



MINISTRY OF EDUCATION

Te Tāhuhu o te Mātauranga

BES Exemplar 1 Ngā Kete Raukura – He Tauira 1 Developing communities of mathematical inquiry

This is the first of a series of exemplars being prepared for Quality Teaching for Diverse (All) Learners in Schooling: Best Evidence Synthesis Iteration [BES]

He Ako Reikura, He Ākonga Rerekura (Te Katoa): Hei Kete Raukura [BES]

This publication, currently in development, is a second iteration of *Quality Teaching for Diverse Students in Schooling: Best Evidence Synthesis [BES]* (2003).

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ITERATIVE BEST EVIDENCE SYNTHESIS PROGRAMME
HEI KETE RAUKURA
<http://educationcounts.govt.nz/goto/BES>
New Zealand

Background to BES Exemplar 1: Developing communities of mathematical inquiry

This exemplar, ‘Developing communities of mathematical inquiry’, illustrates how two teachers developed teaching practices that proved highly effective for diverse learners. The teachers were working with year 4 to 6 students, most of whom were Māori or Pasifika. However, the pedagogy that accelerated the mathematics achievement of these students has implications for all students in primary, intermediate, and lower secondary school.

BES exemplars celebrate and support teachers’ work

The teachers whose work is featured in this exemplar took part in a professional development programme designed to help them build classroom communities of mathematical inquiry. Within those communities, their students developed the skills and confidence necessary to engage with their teachers and peers in mathematical inquiry, reasoning, and argumentation. While the context of this exemplar is mathematics, its message about the value of creating a peer environment where students feel safe to engage in constructive learning talk is of relevance across the curriculum.

Professor Courtney Cazden of Harvard University described this intervention as “among the best you would find anywhere in the world.”

Addressing areas of need

The Trends in International Mathematics and Science Study (TIMSS, 2006)¹ showed that the mathematics achievement of New Zealand students in their middle primary school years is below the international mean. The TIMSS findings revealed that students whose teachers participated in the Numeracy Development Project (NDP) did significantly better than those whose teachers did not. Yet the National Education Monitoring Project (NEMP) findings for 2009 indicate continuing disparities for Māori and worsening disparities for Pasifika in mathematics. It is clear that many teachers need more support.

This first exemplar describes an approach that helps students develop all five of the key competencies, supporting teachers to implement the New Zealand Curriculum. The exemplar also demonstrates how the development of a learning community countered bullying, another issue shown by international research to be an area of need in our schools.²

Other resources

This resource also exemplifies the findings of the *Effective pedagogy in mathematics/pāngarau BES*. Summaries of this BES are available electronically in English and Māori on the UNESCO website:

- Anthony, G. & Walshaw, M. (2009). *Effective pedagogy in mathematics: Educational practices series, 19*. International Academy of Education & International Bureau of Education, UNESCO. Retrieved from www.ibe.unesco.org/en/services/publications/educational-practices.html
- Anthony, G. & Walshaw, M. (2010). *Te ako pāngarau whaihua: Educational practices series, 19*. International Academy of Education, International Bureau of Education, UNESCO. Retrieved from www.ibe.unesco.org/en/services/publications/educational-practices.html

Hard copies of both the BES itself and the summaries are available free on request within New Zealand from orders@thechair.minedu.govt.nz

Acknowledgments

The Ministry of Education acknowledges the work and outstanding expertise of Dr Roberta Hunter of Massey University, Albany, who led the research and development and the teacher professional learning that is described in this case.

This work was possible also because of the larger Teaching and Learning Research Initiative, Numeracy Practices and Change Project, which was co-directed by Professors Glenda Anthony and Margaret Walshaw.

The Iterative Best Evidence Synthesis Programme pays tribute to the outstanding teaching of ‘Ava’ and ‘Moana’, whose commitment to the collaborative professional learning opportunity described in this case made possible such extraordinary gains for students. We acknowledge also the contribution of your principal and colleagues in forging such a powerful school-based professional learning community.

The development of this case has been strengthened by formative quality assurance. We acknowledge and thank:

- Dr Roberta Hunter and Professor Glenda Anthony, Massey University
- Liz Patara, principal/tumuaki, and Mary Lee Bogard, teacher, Clyde Quay School
- Dr Earl Irving and Dr Claire Sinnema, University of Auckland
- Associate Professor Jenny Young-Loveridge, University of Waikato
- Stephanie Greaney, Education Review Office
- Professor Courtney Cazden, Professor Emeritus, Harvard University.

Thanks also to the team at Learning Media for your patient and iterative work in developing this exemplar to date.

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- 1 Mullis, I., Martin, M. O., & Foy, P. (2007). *TIMMS 2006 international science report: Findings from IEA's trends in mathematics and science study at the fourth and eighth grades*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.
 - 2 Mullis, I., Martin, M. O., & Foy, P. (2007). *Findings from IEA's trends in mathematics and science study at the fourth and eighth grades*. In collaboration with J. F. Olson, C. Preschoff, E. Erberber, A. Arora, & J. Galia (Eds.), *Index of students' perception of being safe in school (SPBSS) and trends*, (p. 367). Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

About the BES exemplars

This new series of BES exemplars is being prepared by the Iterative Best Evidence Synthesis (BES) Programme. Each exemplar has been selected because it illuminates highly effective teaching approaches that accelerate progress for diverse (all) learners in areas where improvement is needed. They exemplify the eleven dimensions of quality teaching using examples that come from across the curriculum and are relevant to primary, intermediate, and secondary levels of schooling.

The series has been given priority in response to requests from teachers and principals for real-life examples that make transparent the nature of highly effective teaching and the professional learning, leadership, and educationally powerful connections with families, whanāu, and communities that support such teaching. The exemplars are derived, where possible, from research and development carried out in New Zealand schools and kura. They celebrate the outstanding work of New Zealand educators.

While the BES exemplars show how significant improvements can be made through teaching, they are not ‘magic bullets’. Rather, the exemplars illuminate the high-impact research and development that informed and developed the expertise of the teachers, facilitators, school leaders, and researchers they feature.

The BES exemplars are being progressively released online. They will be a core resource for the forthcoming:

Quality Teaching for Diverse (All) Learners in Schooling: Best Evidence Synthesis Iteration [BES] He Ako Reikura, He Ākonga Rerekura (Te Katoa): Hei Kete Raukura [BES].

