Mathematics: Achieving and sustaining success

Monica Wong, Australian Catholic University, Australia

The context

Many pre-service teachers approach tertiary teacher education with limited confidence and even fear of mathematics often associated with poor mathematical understanding. Evidence from activities undertaken by first year Bachelor of Education students attending Public University (pseudonym) in Sydney, Australia has shown that at least one-quarter of students "hate" or "are indifferent" to mathematics and could relate negative experiences from primary and secondary school. This situation is not unusual. At another Australian university, Hamlett (2009) found that less than 10% of first year Bachelor of Education (primary and early childhood studies) students met the mathematics literacy requirements on entry within their foundation unit "Becoming Multiliterate," which was designed to address student needs in written, mathematical, computer and scientific literacy.

Within the Bachelor of Education (primary) program at Public University, students/pre-service teachers are required to complete four mathematics units, two content knowledge and two pedagogy based units. A mathematics unit is undertaken during every year of their four year degree program. The first *mathematical content knowledge* unit (*MATH1*) is undertaken in semester 1 of first year. This is followed by a pedagogy unit in second year, another content knowledge unit (*MATH2*) and the final pedagogy unit in fourth year. Five offerings of the unit to 1079 students in the previous three years have seen an average failure rate of 26% ranging from 23% to 29% for the various cohorts.

Assisting pre-service teachers overcome their negative attitude towards mathematics and improving their mathematical knowledge and understanding will have far reaching effects for the children they teach. This paper describes the results of the pilot program of the *Mathematics: Achieving and Sustaining Success* (*MASS*) pilot program which offered weekend workshops in mentoring, tutoring and academic support in mathematics for Bachelor of Education students undertaking their *MATH1* unit at Public University. The aim of this paper is to address three questions:

1. In what mathematics content areas do pre-service teachers encounter difficulties?
2. Are the weekend workshops perceived as effective and beneficial by participants?
3. To what extent does performance differ between participants who attended and those who did not attend the workshops?

The literature

Over the last two decades, research into effective teaching of mathematics has focused on pedagogical content knowledge and mathematical content knowledge. Effective teachers exhibit this knowledge by knowing the content and "how to get it across" to the students they are teaching (Ball & Hill, 2009). Content knowledge or knowing the content represents teacher's knowledge of the mathematics they teach, including the use of correct mathematical terms and notation, and recognising when their students give an incorrect answer. This type of knowledge implies that teachers "must be able to do the

work that they assign to their students" (Ball, Thames & Phelps, 2008, p. 399). Hence pre-service teachers must be able to show they understand and can do the mathematics they teach.

Effective teachers also possess self-confidence, positive beliefs and attitudes towards mathematics. Beswick, Callingham and Watson (2012) believe that teachers' confidence to use and teach various mathematics topics along with their beliefs about mathematics has a marked effect on students' learning and mathematical achievement. While pre-service teachers' negative attitudes towards mathematics impacts the learning of mathematics, White, Way, Perry and Southwell (2005/6) found that "positive attitudes are necessary, but not sufficient" (p. 47) to predict students' success in teaching. Positive attitudes in combination with deep knowledge of their mathematical content are needed (White et al., 2005/6).

Tutoring has been found to be effective for improving students' mathematical knowledge (Halcrow & Iiams, 2011; Xu, Hartman, Uribe & Mencke, 2001). Xu and colleagues (2001) found that students' final mathematics examination score in a first year mathematics unit was correlated to the use of free tutoring, either individually or group, which was provided by the university study centre. Further the tutoring helped students "at the lower math performance level to a larger degree than students at the average or above average levels" (p. 28). Halcrow and Iiams (2011) assigned students to a control group who were made aware of tutoring services but were not required to attend; and an experimental group whereby students were required to attend tutoring for one hour per week for the duration of the mathematics unit. For those students in the experimental group, the authors found the number of hours spent utilising university provided free tutoring support was moderately correlated to students' final grades.

