A Comparison of STEM and non-STEM Teachers' Confidence in and Attitudes towards Numeracy

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This study reports initial results of a larger study examining teacher practices in numeracy in the secondary sector. Survey data examined STEM teachers' confidence in mathematics topics and attitudes towards numeracy in everyday life, and the responses were compared to teachers trained in non-STEM areas. The data indicate that teachers' specialist backgrounds influence certain aspects of their numeracy. Similarities between groups highlight the contribution made by all teachers to secondary school numeracy education.

Increasing demands on Australian teachers to equip students with the knowledge, skills and dispositions to participate as effective citizens have been led by government (Ministerial Council on Education Employment Training and Youth Affairs [MCEETYA], 2008), and is driven by the Australian Curriculum (AC) and its embedded General Capabilities (Australian Curriculum Assessment and Reporting Authority, 2013). The AC and General Capabilities propose a path for education that delivers content knowledge within traditional learning areas such as Science and English, while the General Capabilities sit alongside these traditional content areas and highlight additional skills necessary for students to contribute to a global society. Teachers of all grade levels and subject areas are responsible for developing students' General Capabilities, which include such things as literacy, critical and creative thinking, and ethical understanding. Numeracy is also considered a General Capability with the aim that students:

> … develop the knowledge and skills to use mathematics confidently across other learning areas at school and in their lives more broadly. Numeracy involves students in recognising and understanding the role of mathematics in the world and having the dispositions and capacities to use mathematical knowledge and skills purposefully (Australian Curriculum Assessment and Reporting Authority, 2013, p. 31)

To support the implementation of the AC and General Capabilities in schools, teachers in Australia are required to provide evidence against the Professional Standards for Teachers (Australian Institute for Teaching and School Leadership [AITSL], 2011) as a part of mandatory teacher registration processes. The Professional Standards seek to articulate quality teaching practices and describe expectations for teachers' professional knowledge, practice and engagement. Pertinent to this study, two of the Standards relate to numeracy Capability. The first concerns the expectation that teachers, "apply knowledge and understanding of effective teaching strategies to support students' literacy and numeracy achievement" (p. 11), and the second emphasises teachers' capacity to interpret student assessment data to inform and evaluate learning and practice. Thus, teachers must have strong professional numeracy skills for the purposes of managing their professional administrative work, as well as for effective teaching practice in support of student numeracy outcomes.

Teachers' capacities to embed numeracy skills and model numerate behaviour is paramount to supporting students who are required to meet numeracy standards for both

2018. In Hunter, J., Perger, P., & Darragh, L. (Eds.). Making waves, opening spaces *(Proceedings of the 41st annual conference of the Mathematics Education Research Group of Australasia)* pp. 298-305. Auckland: MERGA.

credentialing purposes and as future citizens of a global society. Teachers' numeracy capacity has been the subject of international comparison in studies such as The Programme for the International Assessment of Adult Competencies (PIAAC) and the Adult Literacy Life skills Survey. Golsteyn, Vermeulen, and de Wolf (2016) compared the literacy and numeracy skills of primary and secondary school teachers relative to other survey respondents and found that teachers score on average higher on literacy and numeracy tests than the country average. At the lower end of the distribution, the lowest scoring teachers significantly outperform the lowest scoring other respondents. The highest performing secondary teachers are comparable to other respondents and the primary teachers are only slightly outperformed than the best other respondents. Although Australian data is limited due to differences in local collection methods there are no reasons to expect that the local data would be different from the international data.

Research into teaching numeracy in Australia has predominantly examined the practices of teachers with a strong mathematical background, or those who teach mathematics or numeracy, particularly in the primary or middle school sectors (e.g., Beswick, Watson, & Brown, 2006). Relatively few studies have explored the practices of secondary teachers, although perceptible differences between primary and secondary teachers in relation to aptitude and confidence in teaching mathematics and numeracy have been identified (Forgasz, Leder, & Hall, 2017; Watson, Beswick, Caney, & Skalicky, 2006).

