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IMPROVING THE MATHEMATICS PERFORMANCE OF AUSTRALIA'S STUDENTS

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Our most improved schools show that rapid progress is possible

INTRODUCTION

The state of mathematics in Australian schools is a widely shared concern. Parents, educators, industry groups and governments all query why a prosperous country, placed second on the United Nations' Human Development Index, is sliding down the global education rankings.[1]

The trend is clear: Australia's mathematics performance has stalled or declined in NAPLAN (the National Assessment Program – Literacy and Numeracy), TIMSS (the Trends in International Mathematics and Science Study), and PISA (the Programme for International Student Assessment) whilst government funding per student has increased.[2,3,4]

In TIMSS, strong international performers like Singapore and Japan continue to extend their lead.[5,6] Canada, a nation to which we are often compared, now significantly outperforms us in all PISA and Year 8 TIMSS domains, despite its similar levels of per-student expenditure.[3,4,7]

At a glance

Australia's schools can turn around stalling mathematics results in two years.

A mastery-focused classroom and teachers enthusiastic about teaching mathematics are key.

Additional discipline-specific training and professional development of teachers improves conceptual understanding.

Principals can lead a culture of improvement from the top.

Professional learning communities are important for success.

Principals and teachers need support to develop data analysis skills.

Looking internally, there is a worrisome performance gap between students from different demographics, and a growing and significant tail of underperformance.

In PISA 2015, the mathematical literacy gap between Australia's top and bottom socioeconomic quartiles was equivalent to three years of schooling. There was a gap of more than two years between Indigenous and non-Indigenous students. There was a gap of one and a half years between students from metropolitan and remote areas.[4]

The trends in recent years defy the ambitious objective of the Australian Education Act of 2013, which is "for Australia to be placed, by 2025, in the top five highest performing countries based on the performance of school students in reading, mathematics and science".[8]

Without change, Australian students will continue to be outperformed by their international counterparts, and the achievement gap between advantaged and disadvantaged students will remain. Australia risks a future without the specialised mathematical skills and the population-wide mathematical literacy that the nation requires.[9,10] The question is: what should this change be? One way to find out is to investigate schools where students' mathematical abilities have improved at a much faster rate than comparable schools, regardless of their starting points.

NAPLAN AS A SPOTLIGHT FOR IMPROVEMENT

In 2015, the Office of the Chief Scientist worked with the Australian Curriculum, Assessment and Reporting Authority (ACARA) to identify 619 primary and secondary schools nationally with outstanding improvement in NAPLAN numeracy scores over a two-year period. NAPLAN was used as it is the only common tool across the whole of Australia to measure student performance in mathematics. Outstanding improvement was defined as a performance gain of matched students of greater than one standard deviation above mean growth.

The Office of the Chief Scientist commissioned a consortium of universities led by the University of Tasmania (UTas) to explore the factors that contributed to the outstanding improvement in these schools. Researchers used surveys and case studies of school leaders (such as principals), teachers and students. Survey results of these schools were compared to schools with lower levels of improvement. Eleven key findings were identified, some of which are outlined in Figure 1.[11]

This occasional paper highlights the key findings from the report to inform teachers, school leaders and system-level policymakers in their efforts to improve performance. It is acknowledged that each school operates in a unique environment, so teachers and administrators should reflect on the findings with regard to their own circumstances.

Figure 1: Key findings from case study schools with outstanding improvement

100% of case study schools had **senior leadership** who **understood and valued** mathematics, and a mathematics leader who had input into school **policy decisions**

94% of case study schools had in-school **professional learning communities**, and 73% had had formal, in-school professional learning

90% of case study schools had teachers who **like mathematics**, and were **enthusiastic** in their teaching

87% of case study schools used **data to monitor** individual students' progress

87% of case study schools had a classroom focus on **mastery (i.e. developing conceptual understanding)** rather than just procedural fluency

MASTERY OF MATHEMATICS IS THE GOAL…

After family background and home-life, the most important influence on a child's education is their teachers.[12,13] It is therefore crucial for teachers to create classroom environments that optimise student outcomes.

