Generative Teacher Practitioners: Enacting Adaptive Expertise in and Beyond the Classroom

Colleen Vale
Monash University
colleen.vale@monash.edu

Much of our mathematics education research has focussed on effective teaching practices, yet participation and achievement of Australian students has stagnated and fallen behind other countries of similar standards. Whilst school mathematics leaders, both primary and secondary, support teachers to develop their knowledge and develop whole school approaches much of this work focuses on developing teachers' routine expertise rather than their adaptive expertise. Research on generative teaching focuses on developing students' understanding to improve learning, whereas generative teacher practitioners continually seek to improve their understanding and practice of mathematics teaching by learning to be responsive to their students' mathematics thinking and developing students' mathematical reasoning and problem solving. They are also responsive to the socio-cultural and gender composition of their classrooms. In this presentation, the relationships between teacher adaptive expertise and generative teacher practitioners along with opportunities for further research will be discussed.

Student participation, engagement and achievement in mathematics in Australia is an on-going concern and priority for teachers, leaders and policy makers. As researchers we have focused on a range of aspects of student learning and teaching practice to improve outcomes for students. My current Australian Research Council funded project concerns the development of primary teachers' adaptive expertise in interdisciplinary mathematics and science (Berry et al. 2021). Much of my previous research has focussed on equity, mathematical reasoning and out-of-field teaching and drawn on theories of generative teaching (Carpenter et al. 2004), and developing generative teacher practitioners (Franke et al., 2001; Kemmis et al., 2014; Sherin, 2002). In this paper I will discuss these theories and my research findings and make connections between generative teaching, generative teachers and adaptive expertise (Anthony et al., 2015; Bransford et al., 2005; Timperley & Twyford, 2022; Yoon et al., 2019). In the final section of the paper I will provide some further details of the current ARC project.

Generative Teaching

Since the turn of the century, much of the research on improving teaching and learning has focussed "mathematics teachers' attention to student reasoning and sense making to develop deep and flexible thinkers" (van Es & Sherin, 2021, p. 17). However, as Liljedahl (2021) has pointed out, developing thinking classrooms is a challenge for many mathematics teachers. Generative teaching is inclusive and responsive to the students' and their cultural context (Anthony et al. 2015). That is, teachers provide opportunities for all students to reason and make sense of mathematics. Given the strong emphasis on external assessment scores rather than innovating their practice to include an emphasis on sense making, teachers tend to focus their attention on developing students' recall of mathematics concepts, facts and procedures.

In my PhD study (Vale, 2001) which investigated gender equity in classrooms using digital technology, one of the teachers I observed designed a task for students to form a conjecture about the sum of exterior angles of polygons using Geometer Sketchpad. At the time, there were no online templates and students had to construct their own polygons using the software. While the teacher's intention was to develop students' geometric reasoning, they spent most of the two lessons helping students use the software. One high achieving girl was frustrated as the teacher had not explained what was meant by "conjecture." An Indigenous student who had finished the task for homework and helped other students during the second lesson, was ignored and told to sit down. The teacher was not at all aware that this student had demonstrated skill with using the software and

(2023). In B. Reid-O'Connor, E. Prieto-Rodriguez, K. Holmes, & A. Hughes (Eds.), *Weaving mathematics education research from all perspectives*. *Proceedings of the 45th annual conference of the Mathematics Education Research Group of Australasia* (pp. 3–9). Newcastle: MERGA.

understanding of the geometric property. This example highlights the importance of equity and social justice and that all students need to experience a sense of agency to engage in sense making (Schoenfeld, 2016).

Noticing and responding to students in the moment to develop their understanding and reasoning requires capacity to use a range of teacher actions and questioning strategies (Chan, 2021; Choy & Dindyal, 2021). Therefore, effective professional noticing is a generative teacher practice (Pynes, et al., 2020). To do this successfully teachers need a deep understanding of mathematics, flexibility and to reflect on their actions (van Es & Sherin, 2021).