Small group peer-tutoring programs have improved pre-service teachers' content knowledge and understanding of mathematics (Oates, Paterson, Reilly & Statham, 2005). Within the program at the University of Auckland, students attended their usual tutorial for Maths101/102 with the tutor to student ratio set to a maximum of 1:10. Tutors were chosen from a pool of Graduate Diploma of Teaching (secondary) students based on their academic record and interview. Surveying the Maths101/102 students, the researchers found that 64% of respondents agreed the format helped with their understanding and 62% of respondents liked working in small groups.

The literature suggests that tutoring programs have a positive impact on tertiary students' knowledge, confidence and mathematics examination results. With an average failure rate of 26% of students undertaking *MATH1* funding was gained from the university to develop and implement the *Mathematics: Achieving and Sustaining Success* program.

Methodology

Participants

All students undertaking *MATH1* were invited to participate in the study. One hundred and sixty-seven students (51%; $N = 329$) agreed to participate, completed an assessment of their mathematical knowledge and granted access to their results from *MATH1*.

Instrument

A *mathematics assessment of content knowledge* (*MACK*) instrument comprising 30 multiple choice items was constructed to measure students' mathematical knowledge. Questions were adapted from *PATMaths* (Australian Council for Educational Research, 2005) and *National Assessment Program – Literacy and Numeracy* (*NAPLAN*) (Australian Curriculum, Assessment and Reporting Authority, n.d.). Mathematical content in the pencil and paper instrument included: measurement, mathematical reasoning, decimals, percentage, place value, number facts, multiplication, division, area and ratios. The level of mathematical knowledge required to answer the items ranged from early primary to lower secondary.

The first page of the *MACK* included demographic questions and the final page included the following questions:

- This mathematics assessment was… (5 point Likert scale extremely difficult … extremely easy)
- List the areas you are confident with…
- List the areas you think you need more assistance with…
- After completing the assessment, indicate your level of confidence in understanding mathematics by entering a percentage, where 0 is: "no confidence at all" and 100 is: "extremely confident"
- Two questions addressed students' anxiety levels. "Before" and "After" completing the assessment, indicate your CURRENT level of mathematics anxiety by entering a percentage, where 0 is: "no maths anxiety at all" and 100 is: "the severest maths anxiety possible"

Mathematics workshops

The *MASS* program consisted of three Saturday workshops during semester 1, 2014 which provided up to an additional 18 hours support for students. Attendance was voluntary. Four 1.5 hour sessions comprised each workshop. The workshops were tailored to develop and enhance students' foundational mathematics knowledge and understanding, not reteach the content from *MATH1*. The workshop program was in part informed by the results of the *MACK* and tutors' knowledge of mathematical content which caused difficulties. The content included:

- Day 1: Place value and mental calculations
- Day 2: Multiplication and division by 10, 100 and 1000; understanding division, and fractions
- Day 3: Length; mass, and percentages and decimals

The final session of each workshop incorporated problem solving tasks and investigations related to the topics discussed during the day or topics nominated by participants.

<u>Workshop questionnaire</u>

Participants attending the final workshop were asked to complete a questionnaire containing the following questions:

- Describe your mathematical knowledge and understanding at the commencement/completion of the program?
- What type of guidance offered during the program was helpful?
- Describe your feelings whilst participating in the program.

- What were your expectations of the program? Were these expectations met?

Procedure and data collection

All participants were administered the *MACK* during their first tutorial for *MATH1* (see Figure 1). No time limit was imposed for completion of the instrument. Completing the *MACK* enabled students to gauge their own knowledge of mathematics.

Students were invited to attend the weekend workshops during *MATH1* lectures and tutorials, and via email. Each workshop was facilitated by an experienced mathematics educator/primary school teacher. Tutor to student ratios of 1:8 were implemented to provide a personalised learning environment for participants.