Broadly speaking, education theory provides for two types of learning orientations: mastery and performance. 'Mastery oriented' classrooms emphasise conceptual understanding, whereas 'performance oriented' classrooms focus on achievement—particularly in comparison to other students.[14] See Box 1 for a comparison between the two. Although the two learning goals are not mutually exclusive, the correlation between them is small.[15]

The report supported existing evidence that a mastery oriented environment is beneficial for mathematics students.[18,19] Mastery oriented classrooms were associated with higher student engagement and lower stress levels. Conversely, students in performance oriented classrooms were more likely to find mathematics difficult. Almost 90% of the high-improvement case study schools displayed a focus on conceptual understanding, not just procedural fluency.

The classroom focus should be on mastering concepts—not competing with other students or schools—and improved performance will follow.

Box 1: Examples of 'mastery oriented' and 'performance oriented' learning goals

MASTERY	PERFORMANCE
Developing competence	Demonstrating competence
Focus on learning, understanding and developing skills	Focus on ability and performance
Orient students to strive to acquire and improve skills and understanding	Orient students to strive to demonstrate superior, or mask inferior, ability relative to others[16,17]

… AND PASSION FOR TEACHING IS KEY

Classrooms must inspire students to understand mathematical concepts, rather than just replicate procedures.

A key step is to employ teachers who are genuinely enthusiastic about teaching mathematics. The report found a clear correlation between teacher enthusiasm and the creation of a mastery environment. Additionally, if a teacher was enthusiastic about teaching mathematics—not just the subject itself—then their students found learning mathematics easier.

A focus on teacher enthusiasm does not mean 'blaming' individual teachers. It means supporting them to reflect and improve, including through professional development, which was recognised recently by the Commonwealth Science Council and the STEM Partnerships Forum (Box 2). School principals play a key role in providing their teachers with opportunities like discipline-specific professional learning, and access to numeracy coaches with expertise in mathematics pedagogy.

Box 2: Discipline-specific professional development

The STEM Partnerships Forum has recommended that a proportion of teacher professional development be dedicated to discipline-specific training. Currently, no Australian jurisdiction mandates discipline-specific professional development.[20]

IT STARTS AT THE TOP…

Principals set the tone in their schools, and with the right strategic focus they can drive a culture that supports mathematics learning. Without that senior leadership, it is difficult for individual teachers to catalyse schoolwide improvement.

The report found that student outcomes were improved when principals encouraged policy input from mathematics leaders in their schools and supported the creation of school-based professional learning communities.

Principals and senior school leaders have a critical role to play in building learning and teaching cultures that improve student outcomes. Just as classroom teachers benefit from training in mathematics pedagogy, principals can benefit from programs that equip them with strategies for creating supportive mathematics learning environments. The Principals as STEM Leaders project, currently in the research and development stage, is one such potential program. [21]

… AND NEEDS SUPPORT FROM POLICY AWARE STAFF MEMBERS

In every case study school, mathematics was led by a staff member who had school-level policy input, and was supported by senior leaders. Part of this support came from a culture of ongoing, in-house professional development.

One avenue for staff development was through professional learning communities, which were observed in 94% of case study schools (see Box 3). These communities explicitly addressed mathematics, and held meetings that were sometimes led by numeracy coaches, mathematics leaders, or the principal.

Box 3: Professional learning community

A cohesive group of teachers with a focus on professional learning and improving their collective knowledge. Professional learning communities can be subject-specific, or have a broader focus.[22]

Nearly three-quarters of case study schools also had some form of formal professional learning that occurred within the school. Although the precise method of professional learning varied between schools, they consistently allocated enough time for staff development to be meaningful.