Generative Teachers

A generative teacher of mathematics takes responsibility for the creation and generation of his or her own knowledge (Carpenter, et al., 2004). Generative practitioners have the knowledge, skills and disposition to continuously seek to improve their knowledge of students, mathematics and mathematics learning, and their practice of mathematics teaching through deliberative reflection in collaboration with colleagues (Kazemi et al., 2009; Prestage & Perks, 2000; Sherin, 2002; Valli, 1997):

> … the deliberative approach to reflection emphasizes decision making based on a variety of sources: research, experience, the advice of other teachers, personal beliefs and values and so forth. No one voice dominates. Multiple voices and perspectives are heard. (Valli, 1997, p. 77)

Generative teachers meet outside the classroom to discuss their students' written work (Herbert et al., 2022; Pynes et al. 2020; Vale & Davies, 2005), reflect on their actions-in-the-moment (Eden, 2020), and to co-plan and reflect on action (Eden, 2020; Yoshida 2012).

Vale and Davies (2005) reported on pre-service teachers' (PST) reflection of implementing problem solving and reasoning tasks with groups of Year 4 students in a local school. Two cases were reported of PSTs who had used the problem-solving task, Eric the Sheep (Maths300, https://www.maths300.com), with their group of students. When reflecting on the student learning, the first case David, indicated that he valued procedural knowledge and the traditional practice of teacher transmission. He made distinctions between "better" and "slower" students and did not value the productive power of interactions between students. He clearly explained the procedures for solving the problem using concrete materials and then was surprised when one girl was able to compute the solution very quickly mentally and then explained the concept to the whole group. Rather than thinking about how he might have introduced the task differently, this PST recommended that the groups in the class should be re-organised by skill level. David seems more intent on developing his efficiency with transmission teaching methods rather than changing his teaching practice to support students to learn with and through each other. In the second case, Nerida, reflected on the productive power of the interactions between the students in her group. She valued the discussion among the students and recorded examples of the questions that they posed each other:

> How do you think we should set up the counters? Should we use the same colour counter? Why are we making Eric a different colour? Let's read the task again and work through it together. What do we do next? Why did you do that? Why? What's next? How should we correct our work to check if we got the answer correct? Are we doing this right Miss? What else can we do? What happens if we try to add more counters and more Eric's? Let's work this out together. (Vale & Davies, 2005, p. 749)

The authority that this PST gave to the sense-making of students' questions and explanations illustrates an openness with regard to her learning and support for a generative approach to student learning. These two cases illustrate that whilst individual reflection is valuable, PSTs need to reflect on their teaching collaboratively if they are to generate new understandings of the mathematics and their students' sense making.

In our mathematical reasoning project (Herbert et al., 2022; Vale et al., 2017; Widjaja et al., 2021) which used design-based research to develop a rubric for formative assessment of mathematical reasoning. The rubric, *Assessing Mathematical Reasoning Rubric* (AMRR, Australian Academy of Science, 2018), was created using demonstration lessons of reasoning tasks and then collaboration with the teachers observing the demonstration lesson to develop and refine the rubric. The rubric focusses on three main reasoning actions used across the mathematics curriculum: analysing, generalising and justifying. As a formative assessment rubric it includes descriptions of these actions at different levels of sophistication, rather than using it as summative assessment by defining reasoning competency for each year level. Pairs of teachers met after the demonstration lesson to analyse student work samples using the AMRR. Two rounds of data collection occurred, so we were able to not only refine the rubric, but also compare the teachers' understanding of reasoning over time. We found that in the first round of post-lesson discussions, the teachers focused on the number of properties or examples that students provided and whether or not they were correct, rather than analysing the quality of their argument. Many of the teachers in the first round used the language of summative assessment and, whilst they did describe students' reasoning using phrases from the rubric, some remained focused on the level of reasoning. In the second round during the post-lesson discussion, the teachers more readily used terms from the AMRR to describe students' reasoning. They interacted with each other to reach agreement on their formative assessment of students' reasoning to demonstrate shared meaning (Kemmis et al. 2014) of mathematical reasoning.