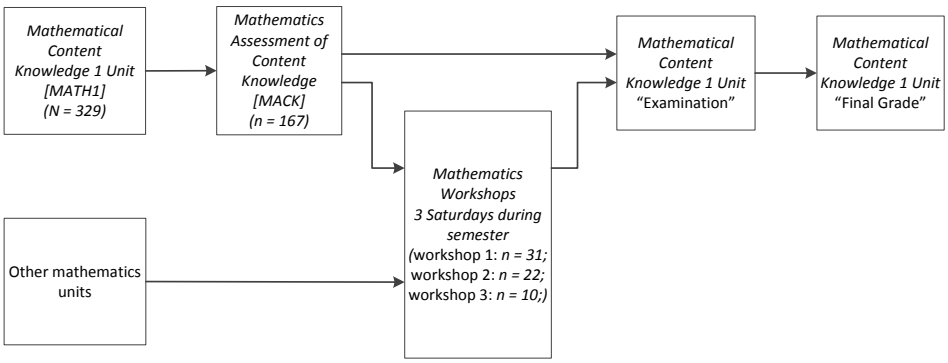

Figure 1. Data collection process

Data analysis

All quantitative data analyses were completed using SPSS v22 for Windows. A multiple linear regression model was employed to determine the extent to which student performance differed between those students who attended and those who did not attend the workshops.

Results

Mathematics assessment of content knowledge

The *MACK* was considered reliable with a Cronbach's alpha = 0.86. Scores ranged from 7 to 30, with two respondents gaining the maximum score. The average anxiety level prior to completing the assessment, confidence level and *MACK* scores by workshop group are listed in Table 1. Participants who attended the workshops possessed higher levels of mathematics anxiety and lower levels of confidence compared to the group of participants who did not attend.

Depending on the percentage of correct responses, *MACK* items were categorised into easy (over 80% correct), medium (30% incorrect) and hard (more incorrect than correct). Easy items incorporated measurement calculating height using centimetres and metres, calculating mass using kilograms and grams; money; addition of whole numbers and a decimal. Medium difficulty items included number operations, decimal ordering, decimal multiplication, mathematical reasoning and percentages. Hard items included recognising division as the inverse of multiplication, non-algorithm based computations and ratio problems.

Table 1. Assessment scores grouped by assessment difficulty

	Attended workshop			Did not attend workshop		
	n	Mean	S.D	*n*	Mean	S.D
MACK(out of 30)	17	17.3	4.7	150	20.46	5.7
Confidence (100% extremely confident)	14	54.3%	21.7	107	62.2%	22.8
Anxiety prior (100% severest anxiety)	13	65.8	29.7	97	49.5	26.6

Workshop

The number of participants for each workshop is listed in Table 2. Nine participants attended all three workshops and 13 attended two sessions. The participants who attended the final workshop completed a questionnaire to gauge their experience and also identify ways of improving the workshops.

Table 2. Workshop participants

Attendees	Workshop 1	Workshop 2	Workshop 3
Undertaking *MATH1*	25	15	8
Other mathematics units	6	7	2
Total	31	22	10

Participants undertaking the *MASS* workshops expressed how valuable the workshops were in improving their understanding and confidence. In relation to their feelings while participating in the program, participant comments were positive. Participant M found her tutor encouraging. Participant C stated “All the tutors look like they want to be here, helping us. Which makes me feel like they care for my learning.” The small class size was also appreciated as Participant B felt she was “able to ask as many questions as needed to grow my understanding of what I have to do” and Participant S who commenced the course as “not very confident and in a way confused” was “happy and comfortable because it was a small class and it would target my challenging aspects of maths”.

Comments from participants demonstrate the significant contribution of the *MASS* workshops to their learning. Participant C stated he was much more comfortable and willing to practice. Participant M wrote: “My maths level wasn’t very high. I was very anxious and wasn’t very confident. I didn’t really know my maths well. I feel much more confident with my maths. My anxiety level has gone from 100% to 20% (still a little anxious)… More confident in my abilities.” Participant A contrasted her learning at the workshop with her high school experience: “Maths in high school (yr 10 2008) wasn't ‘great’. Better- confidence has grown, and I have definitely learnt more here than in high school… I feel very lucky and I am so thankful for this opportunity.”