DATA INFORMS DIRECTION…

In addition to supporting their teachers, part of a principal's role is to shape the direction of their school's teaching program. And for a school to have a well-informed strategy, senior leaders must have a firm grasp of evidence, including data.

Data can improve student achievement by helping to refine and target teaching approaches.[23] This was evidenced by the case study schools, with 90% using data to better understand mathematics students, classes, cohorts or the school as a whole.

The chosen datasets varied between schools, and any given dataset could be used for a range of different purposes. For example, some schools used NAPLAN data to identify commonly misunderstood concepts within a cohort, while others used it to inform whole-of-school programming.

The introduction of a Unique Student Identifier would facilitate the connection of datasets. It would also allow for student progress to be monitored, along with the impact of interventions and policy changes.[24]

… WITH THE BENEFIT OF ANALYTICAL SKILLS

With a working knowledge of data analysis, senior leaders can pinpoint opportunities for improvement, guide staff effort, and monitor progress towards goals. Without this capability, it is easy for schools to interpret data incorrectly, or make poor decisions.[25] Many Australian schools are not 'collecting the right information at the right time and using it effectively'.[23]

There is limited support for teachers to develop their data analysis and interpretation skills.[23,26,27] Development areas include collecting and analysing data; drawing inferences from it; and subsequently developing effective teaching programs that achieve their intended purpose. It is also important for educators to have access to high quality, evidence based resources.[23]

The development and national dissemination of best-practice examples of how to collect, analyse and respond to data would be a useful tool for principals and teachers, and has implications beyond mathematics teaching. One avenue to progress this is through the *Dimensions* initiative (Box 4).[28]

Box 4: *Dimensions*

Dimensions is an online portal for mathematics teachers, which includes evidence-based resources and professional development programs.

Dimensions was developed by the Australian Association of Mathematics Teachers and launched in 2017. It is partly funded by the Australian Government Department of Education and Training.

CONCLUSION

The strategies presented in this paper offer a pathway to lift Australia's mathematics performance:

1) **Teachers** can transform their classrooms into mastery oriented environments, which are linked with increased student interest and reduced learning costs.
2) **Principals** can catalyse schoolwide improvement by building a culture and providing resources to support professional learning and evidenced-based teaching.
3) **Policymakers** can support schools with the resources and training they need to maximise student outcomes through the effective use of data.

Every child possesses a curiosity of the world around them. Mathematics allows us to understand and describe our world like no other discipline. With the policies and practices articulated in this paper, this curiosity can be developed into the mathematical capability that will enable our children to thrive in the modern economy.

NOTES

The full report *Nothing Left to Chance: Characteristics of Schools Successful in Mathematics* is available at http://www.utas.edu.au/__data/assets/pdf_file/0003/1094475/BPME-Report.pdf.