This publication, currently in development, is a second iteration of *Quality Teaching for Diverse Students in Schooling: Best Evidence Synthesis [BES]* (2003). For updates on progress, go to the BES website at www.educationcounts.govt.nz/goto/BES

While teachers are the primary audience for these BES exemplars, they are also intended as a resource for leaders, policy makers, and all those involved in supporting the work of teachers. To support their use in a variety of contexts, each exemplar incorporates the following features:

- A section on background information explains the significance of the exemplar. It highlights the expertise of the educators that enabled accelerated improvement and identifies the area of national need that they addressed in their work. You may prefer to read the exemplar before reading this background information.
- A list of supporting resources is provided for those who wish to investigate further. Full text copies of cited articles can be requested from the BES website.
- A ‘Professional learning: Starter questions’ tool is intended to support schools seeking to use the exemplars as catalysts for improvement. Specifically, it is intended to support an inquiry and a knowledge-building approach to improvement that is responsive to the unique needs of the students, teachers, and wider community in each context.
- An ‘Implementation alerts’ checklist highlights the complexity of change for improvement, emphasising the fact that ‘how’ change happens and is supported is critical to success.

The pedagogical approaches explained in these exemplars do need, of course, to be appropriately integrated into a comprehensive plan for improving teaching and learning.

Feedback to inform BES development

We will draw upon your feedback when finalising the exemplars for this new BES iteration. Please send any feedback to best.evidence@minedu.govt.nz

BES Exemplar 1. Developing communities of mathematical inquiry

<p>Source</p>	<p>Hunter, R. (2007). <i>Teachers developing communities of mathematical inquiry</i>. Albany, Massey University: Unpublished doctoral thesis. Available from the New Zealand Education Theses database at www.educationcounts.govt.nz/goto/BES</p> <p>Hunter, R. (2008). Facilitating communities of mathematical inquiry. In M. Goos, R. Brown, & K. Makar (Eds.), <i>Navigating currents and charting directions</i> (Proceedings of the 31st annual conference of the Mathematics Education Research Group of Australasia, Vol. 1, pp. 31–39). Brisbane: MERGA.</p> <p>Hunter’s 2008 publication received the Beth Southwell Practical Implications Award sponsored by the Australian Association of Mathematics Teachers (AAMT) and the National Key Centre for Teaching and Research in School Science and Mathematics, Curtin University, Perth, Western Australia.</p> <p>.....</p> <p><i>Full text copies of cited articles can be requested by New Zealand schools through the Ministry of Education’s Research Behind BES service: www.educationcounts.govt.nz/goto/BES</i></p>															
<p>Introduction</p> <p><i>‘Effect size’ is a statistical measure of the impact of an intervention on an outcome. Hattie¹ shows that the average yearly effect of teaching in New Zealand in reading, mathematics, and writing from year 4 to year 13 is $d = 0.35$. Effect sizes above 0.40 represent an improvement on business-as-usual and effect sizes of $d = 0.60$ are considered large.</i></p>	<p>This exemplar describes how two teachers worked to develop classroom learning communities in which students learned to engage with the teacher and each other in mathematical inquiry, reasoning, and argumentation.² It traces significant changes in teacher knowledge and pedagogy and in student behaviour and mathematical practices through a collaborative, school-based, professional learning process. That process was led by the researcher over one school year. The effect sizes for the gains in both classes were very large: $d = 2.39$ for Ava’s class and $d = 2.53$ for Moana’s class. This is extraordinary progress, representing the equivalent of several years’ progress (compared with business-as-usual teaching) in just one year.</p> <p>The exemplar dramatically illustrates the benefits of developing a genuine learning community within the peer culture. Many studies across the curriculum report high gains when using co-operative learning approaches (for example, Hattie³ found an effect size of $d = 0.59$ for co-operative learning approaches). On the other hand, studies also reveal the problems that arise when students are not effectively trained to work collaboratively or when they simply work in seating or social groupings. The source study for this exemplar reveals how two teachers took action to transform their teaching, thereby accelerating student development in terms of a wide range of valued outcomes, including cognitive, metacognitive, and social outcomes.</p> <p>Both teachers had previously engaged in the Numeracy Development Project (NDP) but had adapted what they learned to fit with their traditional practices. Through inquiry into their own practice and the use of a smart tool,⁴ the Mathematics Communication and Participation Framework⁵ (see Appendix A), they were able to build on what they had learned in the NDP and transform the ways in which their students interacted and participated. These changes, in turn, accelerated the students’ progress in terms of academic achievement and self-management. The exemplar describes the wide range of instructional strategies, scaffolds, and prompts used by the two teachers, and explains how these influenced student learning and behaviour.</p> <p>The Trends in International Mathematics and Science Study⁶ shows that students in New Zealand schools, especially Māori and Pasifika students, perceive themselves as having a very low level of safety amongst their peers. Given these findings, the magnitude of the changes achieved through teacher actions in Exemplar 1 have important implications for policy and practice nationally. This exemplar highlights the connections between the collaborative inquiry that the teachers engaged in and the shifts for students. It was the professional learning process and support that the teachers experienced that enabled them to achieve the changes.</p>															
<p>Learners and learning context</p>	<p>The learners in this study were two teachers and their students. Ava, a teacher of Māori and New Zealand European descent, was in her ninth year of teaching. Ava’s class included year 4 and 5 students. Moana, a Māori teacher, was in her fifth year of teaching. Moana’s class included year 4, 5, and 6 students.</p> <p>The setting was a small, suburban, multicultural decile 3 primary school. The students were mostly of Māori and Pasifika ethnicity. Tumeke School⁷ had a transient population, with around 30% of the students in each class leaving or arriving during the school year.</p> <table border="1" data-bbox="411 1787 1453 2004"> <thead> <tr> <th>Student ethnicity</th> <th>Ava’s class</th> <th>Moana’s class</th> </tr> </thead> <tbody> <tr> <td>Māori</td> <td>47%</td> <td>40%</td> </tr> <tr> <td>Pasifika</td> <td>25%</td> <td>58%</td> </tr> <tr> <td>NZ European</td> <td>24%</td> <td>2%</td> </tr> <tr> <td>Other</td> <td>4%</td> <td></td> </tr> </tbody> </table>	Student ethnicity	Ava’s class	Moana’s class	Māori	47%	40%	Pasifika	25%	58%	NZ European	24%	2%	Other	4%	
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Research and development underpinning the intervention

The professional development and research project described in this exemplar was led by the study’s author, Roberta Hunter, then a doctoral student. The project was funded from the larger Numeracy Practices and Change Project. This project was a Teaching and Learning Research Initiative (TLRI) project, co-directed by Professor Glenda Anthony and Associate Professor Margaret Walshaw.