The professional numeracy demands of teachers relate to the mathematical methods and analytical skills necessary for ensuring high quality work in a professional capacity (Steen, 1990) and is influenced by context (Beswick, 2008). The practices and professional learning requirements of experienced teachers is an emerging field of study. With the value of equipping teachers with the requisite knowledge of mathematical processes and procedures that underpin numeracy in classroom learning is beginning to be examined (Callingham, Beswick, & Ferme, 2015; Ferme, 2015).

For teachers in secondary schools, professional numeracy skills must support the administrative requirements of their work, as well as providing a basis of numerate practices within the specific context of their subject area. Thus, the scope of professional numeracy demands of teachers are as contextually broad as the subjects they teach, include the core requirement of strong mathematical confidence and attitudes, and rely on strong pedagogical knowledge specific to numeracy. The numeracy demands of the profession beyond what is taught to students are recognised by pre-service and experienced teachers (Forgasz et al., 2017), but many teachers lack confidence in planning, teaching, assessing and creating appropriate learning tasks for the development of numeracy in their students (Goos, Dole, & Geiger, 2012).

STEM education (Science, Technology, Engineering and Mathematics) is increasingly acknowledged as critical to addressing the rapid growth of professions that rely on scientific and technical services (Council of Australian Governments, 2015). STEM subject areas are inherently connected by the way they apply mathematical ideas to solve problems, and integrate naturally across disciplines within the real world (Johnson, 2012). It follows therefore, that the numeracy demand of STEM subjects is higher than that of other disciplines. Nevertheless, it is important to recognise that all learning areas have distinctive numeracy demands in relation to the type of mathematical knowledge required by students in order to demonstrate successful learning (Goos, Geiger, & Dole, 2010). Teacher confidence and attitudes in numeracy, therefore, are critical to student outcomes irrespective of subject.

The Study

The study described here used a quantitative survey design to answer the research question: To what extent does STEM specialisation effect teachers' confidence in mathematics topics and attitudes towards numeracy?

This paper reports on two sections of a survey which was part of a mixed methodology study about secondary teachers' practices in and understanding of numeracy.

Participants. Forty-seven teachers from eight regional and metropolitan government secondary schools (Grades 7 to 12) in NSW were participants. Their tertiary qualifications reflected the diversity in educational pathways leading to formal accreditation as secondary teachers, with representatives from a range of undergraduate and graduate-level teacher education pathways. The participant profiles represented similar specialist teaching area qualifications, age and gender demographics when compared to recent teacher workforce data (Commonwealth of Australia, 2014). Figure 1 shows the participants' specialist areas, and the prevalence of teachers with more than one specialist area. For example, of the six English teachers who completed the survey, three also had specialist qualification in Humanities, and one also had qualification in Languages.