MATH1 examination score and final grade

At the conclusion of the *MATH1*, 27% (n = 45) of respondents who completed the *MACK* did not meet unit requirements. Three students who attended the workshop/s and 42 students who did not attend failed. The percentage of students within each group that received a fail, pass, credit and distinction is shown in Figure 2. A higher percentage,

28.7% of students who did not attend workshops failed compared to 16.7% of students who attended. On further analysis, the correlation between their *MACK* score and confidence was not statistically significant (r_s = 0.3, p > .1, n = 29) whereas *examination* score and confidence was moderately correlated (r_s = 0.5, p < .05, n = 29).

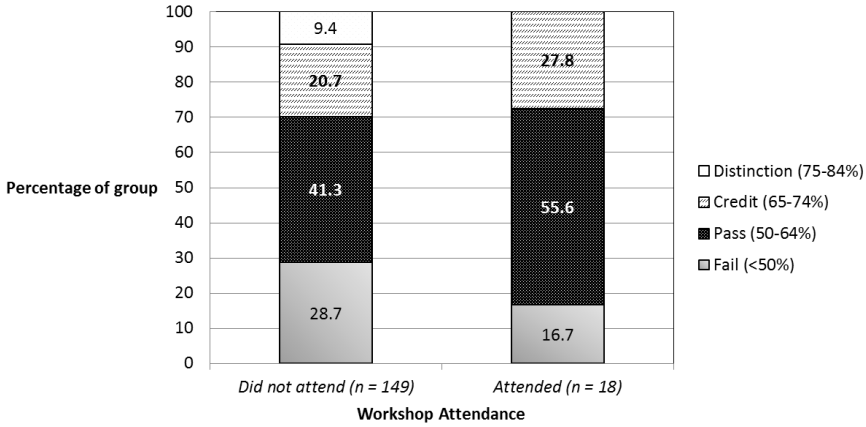

Figure 2. Percentage of grades grouped by workshop attendance.

To determine the extent student performance differed between students who attended and those who did not attend the workshops, a multiple linear regression was employed. In model 1, *MACK* score and *workshop attendance* were coded as independent variables and *MATH1 examination* score (*Examination*) was assigned the dependent variable.

The linear regression models tested appear in Table 3. Although there was negligible decrease in variance explained from model 1 to model 2, model 1 with two independent variables *MACK* and *workshop attendance* was selected as the most appropriate regression model and was statistically significant (F(2,162) = 122.59, p < .001) with 60% (R^2 = .602) of the *examination* score variance explained (Field, 2005).

Table 3. Linear regression models tested

	B	Std. Error	Beta	*t*	Sig.
Model 1					
(Constant)	6.23	2.90		2.17	.03
MACK	2.13	.14	.79	15.65	.001
Workshop attendance	5.25	2.54	.10	2.07	.04
Model 2					
(Constant)	7.75	2.84		2.73	.007
MACK	2.08	.14	.77	15.37	.001

Model 1: R^2 = .602; Model 2: R^2 = .592 ΔR^2 = -.01;

The proposed regression model follows:

$$\textit{examination} = 6.23 + 2.13\,(\textit{MACK}) + 5.25\,(\textit{workshop attendance}) \qquad (1)$$

where *workshop attendance* = 0, did not attend
workshop attendance = 1, attended

The regression model represented by equation 1 suggests that for the same *MACK* score, students who attended one or more workshops achieved an *examination* score on average 5.25 marks more than a participant who did not, suggesting the workshops had a positive effect on examination scores for *MATH1*. However, caution must be taken when interpreting the results as participants who attended the workshops may possess another characteristic for example, motivation to learn, which introduces a variable not measured within this study.