Outcomes

The students in these classrooms experienced a variety of ways of engaging in mathematics. Working through a collaborative process of mathematical inquiry supported the students’ well-being, enhanced their understanding of mathematics, and developed their mathematical proficiency.

The qualitative data reported in this exemplar shows that the collaborative inquiry process supported the students in developing productive dispositions and mathematical identities. The students grew in their confidence as mathematicians. They could see the value of mathematics, wanted to learn mathematics, and believed that they could succeed if they applied themselves. These dispositions are not just a desirable end product of mathematics education; they are the means by which students learn and do mathematics.

The following graphs show levels of student achievement in mathematics on the number framework, as revealed by the NumPA diagnostic interview. It compares the students’ achievement at the start of the year, before the process began, to their achievement at the end of the year, after the development of communities of mathematical inquiry. The teachers and the researcher checked the data independently.

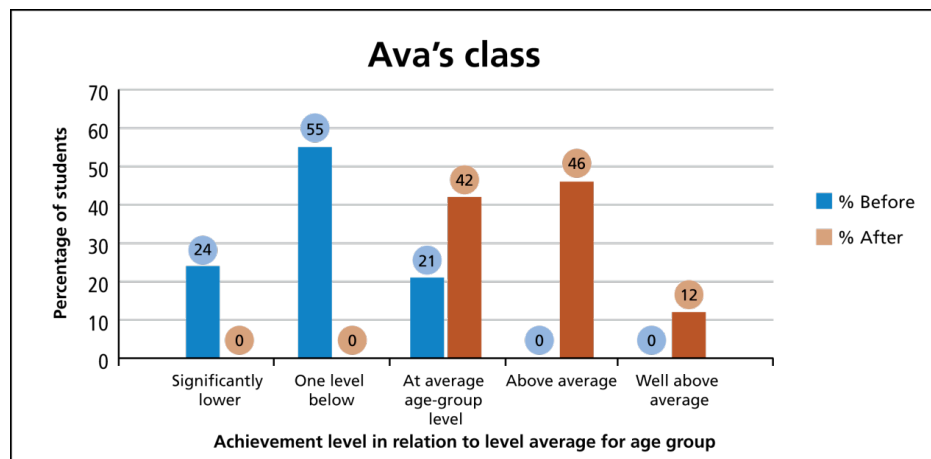


Figure 1. Shifts in mathematics achievement in Ava’s class after collaborative professional development underpinned by research and development

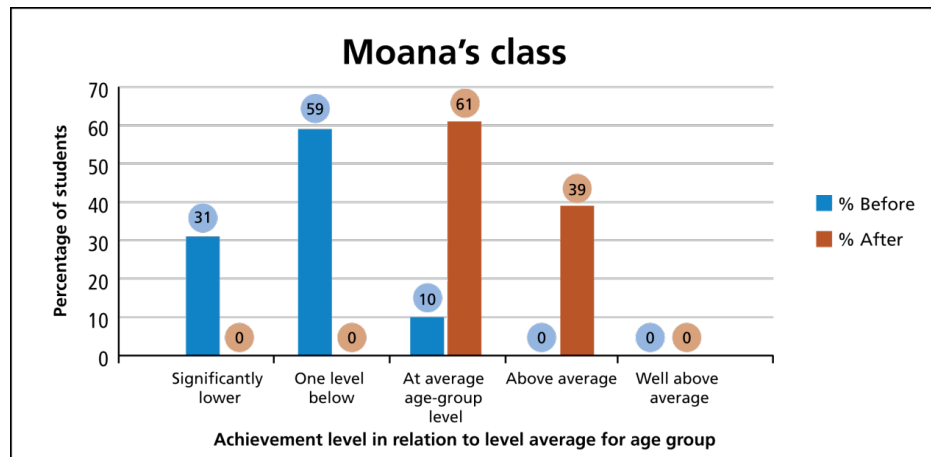


Figure 2. Shifts in mathematics achievement in Moana’s class after collaborative professional development underpinned by research and development

As discussed, the effect sizes for the gains in both classes were very large: $d = 2.39$ for Ava’s class and $d = 2.53$ for Moana’s class.⁸ In practical terms, the intervention accelerated students’ progress by the equivalent of around four to five years’ business-as-usual achievement gains. By the end of the year, all students were achieving at least at their average age-group level and many were achieving above this on the NumPA assessment.

<p>Curriculum relevance:⁹ New Zealand Curriculum</p>	<p>Studying mathematics helps students develop the ability to think creatively, critically, strategically, and logically. They learn to create models, conjecture, justify and verify, and seek patterns and generalisations. In this exemplar, both teachers developed units that included the study of fractional numbers, statistics and measurement, and adding, subtracting, multiplying and dividing. A further extension unit focused on algebraic reasoning was developed within the project. The students actively built capability in all five key competencies: thinking, using language, symbols, and texts, managing self, relating to others, and participating and contributing.</p>
<p>Te Marautanga o Aotearoa</p>	<p>Ka tipu ana te tamaiti, ka matau haere ia ki te reo matatini o te pāngarau, koia hoki te huarahi matua e marama ai ia ki nga aria pāngarau, e whakawhitiwhiti korero ai, e eke panuku ai i nga taumata o tenei wahanga ako.</p> <p>As the child grows, their pāngarau literacy develops and becomes essential to their understanding of pāngarau concepts, and to their communication in pāngarau, in order to achieve success in this learning area.</p>