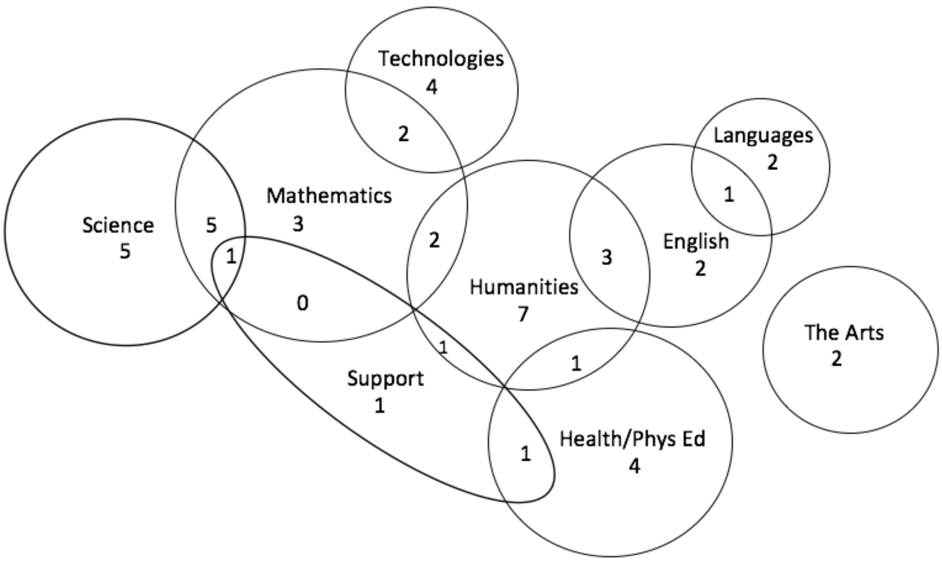

Figure 1. Representation of Participants' specialist areas.

Instrument. The survey comprised six confidence items and eleven attitude items, and were adapted from instruments used in previous studies examining teacher confidence and beliefs (Beswick et al., 2006; Watson, 2001). The confidence items were modified to focus on mathematical topics to reflect the Australian Curriculum: Mathematics strands, and the attitude items were based on Beswick's (2006) instrument and examined participants' attitude towards numeracy in everyday life. This set of items refer to numeracy rather than the original quantitative literacy to reflect the local preference for these often interchangeably used terms. Teachers responded to all items on 5-point likert scales from 1 (Strongly Disagree) to 5 (Strongly Agree).

Procedure. The teachers completed the approximately 15-minute survey via an online commercial platform. There was no time limit. Results from participants were grouped according to their teaching specialisation. Table 1 shows the numbers of teachers with STEM and non-STEM specialisations and the numbers whose highest level of mathematics studied was secondary or tertiary. That participants with STEM specialisations were much more likely to have studied mathematics at the tertiary level reflects the significance of mathematics in STEM (Johnson, 2012).

Results and Discussion

Participants' highest level of attainment in formal mathematics was recorded. The context in which it was studied was also noted, i.e. whether it was undertaken as part of a secondary school leavers certificate, a tertiary mathematics subject (e.g. Engineering Mathematics), led to a qualification in a mathematics-dependent field such as Physics, or was part of a postgraduate degree. Note that only one participant did not undertake senior secondary mathematics (Grades 11 and 12) at all. It is not known whether participants considered statistics to be a mathematics subject in this context, although the example provided in the survey item ("Engineering Mathematics") was intended to indicate to participants the item's focus on mathematics rather than statistics.

Table 1
Highest mathematical attainment of participating teachers

Teaching Specialisation	Mathematics Attainment Tertiary	Secondary
Science, Technologies, Mathematics	17	5
Other (The Arts, Humanities and Social Sciences, Languages, English, Physical and Health Education)	4	21

The means and standard deviations were calculated for each survey item for each of the groups. A two-tailed *t*-test comparison of scores was also calculated. Missing data were not included in the calculations. Pooled results for the mean and standard deviation for each set of items were calculated. These results appear in Tables 2 and 3 respectively.

Table 2
Means and standard deviations of teachers' responses to Confidence items

Item	STEM teachers (n=21) Mean	St. dev	Other teachers (n=26) Mean	St. dev	*t* (2 d.p.)	*p*-value
1. Estimating and calculating with whole numbers	4.95	0.21	4.32	0.90	3.22	0.0024**
2. Recognising and using patterns and relationships	4.73	0.46	4.20	0.87	2.56	0.0139*
3. Using fractions, decimals, percentages, ratios and rates	4.91	0.29	4.12	0.73	4.76	0.00002**
4. Using spatial reasoning	4.59	0.59	3.79	1.06	3.11	0.0032**
5. Interpreting statistical information	4.68	0.57	3.96	0.68	3.93	0.0003**
6. Using measurement	4.91	0.29	4.28	0.74	3.74	0.0005**
Pooled Results	4.80	0.30	4.08	0.69	4.24	0.0001**

Note: * indicates significance at $p < 0.05$ and ** indicates significance at $p < 0.01$

That there were statistically significant differences between the groups for all items reflects the overall higher confidence in mathematics of STEM-trained teachers compared to teachers trained in other areas, analogous to the evidence of differences between primary and secondary teachers (Watson et al., 2006).

