Numeracy and Australian teachers

Helen Forgasz
Monash University
<helen.forgasz@monash.edu>

Gilah Leder
Monash University
<gilah.leder@monash.edu>

Australian teachers, recruited via Facebook, completed an online survey about aspects of numeracy. The survey was designed to explore views on numeracy and capacity to respond to numeracy tasks. In this paper, we focus primarily on responses to two numeracy tasks – one numerical, the other requiring critical evaluation. On the first item, 40% answered correctly; on the second, 60% performed at a level expected of people aged 17 or older. The provocative findings warrant further research with a larger sample.

Introduction

In Australia it is expected that teacher education programs will prepare all graduates to "[K]now and understand literacy and numeracy teaching strategies and their application in teaching areas" (Australian Institute of Teaching and School Leadership [AITSL], 2014). There is a further expectation that all pre-service teachers will have achieved a specified level of numeracy (and literacy) proficiency prior to graduation; as from July 1 2016 it will be required that numeracy and literacy tests be passed in order to graduate.

According to AITSL (2014), all proficient practicing teachers in Australia should be able to "[a]pply knowledge and understanding of effective teaching strategies to support students' literacy and numeracy achievement". To date, insufficient attention has been paid to the numeracy skill levels of those already in the profession. Data from a study in which this topic was explored are reported in this paper.

Theoretical perspectives and previous research

Geiger, Forgasz, and Goos (2015) defined numeracy as "the capacity to make effective use of mathematics in contexts related to personal life, the workplace, and in exercising civil responsibilities" (p. 611). This definition is consistent with the description of numeracy as one of seven general capabilities in the Australian Curriculum (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2014). All teachers are charged with the responsibility of developing students' numeracy capabilities across all disciplines areas within the Australian Curriculum and at all grade levels (ACARA, n.d.).

The *21st century numeracy model* was initially designed as a framework to audit mathematics curriculum designs and was later used in a range of research projects for related purposes (Geiger et al., 2015). In particular, it has been adopted "to guide the design of numeracy tasks for implementation in subjects outside of mathematics" (Geiger et al., 2015, p. 613). *Context* (real world setting) is central to the model. *Mathematical knowledge*, *tools*, and *dispositions* surround the context – they are considerations in the design of the numeracy task which is designed to develop *personal and social*, *citizenship*, and/or *work*-related numeracy skills. These dimensions of the model "are embedded within an overarching construct – *critical orientation* – an analytical and evaluative demand" (Geiger et al., 2015, p. 614). The numeracy model served as the framework for the development of the survey instrument used in this study, an earlier version of which had been administered to pre-service teacher education students at one university (see Leder, Forgasz, Kalkhoven, & Geiger, 2015).

2016. In White, B., Chinnappan, M. & Trenholm, S. (Eds.). Opening up mathematics education research (Proceedings of the 39th annual conference of the Mathematics Education Research Group of Australasia), pp. 238–245. Adelaide: MERGA.

Leder et al. (2015) were interested in pre-service teachers' views about their proficiency in mathematics and the importance of mathematics for teaching, whether they recognised the mathematical demands in everyday life as well as on teachers in schools, apart from what students are taught. Over 50% of the respondents considered themselves to be good or excellent at mathematics, 76% agreed that it was important for teachers to be good at mathematics, and a large majority generally recognised the importance of mathematics and its applications in everyday life. Yet, only 44% believed that there were numeracy demands on teachers within the school that were outside the classroom.

Callingham, Beswick, and Ferme (2015) reported on three separate secondary level contexts in which the development of teachers' numeracy knowledge were central: a school focussing on project-based learning, teachers of subjects other than mathematics, and pre-service teachers formally studying a numeracy course. Their research findings highlighted two challenges: that all "teachers, including teachers of mathematics, need to understand and recognise the nature of numeracy" (p. 559), and that "teachers need to develop strategies to address numeracy in their subject areas in ways that are not about formal mathematics teaching" (p. 559). They felt that some progress had been made on the first challenge in the three case studies, but that the second proved more difficult. Systemic support over time was recommended.