The Quality Teaching Dimensions

<p>Outcomes focus</p> <p>Hua te ako, hua te ākonga</p> <p>Quality teaching is focused on valued outcomes and facilitates high standards for diverse learners.</p>	<p>Ava and Moana’s initial focus</p> <p>At the outset of the intervention, Ava was confused about the outcomes she intended to focus on. She wanted her students to learn the rules and procedures of mathematics and, in light of her previous professional learning, she also wanted them to be able to articulate, within their groups, the mathematical strategies they were using. However, she did not set out to create a mathematical discourse community (that is, a classroom community of novice mathematicians whose learning includes understanding and using the specialised language of mathematics). As each student spoke, the other students sat silently.</p> <p>Initially, Moana was focused on a limited set of low-level outcomes. She ascribed her students’ low achievement levels to their lack of prior experiences at home, their lack of interest and engagement in mathematics, and their passive approach to learning. She later reflected, “I thought I had high expectations ... I have realised I [had] low expectations.”</p> <p>Ava and Moana’s shift in focus</p> <p>Both teachers developed a comprehensive new approach that focused on valued outcomes. They set out to develop in their students the communication and participatory skills needed to advance their thinking and extend their mathematical knowledge through active participation in the classroom mathematical discourse community.</p> <p>The teachers aimed to develop their students’ abilities to explain mathematical concepts, justify their arguments, and make generalisations. They expected the students to use mathematical language and definitions and also to use generalisations and inscriptions¹⁰ to support their explanations and to clarify their understandings of others’ explanations. The teachers did not form these new expectations overnight. Rather, as the teachers participated in the iterative professional learning process and the changes began to be embedded, they saw how their students extended their mathematical proficiency through the new teaching and learning approach.</p> <p>Both teachers began to develop their students’ identities as mathematicians and members of a learning community in which each person had high expectations for their own outcomes. The teachers became adept at identifying and addressing barriers to progress and keeping the focus on the outcomes.</p>
<p>Teacher knowledge and inquiry</p> <p>Te mōhio o te kaiako, te tikanga uiui</p> <p>Teachers work smarter, not harder, through the use of evidence for continuous improvement.</p>	<p>Teacher knowledge and inquiry at the outset of the study: Ava</p> <p>Ava explained that she had initially liked teaching mathematics but had lost confidence in her mathematics teaching expertise after participating in the NDP. The NDP professional development had created dissonance between her prior view of mathematics teaching as focused on rules, procedures, and routines and the new focus on students developing their mathematical thinking.</p> <p>Observations revealed that Ava had tried to implement what she had learned from the NDP. But in practice, she had done what many teachers do when confronted with new curricula designed to change the nature of teaching. She had transformed the NDP learning experiences to fit with her old way of doing things. Her students listened to each other in silence and answered the teacher’s questions, but there was no process to build a mathematical learning community amongst students.</p> <p>Teacher knowledge and inquiry at the outset of the study: Moana</p> <p>Moana had always disliked mathematics. Her memory of her own schooling was negative: “I didn’t have the ideas that other kids had so I just never said anything. I thought they were all brighter than me.”</p> <p>Before the intervention, Moana was using a learning styles approach. She saw her Māori and Pasifika learners as kinaesthetic learners needing practical activities. This approach has been found to have little benefit for student achievement and has even had negative effects on Māori and Pasifika student achievement.¹¹</p>

	<p>In her mathematics lessons, Moana did most of the talking because she saw her role as instructing students in how to use mathematical procedures. She explained that she had adapted the NDP's knowledge and strategy activities so that they were always at a concrete and manipulative level. She focused on students 'learning by doing', because she believed that they found explaining difficult.</p> <p>Teacher inquiry through the study</p> <p>The professional development was delivered through a mix of whole-staff meetings and eight meetings of a teacher study group. The professional learning activities included examining research, considering how other teachers had changed the forms of mathematical talk towards inquiry and argumentation, and reading about mathematical practices used by students in inquiry environments. The researcher used a DVD from an international research study to stimulate examination of inquiry practices. The teachers re-examined the materials in the NDP and discussed which learning tasks best supported their goals, which involved changing the classroom discourse patterns. The TLRI project funded the necessary teacher relief time. This amounted to at least six days for each participating teacher.</p> <p>Initially, the researcher was in the school for two mornings a week and worked collaboratively with the teachers to provide support both in and out of class. Data gathering in the classrooms commenced from term 2 and included the researcher making video recordings of lessons, which were later transcribed. The study group used these recordings extensively. They viewed them repeatedly, collaboratively examining and identifying critical incidents and the antecedents and consequences of these incidents. The teachers recorded their lesson intentions and drew on excerpts from the transcripts to trace how their actions had influenced what students actually said and did.</p> <p>The researcher perceived that the classroom videos were key to the professional learning, especially at the start, because they illustrated "the power of who asks what in the classroom". It was also important to provide the teachers with a small number of research articles in a timely way that addressed a specific need. The DVD had helped motivate the teachers by "pushing their vision of possibilities".</p> <p>The collaboration between the researcher and teachers persisted beyond the study when some teachers co-presented their findings with the researcher in conference workshops. The teachers became members of a local mathematical professional group.</p>
<p>Smart tool Te raweke tapu ngaio</p>	<p>The researcher built on overseas research to develop the Mathematics Communication and Participation Framework (see Appendix A of this exemplar). She then worked with the teachers to refine this smart tool. The framework provided an outline of both communicative and participatory actions, along with examples. Teachers could use it to scaffold students' learning about how to participate in communities of mathematical inquiry.</p>
<p>Teacher inquiry Te tikanga uiui</p>	<p>Teacher inquiry: Ava</p> <p>After reading relevant research and taking part in discussion, Ava was convinced of the value of the new approach and decided to take immediate action to change her teaching practices, using the Mathematics Communication and Participation Framework. Her initial focus was on students' participation in mathematical explanations. Within a month, she decided to stop the use of ability-group streaming.</p> <p>Teacher inquiry: Moana</p> <p>Moana was quiet when the study group discussed the framework. She believed strongly in certain theories about teaching and learning, and at first she did not believe that the students would learn more through a learning community. She was focused on students getting the right answers. However, the videos stimulated Moana to build on what she had learned about how other teachers were changing their classroom practices. She decided to start by developing students' ability to construct and present mathematical explanations. When she saw the initial changes in her students, she was convinced of the value of the new approach and whole-heartedly engaged with the change process.</p>
<p>Opportunity Kapohia, akona Opportunity to learn is effective and efficient.</p>	<p>In both teachers' classes, the opportunities to learn included a whole-class session, small-group work, and later whole-class report-backs and sharing sessions.</p> <p>The teachers paid careful attention to giving students the time they needed to learn, scaffolds and learning supports (including support from peers and from visual representations), and opportunities for practice and application. The teachers developed their students' ability to resolve cognitive conflicts through peer interaction. The intervention vividly illustrates the intensive and scaffolded opportunities to learn that students can access within a peer learning community where each student engages in thoughtful and respectful interaction with others. Such opportunities are far more limited when students can only rely on the teacher for feedback.</p> <p>The use of mixed-ability groups rather than fixed-ability groups was critical to the effectiveness of this intervention. Students were not publicly labelled as low achievers. Rather, their opportunities for mathematical argumentation were scaffolded and extended, whatever their level of prior knowledge.</p>

Caring and inclusive learning communities

Te ako, he tohu manaaki, he piringa tangata

Pedagogical practices enable classes and other learning groups to work as caring, inclusive, and cohesive learning communities.