At least 84% of all participants indicated Agree or Strongly Agree to each of the six confidence items. With respect to the mathematics strands identified, both groups of teachers were most confident in *Estimating and Calculating with Whole Numbers* and least confident in *Using spatial reasoning*. The latter item's lower confidence level may reflect teachers' lack of knowledge of what constitutes spatial reasoning due to unfamiliarity with mathematical terms (Ferme, 2015) or the narrow conception of numeracy many teachers have (Callingham et al., 2015). The only non-response recorded for confidence items was for this item.

Previous research on teacher perceptions has identified that teachers tend to focus on numerically-based aspects of numeracy (Callingham et al., 2015) which is reflected above in the results for Items 1, 3 and 6. Ninety six percent of participants indicated either Agree or Strongly Agree for Item 6. The disparity between groups for Items 3 and 6 may be because they pertained to proportional reasoning. The essential nature of proportional reasoning in developing higher-level mathematical ideas, as well as applications in other subjects, and the difficulties students have with developing proportional reasoning has been well researched (e.g., Hilton, Hilton, Dole, & Goos, 2016). Many teachers have the same conceptual difficulties as students (Sowder et al., 1998). Given measurement's strong basis in proportional reasoning (Lesh, Post, & Behr, 1988), these findings support previous research in that teachers' confidence in proportional reasoning may impact upon other mathematical topics (Beswick et al., 2006; Sowder et al., 1998).

Table 3
Means and standard deviations of teachers' responses to Attitude items

	STEM teachers		Other teachers			
Item	Mean (n=21)	St. dev	Mean (n=26)	St. dev	*t*	*p*-value (2-tailed)
A. I need to be numerate to be an intelligent consumer	4.77	0.43	4.48	1.00	1.27	0.2116
B. I am confident that I could work out how many times I would need to tile my bathroom	4.82	0.85	4.32	0.80	2.06	0.0449*
C. I often perform calculations in my head	4.86	0.35	4.04	0.98	3.74	0.0005**
D. Understanding fractions, decimals and percentages is becoming increasingly important in our society	4.27	0.70	3.76	1.09	1.89	0.0658
E. Numeracy is just as necessary for citizenship as literacy	4.59	0.59	4.28	0.84	1.45	0.1552
F. I have difficulty identifying mathematical patterns in everyday situations	*1.63*	*1.26*	*2.48*	*1.34*	-2.09	0.0428*

G. Proportional reasoning is needed to understand claims made in the media	4.10	0.83	3.50	0.93	2.25	0.0299*
H. Given the price per square metre, I could estimate how much carpet I would need for my lounge room	4.80	0.89	4.38	0.82	1.64	0.108781
I. Mathematical ideas are not always communicated well in newspapers and the media	4.32	0.84	3.80	1.04	1.86	0.069106
J. I often use mathematics to make decisions and choices in everyday life	4.41	0.67	4.12	0.88	1.25	0.216087
K. I can easily extract information from tables, plans and graphs	4.91	0.29	4.44	0.82	2.54	0.0147*
Pooled Results	4.57	0.35	4.07	0.46	4.07	0.0002**

Notes: Item F was reverse scored for the purposes of calculating the pooled result. * indicates significance at $p < 0.05$ and ** indicates significance at $p < 0.01$.

The eleven attitudes items show an overall similar difference between the two groups of participants as for the confidence items, with higher means and lower standard deviations in the STEM group. There were statistically significant differences for five of the items (B, C, F, G and K). Once again, the data indicates that appreciation of proportional reasoning (Item G) was different between STEM-trained teachers and others, however an item on media communications (Item I) that often involve proportional concepts such as percent and risk showed no significant difference. Differences for Item G may again be linked to limited of knowledge of the term among non-STEM teachers (Ferme, 2015) or teacher's conceptual difficulties (Sowder et al., 1998).