In Lesson Study, teachers undertake generative practices as they co-plan, co-observe and co-reflect. They analyse student work collaboratively and reflect (Yoshida, 2012):

> In order for lesson study to be successful, teachers need to think of lesson study as *a way to improve their own learning* as well as student learning. Spending more time studying mathematical content and curriculum, developing a strong pedagogical content knowledge with colleagues, and establishing a community of learning through lesson study. (Yoshida, 2012, p. 140)

Widjaja, Vale and Doig (2020) reported on the collaborative practices of Lesson Study. In this study, teachers, from three local primary schools formed two cross-school Lesson Study Teams. Each team included teachers with a diversity of teaching experience and expertise: a Year 3, Year 4 and Year 3/4 teacher, and a numeracy leader or coach. We observed the collaborative practices of these two Lesson Study teams and tracked their professional growth. We found that trialling the planned lessons prior to conducting the Lesson Study lesson when lots of teachers and experts would observe the lesson, enabled them to revise their planning of questions to elicit students' thinking. The participants in each of the Lesson Study teams valued the range of expertise among members of the team, including the knowledge and expertise of teachers from the other schools in the project, together with the collaborative processes of planning and trialing lessons and reflecting on these lessons through the post-lesson discussion. One of the teachers in an interview about the Lesson Study process reported on the importance and meaning of collaboration for her own practice and stated:

> [The] big thing that's dawning on our teachers here, is that collaboration doesn't mean, someone else does the work for you and its less work. It's about really challenging each other's thinking and questioning each other, and that's been a big feature of this. (Widjaja et al., 2020, p. 16)

This finding accords with Brodie (2020) who found that for collaborative practices to be generative, "[teachers] need to able to challenge each other's thinking and practices" (p. 40).

Adaptive Expertise

Bransford and colleagues (2005) identified innovation and efficiency as two main components of expertise. Routine experts work efficiently in standard situations and use known routine tasks and practices, while frustrated novices are keen to innovate but still need to develop efficient practices for standard situations. Adaptive experts exhibit both innovation and efficiency. They quickly become accustomed to unfamiliar, unexpected and complex situations as they purposefully apply professional knowledge, innovation and creativity (Hatano & Inagaki, 1986; Hatano & Oura, 2003).

Anthony, Hunter and Hunter (2015) have led the research on adaptive expertise of prospective teachers within the MERGA community. They, and others, argue that the adaptive expertise of teachers is a critical component of quality teaching (Anthony et al., 2015; Timperley & Twyford, 2022; Yoon et al., 2019). According to Timperly and Twyford (2022) adaptive expertise evolves as the teacher shifts their focus from self to students and from simplicity to complexity. Characteristics of adaptive expertise relate closely to teacher noticing of critical moments for student engagement and learning in the classroom and their actions in these moments (Anthony et al., 2015; Chan, 2021; Choy & Dindyal, 2021; Pynes et al., 2020; van Es & Sherin, 2021).

Adaptive expert teachers also have a propensity to experiment with new and different teaching and learning activities that is, to innovate (Anthony et al., 2015). They may do this individually or collaboratively. One approach to innovation is action research, a form of critical praxis involving reflection that is action-orientated, social and political (Kemmis et al., 2014). It involves participants in planning actions, implementing these plans, monitoring and evaluating the processes and consequences of their action, and re-planning for further action. Hence it involves a series of on-going cycles of action. As practising teachers, two colleagues and I used action research to investigate sexually (gender) inclusive curricula. This project got me interested in curricula and pedagogies to improve student engagement, equity and social justice. Recently my colleagues and I reported on findings from a professional learning project in which school mathematics leaders used the Teaching Sprint model (Breakspeare & Jones, 2020) to conduct an action research cycle (Vale & Delahunty, 2022). These small-scale action research projects (teaching sprints) conducted with small teams of teachers at their school provided the school mathematics leaders with evidence of practices that were effective for their students and worthy of both celebrating and continuing. The Teaching Sprint also provided a collaboration and consultation process that supported them to develop respectful relationships with teams of teachers.