E rima te 'arapaki, te aro 'a, te ko 'uko 'u te utuutu, 'iaku nei.

Under the protection of caring hands, there's a feeling of love and affection.

Ava builds a mathematical learning community

Ava began by developing new 'rules for talk'. At the beginning of each maths lesson, she discussed with her students how they were to work together in a mathematical community. During the lesson, she repeatedly reviewed with them how this was going and modelled the changes she wanted to see. For example, she used collective first person pronouns when she was speaking to the students:

Can you show us with your red pen what would happen? We want to know.

Moving beyond cumulative talk

When Ava and the researcher reviewed the video recordings of her class together, she saw that the student talk was mainly cumulative or disputational. 'Disputational' talk involves cyclical assertions and counter-assertions that remain unexamined as participants concentrate on defending their ideas. In 'cumulative' talk, questions and arguments are avoided as students uncritically build on each other's thinking. The students come to a collective view but not one that they have evaluated. Both kinds of talk are unproductive in terms of mathematical reasoning.

Requiring mathematical reasoning

Ava sought to develop her students' ability to engage in talk that probed mathematical ideas. She explicitly required them to listen, discuss, question, and make sense of the reasoning used by others. She also used modelling to scaffold the students into how to construct mathematical explanations that would be well-reasoned, conceptually clear, and logical:

Talk about what you are doing ... so whatever number you have chosen, don't just write them. You say, "I am going to work with ..." or "I have chosen this and this because ...".

Ava regarded building the students' capacities to act as a learning community not as a prelude to the mathematical work but as integral to developing mathematical discourse. For example, after giving the students individual time to think about how to solve a problem, Ava said:

You are going to explain how you are going to work it out in your group. They are going to listen. I want you to think about and explain what steps you are doing, each step you are doing, what maths thinking you are using. The others in the group need to listen carefully and stop you and question [at] any time or at any point where they can't track down what you are saying.

Using think time

Ava used 'think time' as a form of social nurturing for less confident members of the group. This involved halting the discussion to allow them time to reflect and making it clear that their learning mattered.

Promoting constructive argumentation

Ava explicitly directed the students to argue their ideas in a productive manner, as in the following exchange with students:

Ava: Argue your maths. Explore what other people say. Listen carefully, bit by bit, and make sense of each bit. Don't just agree. Check it all out first. Ask a lot of questions. Make sure that you can make sense – that you understand. What's another important thing in working in a group?

Alan: Share your ideas. Don't just say "I can do it myself" ...

Ava: That's right. We need to use each other's thinking ... because we are very supportive and that's the only way everyone will learn.

Ava believed that many of her students would be used to oppositional or aggressive argument and that this would have shaped negative beliefs about arguing:

Ava: I am aware that the students are growing into this behaviour now, but disagreeing can be so hard for these students, so I find I have to keep almost giving them permission to disagree or argue.

This meant that teaching the skills to argue constructively was an ongoing focus:

Ava: 'Arguing' is not a bad word ... sometimes I know that you people think to argue is ... I am talking about arguing in a good way. Please feel free to say if you do not agree with what someone else has said. You can say that as long as you say it in an OK sort of way.

Caring and inclusive learning communities

Te ako, he tohu manaaki, he piringa tangata

Pedagogical practices enable classes and other learning groups to work as caring, inclusive, and cohesive learning communities.

Scaffolding newcomers

Importantly, given the transient nature of the student population, Ava took care to induct newcomers into the norms of behaviour that would enable them to participate in the mathematics discourse community. The transcripts show how the students learned to scaffold and support each other in managing the mathematical argumentation. For example, when Hemi's body language indicated discomfort after Hone had asked "How can you prove it to us?", Pania took up the challenge:¹²

I can show them. This group, that's Hemi and his group, are saying that Jack is arguing that $\frac{5}{8}$ is less than $\frac{3}{4}$. [Pania draws a rectangle and divides it in eighths. She records $\frac{2}{8}$ three times as she shades two sections, and then she records $\frac{6}{8}$. She draws another rectangle and this time shades in $\frac{5}{8}$]. They are saying $\frac{3}{4}$ is an equivalent fraction to $\frac{6}{8}$. Like them, I can prove it is bigger because, look, this is only $\frac{5}{8}$, which is smaller than $\frac{6}{8}$. Is that right, you guys?

Moana builds a mathematical learning community

Moana was a caring and concerned teacher, but when she looked back on the first recordings of her practice, she realised that her students had shown fear in whole-class discussions. By demanding the right answers without providing sufficient scaffolding, she had failed to provide a genuinely caring classroom environment.

When Moana first set about creating a learning community, she presented the students with another teacher's chart of ground rules and instructed them to work collaboratively by following the rules. This did not work. Students constantly interjected and made negative comments to each other, both in the small groups and in the larger sharing sessions.

Scaffolding students in working together

After reflecting on the video recordings, Moana was concerned about the disengagement and silence of the girls, and especially their reluctance to question or argue with the boys. Together with the researcher, Moana planned how to make incremental changes through scaffolding the students' ability to work together. In a three-step process, Moana:

1. stopped using small groups and returned to the previous whole-class discussion format
2. asked the students to work in pairs and scaffolded the way they were to talk to and listen to each other
3. required the paired students to explain each other's reasoning (using materials to demonstrate this) as a report-back process.

Ground rules for talk

At this stage, Moana again reflected on the videos and started to develop her own repertoire of talk to explain to the students what she meant by 'active participation in mathematical discourse'. She developed her own classroom-specific chart of the Ground Rules for Talk: How do we *kōrero* in our classroom? (See Appendix B of this exemplar.) She began each lesson by explicitly explaining how she wanted the students to work.

In one lesson, Moana observed that the students had begun recording a response without discussion. She intervened:

Before you pick up a pen or touch the paper, you need to discuss it first, and I want you to show me how you can work together, listening and building on each other's thinking with those questions.

Considered pairings

Moana noticed that the Māori and Pasifika girls in particular were diffident in pairs with boys. She responded by putting students in single-sex pairs and putting particular girls together (for example, pairs of Pasifika girls) to scaffold a safe environment for talk. She set about creating an environment in which the students encouraged each other to be risk-takers and built up their confidence:

Moana: You don't have to whisper. You can talk because you want to make sure that you are heard.