The Programme for the International Assessment of Adult Competencies (PIAAC) (OECD, n.d.a) was developed to assess adults' (aged 16-65) literacy, numeracy, and problem-solving skills in technology-rich environments skills. Overall, Australians' literacy skills were well above the OECD average, but their numeracy skills were slightly below (OECD, n.d.b). There are six levels of proficiency: below 1, 1-5. For numeracy, Australian data were: 6.5% below level 1, 15% at Level 1, 32% at Level 2, 31% at Level 3, 11% at Level 4, and 1.4% at Level 5 (ABS, 2014a). Among those with postgraduate degrees, 77% were at Level 3 or above; for those whose highest qualifications were Bachelor's degrees, it was about 70% (ABS, 2014b). Teachers would fall into these two qualification categories; their anticipated numeracy skills should therefore generally be good.

Biggs and Collis (1982) developed the SOLO (Structure of Observed Learning Outcomes) Taxonomy to provide information on students' reasoning levels when engaged in mathematical problem-solving. Collis and Romberg (1992, p. 32) provide descriptions of the four main SOLO levels and how they apply in interpreting students' responses to mathematical problem solving items, accompanied by the expected (average) age of performance at each level:

> Unistructural: use of **one obvious** piece of information from the problem stem (≈ 9 years of age)
>
> Multistructural: use of **two or more** separate pieces of information… (≈ 13 years of age)
>
> Relational: Use of an **integrated** understanding of two or more pieces of information… (≈ 17 years of age)
>
> Extended Abstract: Use of an **abstract general principle** or hypothesis which is derived from, or suggested by, the information… (≈ 17 + years)

It should be noted that the SOLO taxonomy (Biggs & Collis, 1982) also described a *pre-structural level,* which was not included in Collis and Romberg (1992). In terms of problem-solving, a response at the pre-structural level would suggest that the respondent had misunderstood, or missed the point, of the question.

In this study, we used the descriptors for the SOLO levels as a guide in determining participants' performance levels on one of the numeracy tasks, the *Chips question* (see below), that was included in our survey instrument.

The study

In the study reported here, we sought to identify Australian teachers' competence and confidence with numeracy tasks consistent with the 21st century numeracy model. The two numeracy items (one numerical, the other involving critical evaluation) reported on in this paper are described in detail below. We were also interested to discern if there were differences among various sub-groups of teachers. Our specific research question and its three sub-questions were:

How well do Australian teachers respond to numeracy items?

a. For the numerical item, is there a difference in the accuracy rates of primary/secondary teachers, those who have/have not studied tertiary mathematics, or among older/younger teachers?
b. How do confidence levels in the answers given compare for these same groups?
c. For the critical evaluation item, what, and how much, information did the teachers focus on to justify their decisions?

The instrument

The instrument used in this study was a slightly modified version of the one piloted with pre-service teachers (see Leder et al., 2015). The full instrument included biographical and teaching background items, and items probing views about mathematics and numeracy and their utility in a school setting and in everyday life. Also included were mathematical/numeracy items drawn from publicly available Australian grade 9 NAPLAN (National Assessment Program for Literacy and Numeracy) tests[1], items (with permission) from the pool of released PISA[2] items, and two items developed by the researchers and colleagues. When appropriate, respondents were asked to elaborate on the answer they had given. Qualtrics (www.qualtrics.com) was used to prepare the instrument for online completion. To comply with space constraints, only those items of interest to the study reported here are included in paper.

Data gathering

To obtain a broad sample of Australian teachers (as well as teachers from elsewhere in the world), an advertisement to recruit participants was placed on Facebook; Forgasz, Leder, and Tan (2014) provide detailed information on the method for doing so. Since the AITSL numeracy (and literacy) standard applies to all teachers, primary or secondary, including those who do not teach mathematics, all Australian teachers were invited to complete the online survey.

The sample

Of the 1198 who responded to the Facebook advertisement and clicked on the link to the survey, 1040 went further and completed the items in which biographical data were requested: sex; age; school (country) location, type and level in which they were working; years of teaching experience; whether they had studied mathematics at the tertiary level; and

[1] NAPLAN is the National Assessment Program for Literacy and Numeracy which, since 2008, has been administered to all Australian students in grades 3, 5, 7 and 9.

[2] PISA is administered every three years to samples of 15 year old students in many countries around the world, including Australia.

whether mathematics was among the subjects they taught. Approximately half of the 1040 respondents persisted and provided responses to all or most of the remaining items.