Whilst the model of adaptive expertise used by Bransford and colleagues (2005) included the components of innovation and efficiency, the framework developed by Yoon et al. (2019) has three components: flexibility, deep level of understanding, and deliberate practice. Flexibility is manifested in the teacher's ability to integrate aspects of their knowledge in relation to the teaching act with the goal of improving outcomes while responding to their specific contexts. This may involve acknowledging and recognizing cultural and gender diversity of students as well as knowledge of their prior learning. A deep level of understanding involves the teachers' ability to recognise meaningful patterns quickly, allowing one to attend to deeper-level problem solving and, in turn, facilitating students to perform at a higher level. That is, the ability to act in the moment is a manifestation of a deep level of understanding. Finally, deliberate practice concerns the teacher's ability to engage in reflection during the lesson and when reviewing the lesson individually, or with a co-teacher, to consciously deliberate about students' engagement and learning, their teacher actions, and the use of regulation processes to ensure cognitive engagement of all students.

What's interesting about the Yoon and colleagues' (2019) model of adaptive expertise, is the similarity of the components of adaptive expertise with those of generative teachers. Generative teachers use deliberative reflection to improve their knowledge, planning and teaching. They aim to be flexible when acting-in-the moment and when responding to individual student. They also aim to develop their knowledge of the content and their teaching context, their students and the school's practice architectures (Kemmis et al., 2014).

Adaptive Expertise in Interdisciplinary Mathematics and Science Project

The aim of the three-year Adaptive Expertise in Interdisciplinary Mathematics and Science project is to improve theoretical and practical understanding of the nature and development of primary teachers' adaptive expertise in interdisciplinary mathematics and science. The key research questions are:

- How can primary teachers' adaptive expertise in interdisciplinary mathematics and science be characterised in terms of components and levels?
- To what extent, and how, does primary teachers' adaptive expertise change and develop during a trajectory across two school years aimed at interdisciplinary mathematics and science in a co-plan, co-teach and co-reflect approach?

The study uses a mixed method longitudinal research design. Pairs of Year 5 or Year 6 teachers from five schools will co-teach the same two sequences of STEM lessons twice, that is, in two of the three years of the study. The two sequences of STEM lessons designed for the study were Keep your Finger on the Pulse and Journey through Space (Hughes et al., 2022). Data will be generated using an initial teacher interview and an online questionnaire constructed using videoed episodes of teachers' practices. These video episodes were collected during the pre-study trial of Keep your Finger on the Pulse. Each of the STEM lessons taught by the co-teachers will be video-taped and co-teacher interviews will explore their reflections on their teaching using video recordings of their teaching, and researcher observations of these lessons. The adaptive expertise framework developed by Yoon and colleagues (2019) has been used to select video episodes and construct items for the video-based questionnaire. This framework will also be used to analyse post-lesson co-teacher interviews.

Research about the development of teacher's knowledge and practice of mathematics teaching is essential for improving student engagement, learning, equity and social justice. We need to continue to develop understanding of students' mathematical thinking as the socio-political context for learning changes and evolves as this research provides resources for teachers' deliberative reflection. We also need to continue to research the socio-political-economic context of schools and systems to ensure that teachers can engage in generative practices and develop adaptive expertise.

Acknowledgements

I would like to thank my many colleagues for their collaboration on various research projects related to developing generative teacher practitioners: Anne Davies, Sharyn Livy, Sandra Herbert, Leicha Bragg, Wanty Widjaja, Esther Loong, Aylie Davidson, Susie Groves, Brian Doig, Kerryn Driscoll, Carmel Delahunty, Penelope Kalogeropoulos, Jill Cheeseman, Amanda Berry, Jan van Driel, Lihua Xu, Joe Ferguson, Jinny Kim, James Russo and Jennifer Mansfield.