At the end of the first month, when the pairs were able to construct and examine their explanations more collaboratively, Moana began to vary the number and combinations of students working together.

Feedback on aspects of the classroom community

Moana gave specific feedback on students' participatory behaviours as well as their mathematical thinking, for example:

Donald is really listening... He is not only listening to the person; he is watching when they write things down. His questions are really specific to what the person is doing.

Moana: You are saying, "Yeah" ... What are you saying "Yeah" to?

Beau: She's just been going ... making up suggestions ... dumb ones ... she's just...

	<p><i>Moana: Well, it's not dumb ones. I have been listening, and she's making you think because she is using the problem and making sense of it. She knows that you have to listen to each group member – listen to their thinking and make sense of what they think. [Turns and asks Anaru] So what was your way? Can you explain it, please?</i></p> <p>Moana closely monitored the less able or less confident students in the context of the heterogeneous groups in order to draw attention to how their reasoning had contributed:</p> <p><i>Moana: Wow, Teremoana, see how you have made them think when you said that? Now they are using your thinking.</i></p> <p>As a result, the students' collaborative skills developed markedly. By terms 3 and 4, the following kinds of comments indicated a strongly functioning student learning community:</p> <p><i>Wiremu: Don't dis her, man, when she is taking a risk.</i></p> <p>This 10-year-old boy's comment exemplifies the shared responsibility students were taking for creating a peer culture that supports intellectual risk-taking. He is telling another boy to stop his disrespectful behaviour towards a female peer so she can take a risk in her public participation in a mathematical discourse. This comment illustrates the depth of the change that Moana was forging in the peer culture.</p>
<p>Connection Tūhono</p> <p>Teaching makes educationally powerful connections to students' knowledge, experiences, and identities.</p>	<p>The mathematical inquiry and discourse approach that the teachers developed was designed to ensure that their students were constantly making links to their existing knowledge and experience as they built their understandings. In addition, the teachers selected and designed mathematical problems that connected to the students' interests, for example, by having them divide pieces of chocolate or by linking to games such as space invaders that the students enjoyed in their lives outside school.</p> <p>Moana also explicitly drew upon her cultural knowledge to make connections for both Māori and Pasifika students between their experiences in other settings (such as membership of a kapa haka group or the Cook Islands Māori hair-cutting ceremony) and the new ways of participating in class. She talked about how she wanted them to work together as a whānau (extended family) in which everybody supports each other, with leadership shifting according to who has the greatest expertise in each situation. By allowing time for her students to talk and build upon each other's ideas, she enabled them to tap into and create educationally powerful connections with their cultural knowledge and practices. This 'discursive approach' also supported her in building enhanced relationships with her students that built on these strengths.</p>
<p>Scaffolding Te ako poutama</p> <p>Pedagogy scaffolds, and provides appropriate feed forward and feedback on, learning.</p>	<p>The Mathematics Communication and Participation Framework provided an overview of the actions the teachers could scaffold students into using as they learned to engage in reasoned collective discourse. The framework describes three distinct developmental phases in this learning.</p> <p>The teachers used the framework to scaffold the students' use of mathematical language, thinking, and justification and to foster the behaviours that would help them to interact in a mathematical learning community. The excerpts below further demonstrate the scaffolding teachers provided through their interactions with students and careful design of learning tasks. The excerpts also demonstrate how the students themselves took on the responsibility of scaffolding their own and other group members' learning.</p> <p>In this excerpt, Ava uses revoicing to clarify and define mathematical terms:</p> <p><i>Jo: Isn't that just plussing three sticks not timesing it? You are not timesing, you're adding.</i></p> <p><i>Pania: Well, what she sort of means, it is like it is going up.</i></p> <p><i>Alan: Is that timesing, going up?</i></p> <p><i>Ava: When we talk about timesing, what do we actually mean?</i></p> <p><i>Jo: We mean multiplying not adding. Adding is a plus [indicates + with her fingers], that sign.</i></p> <p><i>Sandra: You mean when you add two more squares on, that is multiplying?</i></p> <p><i>Ava: Rachel was saying she is adding 3, adding another 3, so that's 3 plus 3 plus 3. So if you keep adding 3 all the time, what is another way of doing it?</i></p> <p><i>Alan: You can just times instead of adding. It won't take as long and it is more efficient.</i></p> <p><i>Ava: Yes, you are right. Did you all hear that? Alan said you can just times it, multiply by [groups of] three, because that is the same as adding on 3 each time. What word do we use instead of 'timesing'?</i></p> <p><i>Alan: Multiplication, multiplying.</i></p> <p>In this excerpt, Moana scaffolds the use of mathematical language and explanations, beginning as Aporo uses counters to model how his group solved a problem:</p> <p><i>Aporo: Two, four, six, eight, ten, twelve.</i></p> <p><i>Moana: So that's what's called skip-counting, because you are skipping across the numbers.</i></p> <p><i>Tere: We kept adding like two more. We counted in twos.</i></p> <p><i>Moana: Counting in twos. Yes, that is skip counting.</i></p>