In this paper we focus on those who nominated Australia as their place of work (N=100). The respondents comprised 84 females and 16 males. Over two-thirds (N=71) were aged over 40. Most (N=72) taught in a government school, 21 in a non-government school, and seven in a different (e.g., tertiary or early childhood) setting. A high percentage (80%) indicated that mathematics was among the subjects they taught. The majority of these were teaching in a primary school where, as is common in Australian schools, mathematics is among the subjects taught.

Over 60% (N=64) of the group persisted and worked through the whole survey. Because of occasional response omissions the sample size for examination of the research questions listed above varied between 58 and 64 (see Table 1 in the Results section). The two groups, those who finished the survey and those who did not, generally resembled each other on the descriptors listed above, with the inclusion of primary teachers being a noticeable exception; more than three quarters of those who taught at the secondary level, 26 out of 31, completed the survey, compared with approximately half of those working in a primary setting, 34 out of 63.

Analyses

Descriptive statistics were used to describe the sample and the teachers' performance levels on the first numeracy item. To compare the responses of the various sub-groups of teachers, cross-tabulations and chi-square tests were conducted. For the second numeracy item, frequency counts were accompanied by categorisations of responses, based on the numbers of pieces of information used to justify the choice of chips brand, into the SOLO taxonomy levels of performance.

Results

In this paper, we focus on those who responded to two numeracy questions included in the online survey. The first was taken from the 2010 grade 9 NAPLAN test and required a numerical response to be supplied. The other, devised by the researchers and colleagues, required a decision to be made and justified by drawing on the information provided.

Numeracy question 1 – the "Keypad question"

The wording of the grade 9 NAPLAN item (the "keypad question") was as follows:

> Helen's office has security alarm. To turn it off Helen has to type her 4-digit security code into this keypad. [A diagram of a 10-digit keypad was included.] Helen's code is 0051. Including Helen's code, how many different 4-digit codes are possible?

To ascertain respondents' confidence in the answers they provided, we included the following question:

> Do you think your answer is correct: [Yes / No / Unsure]

For this item, we explored response patterns by age, teaching level (primary/secondary), and whether mathematics had been studied at the tertiary level (yes/no). Since the majority of respondents were female, and because so many were primary teachers who all teach mathematics, analyses were not conducted by gender or by whether or not they taught mathematics.

Overall performance for this item

Sixty participants provided answers to the keypad question, 24 (40%) provided the correct answer (10,000), and 36 (60%) were incorrect with an amazing range of answers.

The sample sizes for the different groups being compared on the keypad question are shown in Table 1.

Table 1
Respondents for keypad question by category

Category		Correct	Incorrect	Thought correct	Thought incorrect	Unsure
Age	≤ 40	7	11	9	2	8
	>40	17	25	24	4	17
Teach	Primary	9	22	13	3	18
	Secondary	14	12	19	3	4
Tertiary mathematics	studied	14	10	18	1	7
	not studied	10	26	15	5	18

Participants' confidence in their answers – overall and by respondent age

Although only 60 provided answers to the keypad question, 64 participants indicated whether they did (or would) get the question correct. Of the 64, 33 (52%) thought that their answer was correct, 6 (9%) expected it to be incorrect, and 25 (39%) were unsure. There was no statistically significant difference in the responses by participants' age (those aged 40 or under; those aged over 40).

Participants' answers and confidence in their answer – by whether or not mathematics had been studied at university

A higher proportion of those who had studied mathematics at the tertiary level answered the question correctly: 14 (58%) compared with 10 (29%) of those who had not. The corresponding data for those who were incorrect were 10 (42%) and 26 (72%) respectively. A test of the frequency distribution of these responses revealed a statistically significant difference: $\chi^2_1 = 5.6$, $p = .02$, $\varphi = .31$

Having studied mathematics at university also seemed to have an effect on the confidence of the answer given: 18 (70%) of those who indicated that they had studied mathematics at that level thought their answer to have been correct compared with 15 (40%) of those who had not. Corresponding figures for those who were uncertain were 7 (27%) and 18 (47%) respectively. Few of those who answered thought that their answer was incorrect: 1 (4%) and 5 (13%) respectively. A chi-square test of the frequency distribution of this set of responses produced a value just short of statistical significance: $\chi^2_2 = 5.73$, $p = .057$, $\varphi = .30$. More of those who studied mathematics at university were confident that they could answer this item correctly.

