is positioned in relation to other subjects varies between some rhetorics. Table 1 summarises how each rhetoric argues for the worth of mathematics education and how some rhetorics position mathematics with other subjects. The way that mathematics is positioned in relation to other subjects within numeracy and STEM discourses was also used to argue for the presence of rhetorics that can be identified in this way.

Selection of Documents

I do not seek to provide a comprehensive review of all policy documents relating to numeracy and STEM, as the research questions that guide this paper can be sufficiently addressed without an exhaustive review. Government publications from the state government of Victoria and the Australian Federal Government have been analysed. One document from the Organisation for Economic Co-Operation and Development (OECD) has also been analysed to provide an international perspective. At least one numeracy and one STEM document whose intended audience are teachers has also been included. I view numeracy and STEM to be discourses that are primarily expressed in these types of text.

Table 2
Summary of Documents Included in the Study

Author	Year	Title	Discourse
Council of Australian Governments (COAG)	2008	*National Numeracy Review Report**	Numeracy
ACER, & Stephens	2009	*Numeracy in Practice: Teaching, Learning and Using Mathematics**	Numeracy
Office of the Chief Scientist	2013	*Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach**	STEM
Department of the Prime Minister and Cabinet	2014	*Increasing the Focus on Science, Technology, Engineering and Mathematics (STEM), and Innovation in Schools*	STEM
OECD	2014	*OECD Science, Technology and Industry Outlook 2014*	STEM
Department of Education and Training	2016	*STEM in the Education State**	STEM
Office of the Chief Scientist	2016	*Australia's STEM Workforce**	STEM

Analysis

The first level of analysis involves locating arguments for the worth and position of mathematics education in the selected documents. Rhetoric is evident when a discourse seeks to persuade (Burke, 1969). Excerpts were located that seek to persuade the reader that mathematics education has value in each document. Each of these excerpts was then analysed in relation to the six rhetorics identified in Skovsmose's work. A statement such as, "the available evidence points to better educational and labour market outcomes generally for those with good levels of numeracy" (COAG, 2008, p. 1) is an example of an excerpt that was taken to be rhetorical as it states a benefit of mathematics education, in terms of the labour market. The reference to the labour market signifies the presence of the *mathematics for human capital* rhetoric in this example. A selection of these excerpts from numeracy texts are contrasted with excerpts from STEM texts to assess if the rhetorics present in both discourses are different or similar and thus if there is evidence that the worth of mathematics education is articulated differently in each discourse.

The next level of analysis assesses the frequency with which key terms are used in each discourse. Documents that were under 20 pages long were not included in this word frequency analysis. Both numeracy documents and three of the STEM documents (those with an asterisk in Table 2) were long enough and available in pdf format, so their word frequency could be assessed. *NVivo* software was used to rank the frequency of terms used in each of these documents. The key terms were chosen after an initial analysis was undertaken to determine potential rhetorics in each discourse. Frequency of terms could then be used as corroborating evidence that particular rhetorics characterise each discourse.

Results

Evidence of Rhetorics in Numeracy Discourse

Within each document, arguments for the worth of mathematics education could be located. In a document designed to discuss numeracy with the teacher community, the worth of mathematics education is explained as follows: "Numeracy and literacy remain key domains of learning which are essential for success at school… and ensure children are well prepared for future economic and social prosperity" (ACER & Stephens, 2009, p. 3). Within this discourse, numeracy is positioned alongside literacy as being worthy due to its impact on students' capacity for effective economic and social participation. Social participation is also prominent in COAG's Human Capital Working Group's 2008 report on numeracy: "mathematics curricula and pedagogy… need to provide the pertinent mathematical knowledge required of the citizens of today and tomorrow, a knowledge that will result in an ability to choose and use the mathematics learned to meet personal and social goals" (COAG, 2008, p. 3). Mathematics has a benefit for society because, "mathematical literacy for developing human capital has at its heart the economic argument for numeracy education, that is, the needs of society are changing and in order for the country to maintain its lifestyle and economic well-being we need better and more mathematically educated adults and school leavers" (COAG, 2008, p. 4). Schools must teach mathematics because, "if numeracy is about using mathematics effectively to meet the general demands of life at school, at home, in paid work and for participation in community and civic life, then it is clearly the role of the school curriculum – both documented/planned and implemented/enacted – to enable young people to learn to use mathematics to meet these demands" (COAG, 2008, p. 8). The arguments for the worth of mathematics located in these documents position mathematics alongside literacy (reading and writing) as fundamental skills. Citizenship and economic participation are also prominent in these documents. This suggests that two rhetorics are evident in numeracy discourse: *mathematics for critical citizenship* and *mathematics for human capital*.