	<p>...</p> <p><i>Moana: What have you actually done there, Mahine?</i></p> <p><i>Mahine: I have plussed 10 onto 47.</i></p> <p><i>Moana: So you have added 10 onto 47? Are there any questions? Questions like “Where did you get the 10 from?”</i></p> <p>When she saw that her students were not taking up opportunities to ask questions and dispute, Moana introduced a non-verbal scaffold – koosh balls.¹³ The koosh balls were placed in the middle of the discussion circle. The students picked them up to indicate that they had a question or challenge. The researcher explained that although picking up the ball indicated to the explainer that there was a challenge, their self-esteem was protected because the non-verbal signal gave time to think and then respond.</p> <p>Teachers creating new knowledge about scaffolding</p> <p>As the teachers engaged in the collaborative professional learning process, they expanded on the Mathematics Communication and Participation Framework and created a wide range of further scaffolds to support the students’ learning (see Appendix C of this exemplar). For example:</p> <ul style="list-style-type: none"> • Practise talking about the bits you agree with and be ready to say why. • Discuss the explanation and explore the bits which are more difficult to understand. • Take turns explaining the solution strategy¹⁴ using a representation.
<p>Responsive-ness</p> <p>Tauaronui</p> <p>Quality teaching is responsive to all students’ learning, identities, and well-being.</p>	<p>Creating a discourse community enabled both teachers to become more diagnostic about and responsive to the students’ learning processes. Hattie¹⁵ calls for teachers to make the learning process as visible as possible so that they can notice and react to feedback from students about what is needed. Both these teachers used non-verbal signals from students to inform next steps. When students had difficulties, their teachers provided time for reflection. Ava called this ‘think time’ and Moana called it ‘rethink time’. As it became safer for the students to actively participate and take risks, the teachers were increasingly able to use the students’ thinking as a resource for improving teaching and learning.</p> <p>Responsiveness in Ava’s class</p> <p>The researcher’s data analysis showed that when Ava gave students opportunities for think time during group work, along with an expectation of accountability (“You have a think about it while I pop over to this group so we can hear their thinking, then we will come back to you”), her students became more willing to express partial understandings or difficulties they had in understanding sections of an argument. This pause in mathematical dialogue was designed to support all students’ active cognitive engagement.</p> <p>Misconceptions as a resource</p> <p>Initially, Ava sidelined erroneous thinking when it was made explicit in students’ explanations. To get students and teachers more used to examining and analysing erroneous reasoning, the wider study group of teachers developed a set of problems devised to include solution strategies based on misconceptions commonly held by students of their age. (See Appendix D of this exemplar.)</p> <p>Responsiveness in Moana’s class</p> <p>Moana’s responsiveness to student learning processes was transformed as her understanding of the nature of mathematical learning shifted:</p> <p><i>[It’s] good to see different thinking coming through, blows me away because before they never had a chance to explore ... I just thought that they understood by me talking all the time.</i></p> <p>Her ability to notice, recognise, and respond to students’ learning processes was supported by her careful listening to their discourse.</p> <p>Moana used the concept of rethink time to help the students when they were confused:</p> <p><i>I can see you are confused. Me, too, [but] that’s all right. We can take some time ... rethink about it.</i></p>

Thoughtful learning strategies

Takina te wānanga

Pedagogy promotes learning orientation, student self-regulation, metacognitive strategies, and thoughtful student discourse.

The whole approach to building the students' engagement in a mathematical discourse community required the teacher (and eventually the students) to press for thoughtfulness. While students were talking, the expectations for others in the group were clear. Each individual was required to:

- actively ask questions;
- follow the line of reasoning;
- take responsibility for the regulation of their own (and others') learning;
- be accountable for their own understanding.

The Mathematics Communication and Participation Framework supported the teachers to scaffold student learning strategies in ways that progressively extended the students' thinking and their repertoire of productive ways of engaging in mathematics. Both teachers repeatedly identified and overcame barriers to the students' use of effective learning strategies. The examples below highlight ways in which these two teachers built their students' ability to engage in thoughtful discourse communities.

Ava scaffolds mathematical thinking

Ava used the Mathematics Communication and Participation Framework to scaffold increasingly complex mathematical thinking. Her students moved from reporting solutions to developing an inquiry or argument culture. The teacher initiated change through modelling the processes of mathematical inquiry while building a safe learning environment. Both Ava's and her students' use of questions and prompts pushed the students to higher and more complex levels of reasoning.

Intellectual risk-taking

Intellectual risk-taking supports intellectual growth. Both teachers explicitly encouraged and supported their students to take intellectual risks, as in this exchange, which took place before Ava's students began a mathematical activity:

Ava: Remember how yesterday we talked about how, in maths learning, you go almost to the edge? So therefore I am going to move you out of your comfort zone. It's lovely being in a comfortable, cosy place. Even as an adult, we love to be there, too. But if you are already there, then it's time to move on, out a little bit ... so you go out there ... maybe a bit more ... a bit further next time and come back in again ...

Sandra: And when you are out there, you will make that your comfort zone. Then move on and make that your comfort zone.

Time and space to question and clarify mathematical explanations

Rather than jumping in when she saw that the students were struggling, Ava scaffolded the students' ability to thoughtfully evaluate their solution strategies. When one small group had not identified the problems in their reasoning, Ava gave them a new opportunity to question and clarify as they explained their solution strategy to the class:

Ava: I know for some of you it pushed you out to the edge. I can see some semi (and that means 'partly') confused looks and that's okay ... you will need to question anything you don't understand. We are going to listen, step by step, and when you finish one step, put the lid on the pen and see if anyone has got any questions ... Remember you need to talk about what your group did.

Sandra: [Records 52 on a sheet] The rule was timesing it by two and it goes up.

Ava: Right, can you stop there and wait for questions.

Pania: How did you get that?

Ava: [Prompts] How did you get what?

Pania: How did you work out it was 52 sticks?

Sandra: We went 25 and 25 equals 50. Number 12 and 12 equals 24 plus 2 would equal 25.

Ava: You people need to be really listening to what is being said here. You have got to ask yourself does it make sense to you.

Pania: I don't think it will make sense because 24 plus 2 would equal 26.

Ava: Well, tell you what. You have done really well. There are some adults who would not even know how to work through that sort of problem, so well done.

In this example, the small group extensively explored a problem and constructed multiple representations of their thinking. There was time for challenge and clarification, and there were clear expectations that 'making sense' was the goal.