Participants' confidence in their answer – by level taught (primary or secondary)

As can be seen from Table 1, the sample comprised 34 primary school teachers and 26 secondary teachers. For these groups, those who thought they had answered the question correctly, incorrectly, or were unsure were, respectively: 13 (38%) and 19 (73%); 3 (9%) and 3 (12%); and 18 (53%) and 4 (15%). A chi-square test of the frequency distribution of these responses revealed a statistically significant difference: $\chi^2_2 = 9.13$, $p = .01$, $\varphi = .39$. Those who taught at the secondary level were more confident that their answer was correct; a much higher proportion of those teaching at the primary level were unsure.

The relatively small sample precludes more detailed analyses of the results.

Numeracy question 2 – the "chips question"

The second numeracy question of interest paper was the "chips question". Participants were provided with the images of three different packets of vinegar-flavoured chips – Red Rock, Smiths, and Kettle. The dietary information, as found on each packet, was summarised in tabular form. Participants were told that "Some people are concerned about the nutritional value and costs of snack food such as chips". The questions asked of participants were:

> You want to by a packet of salt and vinegar chips. Which brand of chips (of those described) would you buy? Explain why you made this choice and include some mathematics in your justification.

Clearly there is no correct response to which brand to buy. Of interest were the justifications provided for the choices made.

There were 64 responses with explanations for the brand of chips chosen. The brands selected were as follows: Red Rock: 24; Smiths: 2; and Kettle (38). The number of bits of information (nutritional, cost, other) that were provided to justify the brand chosen varied from one to 7. The distribution of brands selected by number of pieces of information included in justifications is shown in Table 2.

Table 2
Brand of chips selected by number of pieces of information included in justification

	Number of pieces of information							
Brand	1	2	3	4	5	6	7	Missed point
Red Rock	1	2	7	4	4	3	3	-
Smiths	-	1	-	-	-	-	-	1
Kettle	2	17	11	2	4	1	-	1
TOTAL	3	20	18	6	8	4	3	2

The frequencies of the types of information (nutritional, cost, other) mentioned by respondents in their justifications of brand choice are summarised in Table 3.

Table 3
Frequencies of information type included in the justifications for brand choice

Sugar	Salt	Fat	Fibre	Price	Energy	Protein
22	27	36	11	50	11	5
Net weight	**Cholesterol**	**Carbohydrates**	**Potassium**	**Personal circumstance**	**Like**	**Depends**
25	3	6	1	3	2	1

As can be seen in Table 3, the most frequently mentioned factors were: price (mentioned in 50 of the justifications), Fat (36), Salt/Sodium (27), net weight (25), and sugar (22). It should be noted that when cost was mentioned it was either as “the cheapest” option or that cost was not as important a factor as nutritional value.

Using the SOLO taxonomy levels as a guide, the justifications could be categorised within each SOLO taxonomy level. We used the following for SOLO categorisations:

Prestructural: misses the point
Unistructural: uses 1 piece of information
Multistructural: uses 2 pieces of information
Relational: uses 3/4 pieces of information
Extended abstract: uses 5+ pieces of information

The frequencies of responses at each SOLO level (see Table 2) and representative examples of the responses provided are shown in Table 4.

Table 4
Samples of responses representing each SOLO level

SOLO level	N	Sample responses
Prestructural	2	There is a 1 in 3 chance of choosing the correct chips. only one pack is labelled Salt and vinegar
Unistructural	3	Lower sugar [Red Rock]
Multistructural	20	The Kettle ones, as they are cheapest and have approx 2 kilojoules per gram less than the Red Rock Deli. [Kettle]
		Better value for money. Cheaper, and more weight. [Kettle]
Relational	24	I chose Red rock deli because it has the lowest sugar per 100g. It also has the most fibre and the lowest salt content per100 gram serve as well. [Red Rock]
		Cheapest, Lowest Kilojoules, Less Fat than the second cheapest, High Sodium content, but I happen to know they taste good too. Red Rock appear to be the healthier option, but they are also the most expensive. [Kettle]
Extended abstract	15	I made my choice based on the dietary information, not price. The dietary information for Red Rock Deli more suited my diet as it has the lowest rates of fat, cholesterol, sugars and sodium. It also has the highest level of dietary fibre. If I was looking purely at price and packet size, and not dietary information, I would have purchased the Kettle brand. [Red Rock]

Based on the data in Table 2, the mean number of pieces of information per response was 3.2 (204 pieces of information for 64 people); arguably, the group of teachers were at the *relational* SOLO level, expected of 17 year olds. Using the average age at which each SOLO level is anticipated, together with the frequencies of responses at the SOLO levels shown in Table 4, the teachers’ overall performance could also be determined. These data suggest that only those at the *Relational* and *Extended abstract* levels (39 in total, or 60%) are performing as expected of those aged 17 and above; and 25 (40%) are below that level.