Evidence of Rhetorics in STEM Discourse

Arguments that specifically focused on the worth of mathematics education were harder to locate in STEM discourse. This may be due to the way that mathematics is positioned in STEM discourse. In some documents, there is evidence that STEM rhetoric positions the four individual STEM disciplines in service to "innovation". The OECD (2014) argued that, "the skills associated with innovation include specialised knowledge, general problem-solving and thinking skills, creativity, and social and behavioural skills, including teamwork … [this] goes beyond the traditional focus on STEM disciplines, even though these disciplines occupy a prominent position in innovation policies" (p. 237). Policy decisions, such as increasing participation in STEM education, are "seen as a way to increase the pool of individuals able to enter research occupations or undertake innovation" (OECD, 2014, p. 240). Thus, mathematics education (as well as science, technology, and engineering education) are worthy because they serve innovation. Service to innovation is also present in Australian STEM rhetoric: "STEM must ensure a steady flow of new ideas and knowledge. Innovation must turn knowledge into new and better ways of doing things" (Office of the Chief Scientist, 2013, p. 3). This is also coupled with arguments about economic competition as, "STEM skills are essential in creating and turning new ideas and inventions into lucrative, internationally competitive Australian products, services and exports" (Department of the Prime Minister and Cabinet, 2014, p. 1). Literacy is rarely mentioned, but human capital arguments mirror those present in economics research.

These documents position mathematics as subordinate to either innovation or the other STEM disciplines. While citizenship is less prominent, technological development and global competition strengthen rhetoric relating to human capital goals. This suggests that the rhetorics of *mathematics for human capital*, *mathematics for technological progress*, and *mathematics for global competition* are prominent in STEM discourse.

Table 3
Within Document Frequency Ranking of Key Terms

	Ranked frequency of key terms				
Terms	National Numeracy Review (2008)	Numeracy in Practice (2009)	STEM in the national interest (2013)	STEM in the education state (2016)	Australia's STEM workforce (2016)
Mathematics	1st	1st	34th	16th	58th
STEM	-	-	1st	1st	3rd
Numeracy	4th	2nd	-	80th	-
Science	60th	43rd	2nd	19th	6th
Technology	127th	53rd	11th	31st	47th
Engineering	-	-	17th	-	12th
Workforce	105th	-	39th	34th	26th
Literacy	55th	51st	-	108th	-
International	91st	71st	38th	130th	-
Innovation	-	-	5th	93rd	332nd
Industry	-	-	50th	42nd	19th

Frequency of Key Terms across Both Discourses

Key mathematical terms and terms that underlie each rhetoric appeared in different documents with different frequencies. Table 3 summarises differences between documents. In both of the numeracy documents analysed, the most frequently used terms were "mathematics" or related terms such as "mathematical", and the term "numeracy" was also prominent (4th and 2nd most frequent across the two documents). In STEM documents, "mathematics" was not the most frequently used word. It ranked 34th, 16th, and 58th across the three documents. In the two national documents analysed, the term "mathematics" was used less frequently than science, technology, and engineering. However, in the Victorian government document designed for teachers, "mathematics" is used more frequently than other STEM disciplines. Terms such as "STEM" and "science" are more frequently used in the STEM documents, although "science" also featured in the two numeracy documents (60th and 43rd most frequently used terms). More frequent use of the term "science" in STEM documents supports the claim that mathematics is positioned with science, and is usually subordinate to science, in STEM discourse. In the numeracy documents, the term "literacy" is used in relation to reading and writing and is the 55th and 51st most used term in both documents. This provides corroborating evidence the mathematics is positioned more closely with literacy in numeracy discourse. “Literacy” in relation to reading and writing does not feature prominently in the two national STEM documents but is the 108th most frequently used term in the Victorian teacher-focused document. In STEM documents, terms such as “workforce”, “industry”, and “innovation” are more frequently used than in numeracy documents, supporting the suggestion that the *mathematics for human capital* and *mathematics for technological progress* rhetorics are prominent in STEM discourse in a way that is not present in numeracy discourse.