References

Anthony, G., Hunter, J., & Hunter, R. (2015). Prospective teacher's development of adaptive expertise. *Teaching and Teacher Education, 49*, 108–117. http://dx.doi.org/10.1016/j.tate.2015.03.010

Australian Academy of Science (2018). *Assessing mathematical reasoning rubric*. https://www.resolve.edu.au/assessing-mathematical-reasoning

Berry, A., van Driel, J., Vale, C., Widjaja, W., Xu, L., Ferguson, J., & Kim, J. (2021). Developing adaptive expertise in primary science and mathematics education. ARC Discovery Grant, DP210101171.

Bransford, J., Derry, S., Berliner, D., Hammerness, K., & Beckett, K. L. (2005). Theories of learning and their roles in teaching. In L. Darling-Hammond, & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 40–87). Hoboken, NJ: Jossey-Bass.

Breakspear, S., & Jones, B. R. (2020). *Teaching sprints: How overloaded teachers can keep getting better*. SAGE Publications.

Brodie, K. (2020). Resources for and from collaboration: A conceptual framework. In H. Borko, & D. Potari (Eds.), *ICMI study 25 conference proceedings: Teachers of mathematics working and learning in collaborative groups* (pp. 37–48). Lisbon, Portugal.

Carpenter, T. P., Blanton, M. L., Cobb, P., Franke, M. L., Kaput, J., & McClain, K. (2004). *Scaling up innovative practices in mathematics and science.* Madison, WI; Wisconsin Centre for Education Research.

Chan, K. (2021). Using classroom video-based instruments to characterize pre-service science teachers' incoming usable knowledge for teaching science. *Research in Science and Technological Education*, *41*(4), 1–23. DOI: 10.1080/02635143.2021.1872517.

Choy, B. H., & Dindyal, J. (2021). Productive teacher noticing and affordances of typical problems. *ZDM—Mathematics Education, 53*, 195–213. doi.org/10.1007/s11858-020-01203-4

Eden, R. (2020). Learning together through co-teaching mathematics: The role of noticing in teachers' collaborative inquiry. In H. Borko, & D. Potari (Eds.), *ICMI study 25 conference proceedings: Teachers of mathematics working and learning in collaborative groups* (pp. 300–307). Lisbon, Portugal.

Franke, M. L., Carpenter, T. P., Fennema, E., et al. (2001). Capturing teachers' generative change: A follow-up study of teachers' professional development in mathematics education. *American Educational Research Journal, 38*, 653–689.

Hatano, G., & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azama, & K. Hakuta (Eds.), *Child development and education in Japan* (pp. 262–272). New York: Freeman.

Hatano, G., & Oura, Y. (2003). Commentary: Reconceptualising school learning using insight from expertise research. *Educational Researcher, 32*(8), 26–29. https://doi.org/10.3102/0013189X032008026

Herbert, S. Vale, C., White, P., & Bragg, L. (2022). Engagement with a formative assessment rubric: A case of mathematical reasoning. *International Journal of Educational Research*, *111.* https://doi.org/10.1016/j.ijer.2021.101899 https://doi.org/10.1016/j.ijer.2021.101899

Hughes, S., Russo, J., Mansfield, J., Green, A., Jones, D., Vale, C., & Berry, A. (2022). Co-designing integrated mathematics and science lesson learning sequences for primary education. *International Journal of Innovation in Science and Mathematics Education*, *30*(4). DOI: https://doi.org/10.30722/IJISME.30.04.005

Kazemi, E., Lampert, M., & Franke, M. L. (2009). Developing pedagogies in teacher education to support novice teachers' ability to enact ambitious instruction. In R. Hunter, B. Bicknell, & T. Burgess (Eds.), *Crossing divides. Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia* (Vol. 1). Palmerston North, NZ: MERGA.