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REFERENCES

1. United Nations Development Programme (2016). Human Development Report 2016. United Nations, New York.
2. Australian Curriculum, Assessment and Reporting Authority (2017). NAPLAN Achievement in Reading, Writing, Language Conventions and Numeracy: National Report for 2017. ACARA, Sydney.
3. Thomson S., Wernert N., O'Grady E., Rodrigues S (2016). TIMSS 2015: A first look at Australia's results. ACER, Melbourne.
4. Thomson S., De Bortoli L., Underwood C. (2016). PISA 2015: A first look at Australia's results. ACER, Melbourne.
5. Mullis, I.S., Martin, M.O., Foy, P., Hooper, M. (2016). TIMSS 2015 International Results in Mathematics. International Association for the Evaluation of Educational Achievement, Boston.
6. Martin, M.O., Mullis, I.V.S., Foy, P., Hooper, M. (2016). TIMSS 2015 International Results in Science. International Association for the Evaluation of Educational Achievement, Boston.
7. OECD (2016). Education at a Glance: OECD Indicators. OECD Publishing, Paris.
8. Australian Education Act 2013 (Cth), Section 3.
9. Office of the Chief Scientist (2016) Australia's STEM Workforce: Science, Technology, Engineering and Mathematics, Australian Government, Canberra.
10. PricewaterhouseCoopers (2015). A Smart Move: Future-proofing Australia's workforce. PwC, Sydney.
11. The final report and a full list of the eleven recommendations can be found at http://www.utas.edu.au/__data/assets/pdf_file/0003/1094475/BPME-Report.pdf.
12. Emerson, L., Fear. J., Fox, S., and Sanders, E. (2012). Parental engagement in learning and schooling: Lessons from research. A report by the Australian Research Alliance for Children and Youth (ARACY) for the Family-School and Community Partnerships Bureau. Family-School and Community Partnerships Bureau, Canberra.
13. Hattie, J. (2009). Visible Learning: A Synthesis of Over 800 Meta Analyses Relating to Achievement, 1 edition, Routledge, Abingdon.
14. Ames, C. & Archer, J. (1988). Achievement Goals in the Classroom: Students' Learning Strategies and Motivation Processes. Journal of Educational Psychology, 80(3), 260-267.
15. Pantziara, M. & Phillippou, G. (2007). Students' Motivation and Achievement and Teachers' practices in the Clasroom. In Woo, J. H., Lew, H. C., Park, K. S. & Seo, D. Y. (Eds.). Proceedings of the 31st Conference of the International Group for the Psychology of Mathematics Education, Vol. 4, pp. 57-64. Seoul: PME.
16. Butler, R. (2007). Teachers' achievement goal orientations and associations with teachers' help seeking: Examination of a novel approach to teacher motivation. Journal of Educational Psychology, 99(2), 241-252.
17. Kaplan, A. & Maehr, M. L. (2007). The contributions and prospects of goal orientation theory. Educational Psychology Review, 19(2), 141-184.
18. Guskey, T. R., Gates, S. L. (1986) Synthesis of Research on the Effects of Mastery Learning in Elementary and Secondary Classrooms. Educational Leadership, 43(8), 73-80.
19. Lazarides, R., Watt, H.M.G. (2015). Girls' and boys' perceived mathematics teacher beliefs, classroom learning environments and mathematical career intentions. Contemporary Educational Psychology, 41 (2015), 51-61.
20. STEM Partnerships Forum. (2018). Optimising STEM Industry-School Partnerships: Inspiring Australia's Next Generation Final Report. Education Services Australia, Melbourne.
21. Australian Government Department of Education and Training: Support for Science, Technology, Engineering and Mathematics. Available from https://www.education.gov.au/support-science-technology-engineering-and-mathematics
22. Stoll, L., & Louis, K.S. (2007). Professional learning communities. Divergence, depth and dilemmas. Maidenhead, England: Open University Press.
23. Goss, P., Hunter, J., Romanes, D., & Parsonage, H. (2015). Targeted teaching: How better use of data can improve student learning. Grattan Institute, Melbourne.
24. Gonski, D., et al. (2018) Through Growth to Achievement: The Report of the Review to Achieve Educational Excellence in Australian Schools. Commonwealth of Australia, Canberra.
25. Chick, H & Pierce, R. (2013) The statistical literacy needed to interpret school assessment data. Mathematics Teacher Education and Development, 15(2), 5-26.
26. McKenzie, P., Weldon, P. R., Rowley, G., Murphy, M. and McMillan, J. (2014) Staff in Australia's schools 2013: Main report on the survey, ACER, Melbourne.
27. Craven, G., Beswick, K., Fleming, J., Fletcher, T., Green, M., Jensen, B., Leinonen, E. and Rickards, F. (2014) Action Now: Classroom Ready Teachers. Available from https://docs.education.gov.au/system/files/doc/other/action_now_classroom_ready_teachers_accessible.pdf.
28. AAMT. Dimensions: Professional Resources in Mathematics Education F-12. Available from http://dimensions.aamt.edu.au/