Discussion

When viewed as rhetorical discourses, the shift from numeracy to STEM in public and policy discourse can be seen as a shift in the way that the value of mathematics education is articulated and the way that mathematics is positioned within education. Both are influenced by the *mathematics for human capital* rhetoric, as both discourses describe how mathematics education has value because of the way in which skill in mathematics enhances “workforces” and “labour markets”. The frequency of terms that point to a human capital rhetoric (such as “workforce”, “innovation”, “business”, and “industry”) is higher in STEM discourse, however, which suggests that this rhetoric may be more prominent in STEM discourse. The frequency of terms such as “international” suggests that *mathematics for global competition* is also present in both discourses to some degree.

Social participation, civic competence, and a positioning of mathematics alongside literacy is prominent in numeracy discourse. This suggests that the *mathematics for critical citizenship* rhetoric is evident in numeracy discourse. Within this discourse, mathematics and literacy are foundational; thus, specific discussion of mathematics education occurs more frequently than in STEM discourse. The focus on mathematics’ impact on students’ capacity to engage in democratic processes is also less prominent in STEM discourse.

In contrast, STEM discourse positions mathematics differently. *STEM in the National Interest* (Office of the Chief Scientist, 2013) frequently uses the term “innovation” (5th most frequently used term), and the other STEM documents analysed use the term “innovation” when articulating the worth of STEM. This positions all STEM disciplines in service of innovation – innovation that will drive economic productivity via research and development, and technological advancement. This aspect of STEM discourse can be linked to economic discourses, particularly those about productivity growth. Within STEM disciplines, mathematics’ role as foundational is still present. Mathematics is important as it is required in order to engage in science and engineering, and to develop technology. This suggests that the *mathematics for technological progress* rhetoric is present.

As public and policy discourse has moved from numeracy towards STEM, rhetorics have shifted. The idea that mathematics education is worthy because it enables critical citizenship has become less prevalent. Instead, mathematics education is seen to be worthy because of its contribution to technological progress, and this progress is connected to developing human capital and productivity growth.

Conclusion

For researchers who seek to study mathematics education, shifts in rhetoric at a policy level are likely to affect the research in which our community engages. By examining both numeracy and STEM discourses through the frame of rhetorics, it is hoped that our community could gain productive insight into the way in which these discourses change. This study is not a comprehensive review of numeracy and STEM discourses. I am not able to exhaustively investigate arguments for the worth of mathematics education. Instead, I present a way of thinking about the political and economic discourses that shape our field that appear to be absent in most discussion relating to STEM. If these discourses are primarily driven by economic theory that describes the worth of mathematics education without describing how mathematics can be taught effectively, then shifts in rhetoric will not affect pedagogy directly. As a research community, this rhetoric in the public discourse may not match our own beliefs about the worth of mathematics education, but these shifts in rhetoric do influence research and research funding. My own work in the area of STEM (Jazby, 2016) provides an example of how a rhetorical approach to STEM discourse could affect mathematics education research. As part of an engineering-focused project, mathematical problem-solving pedagogy – developed from mathematics education research that exists outside of STEM rhetoric – was able to be applied to a STEM project. Because STEM was viewed as a rhetorical discourse, the worth of the mathematical components of the project needed to be communicated in terms of developing skills that support innovation. This approach helped gain some modest funding of the mathematical problem-solving component of the project. Engagement with STEM rhetoric did not require radical shifts in mathematics pedagogy, but engagement with the rhetoric did enable project goals to be communicated effectively with those outside of the mathematics education research community. Hence, the analysis presented in this study has some pragmatic value relevant to our research community – a community that exists in an environment in which rhetorics for mathematics education are sure to shift post-STEM.

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