Discussion and conclusion

Students enrolled in *MATH1* attending Public University were invited to undertake the *MASS* pilot program which provided additional academic support in mathematics by providing weekend workshops. The question: "In what mathematics content areas do pre-service teachers encounter difficulties?" was answered through the analysis of *MACK* assessment which was undertaken by 51% of the cohort enrolled in *MATH1*. Areas of difficulty included number operations, mathematical reasoning and mental computation which are topics incorporated in the *MATH1* unit. Other areas of difficulty related to the content incorporated in *MATH2*, including rational number (percentages, decimals, fractions) and, ratios and proportions.

The ten students who attended the final workshop completed a questionnaire to address the question "Are the weekend workshops perceived as effective and beneficial by participants?" Students who attended the workshops cited them as beneficial in improving their confidence in mathematics. The question "To what extent does performance differ between participants who attended and those who did not attend the workshops?" was analysed using linear regression. Results suggest that workshop participants' mathematical knowledge as measured by the *MATH1* examination was 5.25 marks higher than non-workshop counterparts with the same *MACK* score. Thus workshop participants increased their confidence and final examination results were higher compared to the non-workshop group.

The results of the pilot program showed that the workshops had a positive effect for the students who attended. However, 28.7% or 42 students who did not attend the workshops failed *MATH1*. The non-workshop group perceived themselves to be more confident compared to the workshop group. Yet their confidence did not match their mathematical knowledge and understanding.

In conclusion, many students who need assistance in learning mathematics are not seeking it which is consistent with the findings of Halcrow and Iiams (2011). Weekend workshops, additional tutoring outside normal classes may not attract those students who are most in need. Although the workshop content can be modified, or the program structure changed, students need to attend to reap the benefits. Perhaps assigning additional mathematics tutors to the compulsory *MATH1* classes as implemented at the University of Auckland by Oates and colleagues (2005) is a possible solution for future consideration.

References

Australian Council for Educational Research. (2005). *Progressive achievement tests in mathematics.* (3rd ed.). Melbourne, VIC, Australia: ACER Press.

Australian Curriculum, Assessment and Reporting Authority. (n.d.). NAPLAN tests. Retrieved January 30, 2014, from http://www.nap.edu.au/naplan/the-tests.html.

Ball, D. & Hill, H. (2009). The curious - and crucial - case of mathematical knowledge for teaching. *Phi Delta Kappan*, *91*(2), 68-71.

Ball, D., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching. *Journal of Teacher Education*, *59*(5), 389-407.

Beswick, K., Callingham, R., & Watson, J. (2012). The nature and development of middle school mathematics teachers' knowledge. *Journal of Mathematics Teacher Education*, *15*, 131-157.

Field, A. (2005). *Discovering statistics using SPSS (3rd edition).* London: Sage Publications.

Halcrow, C., & Iiams, M. (2011). You can build it, but will they come? *Primus*, *21*(4), 323-337.

Hamlett, B. (2009). Supporting pre-service primary teachers to improve their mathematics content knowledge. *eCulture*, *2*, 76-82.

Oates, G., Paterson, J., Reilly, I., & Statham, M. (2005). Effective tutorial programs in tertiary mathematics. *International Journal of Mathematics Education in Science and Technology*, *36*(7), 731-739.

White, A., Way, J., Perry, B., & Southwell, B. (2005/6). Mathematics attitudes, beliefs and achievement in primary pre-service mathematics teacher education. *Mathematics Teacher Education and Development*, *7*(1), 33-52.

Xu, Y., Hartman, S., Uribe, G., & Mencke, R. (2001). The effects of peer tutoring on undergraduate students' final examination scores in mathematics. *Journal of College Reading and Learning*, *32*(1), 22-31.

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Monica Wong
Australian Catholic University 25a Barker Road Strathfield
Australia 2135.
monica.wong@acu.edu.au