The remaining four items for which there were statistically significant differences (B, C, F and K) could arguably be linked by the requisite mathematical confidence required to perform these tasks. Item H is similar to Item B but in this case the difference between groups was not significant. Steen (1990) observed that, "unless the mathematics studied in school is understood with confidence … it will not be used in any situation where the results really matter" (p. 7). In the context of secondary schools and teachers' capacity to embed numeracy within their subject area, these data suggest that teachers other than STEM teachers may not be able to fully exploit the opportunities the curriculum offers to support students' numeracy outcomes, including in terms of demonstrating a positive attitude towards much of numeracy.

Much of teachers' other numeracy-dependent professional activity involves interpreting data (Item K). The STEM group with a high mean and a very small standard deviation. For the non-STEM group, the mean was quite high but so was the standard deviation, hence the significant difference. By contrast, the confidence item (Item 5 – interpreting statistical information) that dealt with a related area of mathematics was the second lowest-scoring item for both groups. In this case, the separation of the aptitude-focused *interpreting statistical information* in the confidence set from the application-focused *extracting information from tables, plans and graphs* in the attitude set may account for the disparity between them, echoing previous research around the influence of context on teachers' beliefs

(Beswick, 2008) and confidence around interpreting statistics in the media (Watson, 2001). However, as graphs, diagrams, tables, maps and plans are commonly used in many learning areas (Goos et al., 2010) participants would reasonably have a strong familiarity with these concepts and skills as part of their classroom teaching, reinforced by overall high numeracy performance compared to other professions (Golsteyn et al., 2016).

The role that numeracy plays in everyday life is encapsulated in items A, D, E, G, I and J. That there were no significant differences between the two groups is possibly an outcome of the overall mathematics attainment level of all participants, in that 83% of participants had studied an advanced-level mathematics course or above in senior secondary school, exposing them to the range of high-level mathematics knowledge and skills necessary for the modern age (Steen, 1990) and demonstrating the high level of education all teachers have (Golsteyn et al., 2016). Items A and J had the narrowest differences between means, suggesting that teachers' specialist backgrounds have little influence on attitudes towards the important role that numeracy has on their own lives or that of their students. It appears that there is little difference in teachers' disposition or "willingness and confidence to engage with tasks, independently and in collaboration with others, and apply mathematical knowledge flexibly and adaptively" (Goos et al., 2010, p. 212) when accounting for specialist background.

Conclusion

The data reported here are consistent with previous research identifying differences in teacher confidence dependent on their specialist teaching area (Beswick et al., 2006; Forgasz et al., 2017) and identifies that secondary STEM teachers in particular have a greater confidence and tend to have more positive attitudes when compared to other secondary teaching areas. While the interdependence of mathematical concepts and skills within STEM subjects are widely known (Johnson, 2012) attitudes towards numeracy amongst all teachers was positive overall and numeracy is recognised by both groups as playing an important role in everyday life.

The difference in confidence in and attitude towards numeracy between STEM and other teacher groups may be rooted in the same conceptual difficulties that students experience (Sowder et al., 1998). Studies have indicated that sustained programs of professional learning that provide opportunities for teachers who lack confidence in mathematics to experience success are beneficial (Beswick, 2008; Forgasz et al., 2017; Watson et al., 2006).

Teachers generally are numerate individuals and supporting non-STEM specialist teachers to improve confidence in the mathematical foundations of numeracy would have multiple benefits, particularly when effort is made to reconceptualise knowledge (Sowder et al., 1998). Assisting non-STEM teachers to become more confident in mathematical knowledge may also better highlight to them the opportunities present in curriculum and professional contexts to develop more positive numeracy outcomes for their students.

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