Final words

The data base for the work reported in this paper comprised a volunteer sample of practising teachers who responded to a survey on the numeracy capabilities of teachers, advertised on Facebook. Practical considerations led to a focus on the subset teaching in Australian schools and on their responses to two numeracy items. The first was an item included in a NAPLAN test administered to students in Year 9 in 2010. For our sample, those who had studied mathematics at university had a higher expectation of being able to answer the question correctly, and indeed a higher proportion answered the question correctly. Age, with 40 taken as the arbitrary point of division, did not significantly affect the expectation of being able to solve the item correctly. Those who taught at the secondary level, but not necessarily mathematics, were more confident that their answers were correct than those teaching at the primary level, even though for most of the latter group, mathematics was included among the subjects being taught. Only 40% answered this item correctly. Data from the second item yielded more nuanced information about the practising teachers' performance levels. Using the SOLO taxonomy to assess performance, 60% were found to be performing at a level expected of those aged at least 17. On the basis of these items, and for our small sample of Australian teachers, numeracy proficiencies appear to warrant closer scrutiny. The size and self-selection of our sample precludes making credible generalizations about the broader teaching force. The findings are sufficiently provocative, however, to serve as a solid justification for more intensive study.

References

ABS. (2014a). *4228.0 - Programme for the International Assessment of Adult Competencies, Australia, 2011-12. Background characteristics*. Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4228.0Main+Features202011-12

ABS. (2014b). *4228.0 - Programme for the International Assessment of Adult Competencies, Australia, 2011-12. Education.* Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/4228.0Main%20Features502011-12?opendocument&tabname=Summary&prodno=4228.0&issue=2011-12&num=&view=

Australian Curriculum, Assessment and Reporting Authority. (2014). *General capabilities. Introduction.* Retrieved from http://www.australiancurriculum.edu.au/generalcapabilities/overview/introduction

Australian Curriculum, Assessment and Reporting Authority. (2014). *Numeracy. Introduction.* Retrieved from http://www.australiancurriculum.edu.au/generalcapabilities/numeracy/introduction/introduction

Australian Institute of Teaching and School Leadership. (2014). *Australian professional teaching standards*. Retrieved from http://www.aitsl.edu.au/australian-professional-standards-for-teachers/standards/list

Biggs, J. B., & Collis, K. F. (1982). *Evaluating the quality of learning: The SOLO taxonomy (structure of observed learning outcomes).* New York: Academic Press.

Callingham, R., Beswick, K., & Ferme, E. (2015). An initial exploration of teachers' numeracy in the context of professional capital. *ZDM Mathematics Education, 47,* 549-560.

Collis, K. F., & Romberg, T. A. (1992). *Colllis-Romberg mathematical problem solving profiles. Manual.* Hawthorn, Vic: Australian Council for Educational Research Ltd.

Geiger, V., Forgasz, H., & Goos, M. (2015). A critical orientation to numeracy across the curriculum. *ZDM Mathematics Education, 47,* 611-624.

Leder, G. C., Forgasz, H. J., Kalkhoven, N., & Geiger, V. S. (2015). Pre-service teachers and numeracy in and beyond the classroom. In M. Marshman, V. Geiger, & A Bennison (Eds.), *Mathematics education in the margins: Proceedings of the 38th Annual Conference of the Mathematics Education Research Group of Australasia (MERGA38)* (pp. 349-356). Adelaide, SA: Mathematics Education Research Group of Australasia.

OECD. (n.d.a). *OECD skills surveys*. Retrieved from http://www.oecd.org/site/piaac/

OECD. (n.d.b). *Compare your country*. *Skills outlook 2015.* Retrieved from http://www.compareyourcountry.org/PIAAC/?src=ber