Kemmis S., Wilkinson, J., Edwards-Groves, C., Hardy, I., Grootenboer, P., & Bristol, L. (2014). *Changing practices, changing education*. Singapore: Springer.

Liljedahl, P. (2021). *Building thinking classrooms in mathematics: Grades K–12*. Corwin.

Prestage, S., & Perks, P. (2000). Subject knowledge: Developing the fourth sense. *Paper presented at the British Educational Research Association Conference*, Cardiff University, 7–10 September, 2000.

Pynes, D'A., Empson, S., & Jacobs, V. (2020). Supporting teachers in the development of noticing children's mathematical thinking with a web-based tool. In H. Borko, & D. Potari (Eds.), *ICMI study 25 conference proceedings: Teachers of mathematics working and learning in collaborative groups* (p. 676). Lisbon, Portugal.

Schoenfeld, A. H., & the Teaching for Robust Understanding Project. (2016). *An introduction to the Teaching for Robust Understanding (TRU) framework*. Berkeley, CA: Graduate School of Education. http://map.mathshell.org/trumath.php or http://tru.berkeley.edu

Sherin, M. (2002). When teaching becomes learning. *Cognition and Instruction, 20*(2), 119–150.

Timperley, H., & Twyford, K. (2022). Adaptive expertise in educational leadership: Embracing complexity in leading today's schools. *Australian Education Leader, 44*(1), 8–12.

Vale, C. M. (2001). *Gender and computer based mathematics in selected secondary classrooms* [Doctoral thesis, La Trobe University].

Vale, C., & Davies, A. (2005). Glimpses of generative practice: Constructing pre-service teachers' learning in partnership. In P. Clarkson, A. Downton, D. Gronn, M. Horne, A. McDonough, R. Pierce, & A. Roche (Eds.), *Building connections: Research, theory and practice. Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australasia* (pp. 743–750). Geelong, Sydney: MERGA.

Vale, C., & Delahunty, C. (2022). Teaching sprints: Action research led by school mathematics leaders. In N. Fitzallen, C. Murphy, & V. Hatisaru (Eds.), *Mathematical confluences and journeys. Proceedings of the 44th annual conference of Mathematics Research Group of Australasia* (pp. 33–36). Launceston: MERGA.

Vale, C., Widjaja, W., Herbert, E. S., Loong, E., & Bragg, L. A. (2017). Mapping variation in children's mathematical reasoning: The case of 'What else belongs?' *International Journal of Science and Mathematics Education*, *15*(5), 873–894. DOI 10.1007/s10763-016-9725-y

Valli. L, (1997). Listening to other voices: A description of teacher reflection in the United States. *Peabody Journal of Education, 72*(1), 67–88.

Van Es, E., & Sherin, M (2021). Expanding on prior conceptualizatons of teacher noticing. *ZDM 53*, 17–27. https://doi.org/10.1007/s11858-020-01211-4

Widjaja, W., Vale, C., & Doig, B. (2020). Nothing like planning and reflecting together to build trust. In G. Lloyd, & O. Chapman. (Eds.), *Participants in mathematics teacher education: International handbook of mathematics teacher education* (2nd Edition, Volume 3, Chapter 5, pp. 128–150). Kononklijke Brill.

Widjaja, W., Vale, C., Herbert, S., Y-K. Loong, E., & Bragg, L. (2021). Linking comparing and contrasting, generalising and justifying: A case study of primary students' levels of justifying. *Mathematics Education Research Journal, 33*(2), 321–344. DOI 10.1007/s13394-019-00306-w

Yoon, S. A., Evans, C., Miller, K., Anderson, E., & Koehler, J. (2019). Validating a model for assessing science teacher's adaptive expertise with computer-supported complex systems curricula and its relationship to student learning outcomes. *Journal of Science Teacher Education, 30*(8), 890–905.

Yoshida, M. (2012). Mathematics lesson study in the United States: Current status and ideas for conducting high quality and effective lesson study. *International Journal for Lesson and Learning Studies, 1*(2), 140–152.