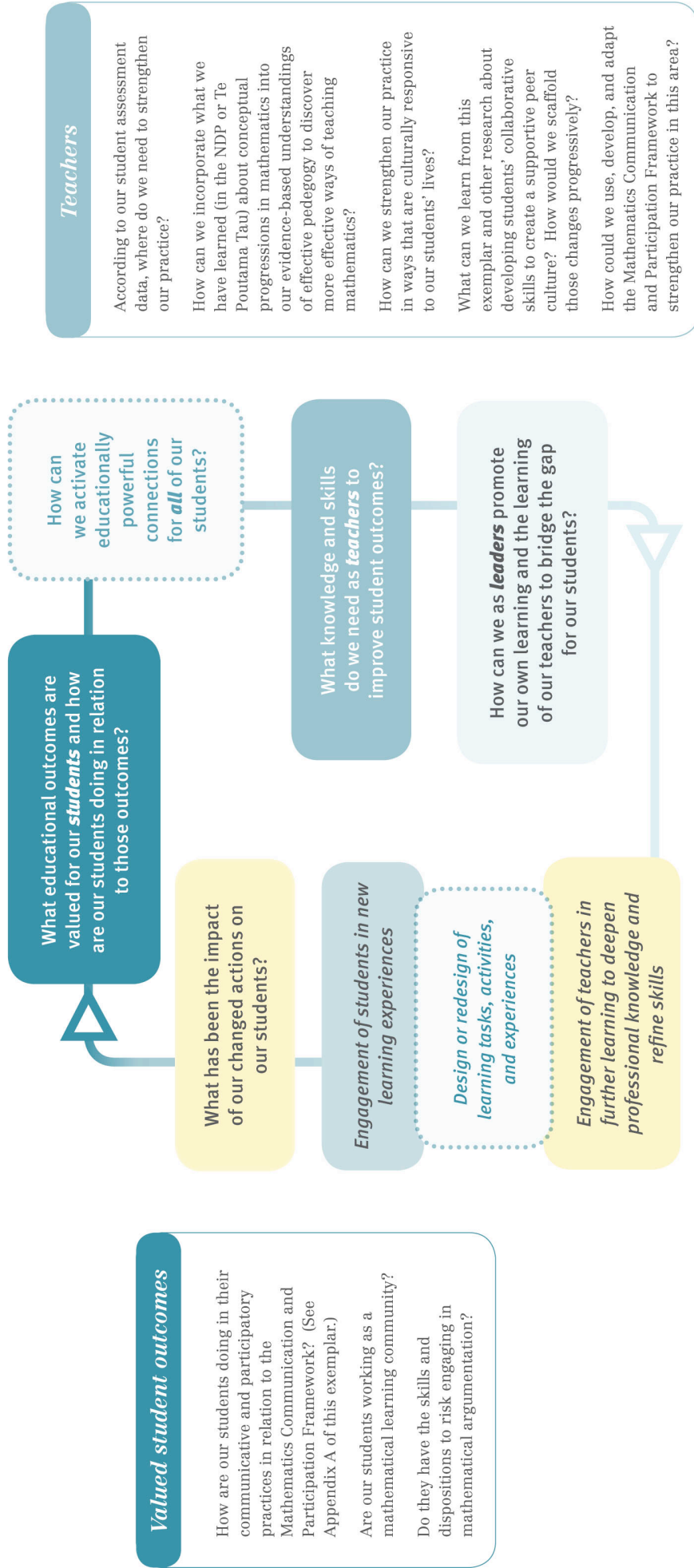
	<p>Moana scaffolds mathematical thinking</p> <p>Mathematical argumentation is an essential strategy for learning mathematics. Like Ava, Moana realised that her students initially struggled with the idea that they should engage in mathematical argumentation and that this was a barrier to their thinking. She set about using incremental steps to shift their attitudes to argumentation and their ability to argue, including teaching them ‘polite’ ways to disagree and challenge.</p> <p>Positioning students as accountable for their opinions</p> <p>Moana made the students aware that she held them accountable for their own understanding. She regularly halted explanations and required students to take a stance. For example, she told them:</p> <p><i>At some point, you are going to have an opinion about it. You are going to agree with it or disagree with it.</i></p> <p>She ensured that they knew they needed a valid reason to support their stance, directing the students to think about what they were saying:</p> <p><i>Make sense of it. If you don’t agree, say so but say why. If there is anything you don’t agree with, or you would like them to explain further, or you would like to question, say so. But don’t forget that you have to have reasons. Remember it is up to you to understand.</i></p> <p>Validating autonomous mathematical reasoning</p> <p>Aroha explains a solution strategy for adding 43, 23, 13, and 3. She records 43, 23, 13, 3, and then $3 \times 4 = 12$:</p> <p><i>Aroha: I am adding 43, 23, 13, and 3, so 3 times 4 equals 12.</i></p> <p><i>Kea: Why are you trying to do that with those numbers? Where did you get the 4?</i></p> <p><i>Aroha: [Points at the 3 digit on each of the four numbers] These 3s, the four 3s.</i></p> <p><i>Donald: All she is doing is, like, making it shorter by, like, doing 4 times 3.</i></p> <p><i>Hone: Because there are only the 10s left.</i></p> <p><i>Donald: Three times 4 equals 12, and she got that off all the 3s; like the 43, 23, 13, and 3. So she is just like adding the 3s all up and that equals 12.</i></p>
<p>Assessment for learning</p> <p>He aromatawai i roto i te ako</p> <p>Teachers and students engage constructively in goal-oriented assessment.</p>	<p>During each lesson, the teachers’ moment-by-moment assessment enabled them to decide what questions to ask, when to intervene, and how to respond to student questions. The teachers used the information gained by observing and listening to the students to focus student attention on key examples and explanations during class discussions.</p> <p>Both teachers sought to develop their classes as mathematical learning communities in which students were accountable, both individually and in their groups, for checking that their explanations and justifications were well-reasoned. The teachers scaffolded the students’ self-regulation by moving from first having them check their understanding of bits of problems to checking whole problems and from checking whether they had the most efficient solution for one problem to (eventually) checking solutions across a set of problems. They received, and progressively internalised, multiple messages from the teacher that they needed to be able to inquire into, explain, and justify their own and others’ solutions to mathematical problems. The students became increasingly autonomous learners, able to analyse and validate their own reasoning rather than placing this responsibility on the teacher. In addition, the development of strong learning community norms meant that the students progressively took responsibility not only for their own learning but also for the learning orientation of their peers. For example, when eight-year-old Pita in Moana’s class saw another student scribbling on a recording sheet during their group work, he said: “Don’t, man. You listen or ask or you aren’t even learning, man.”</p>
<p>Alignment</p> <p>Tātarite</p> <p>Curriculum goals, resources, task design, teaching, school practices, and home support are effectively aligned.</p>	<p>The support they gained through participating in the teacher study group working with the researcher was critical to the teachers’ success. This is consistent with the finding in the <i>Teacher professional learning and development BES</i> that teachers need opportunities to process their new learning with others if significant change is to occur. Moana began making changes after she saw the impact of such changes in her colleagues’ classrooms.</p> <p>The researcher also worked with the whole staff in setting up the project and had the strong support of the school principal, the board of trustees, and senior leadership. The school had an open-door policy towards including the wider community in the life of the school, including this project. The teachers communicated with the parents through their newsletters and homework sheets, explaining the types of problems the students were working with and the questions they were being encouraged to use. The teachers drew on their own knowledge of their students’ backgrounds to structure and discuss the classroom social norms in ways that were socially and culturally responsive.</p>

Resources

Full text copies of cited articles can be requested by New Zealand schools through the Ministry of Education's Research Behind BES service: www.educationcounts.gov.nz/goto/BES

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Professional learning: BES Exemplar 1 starter questions



Leaders

Given the critical importance of providing quality professional learning support and effective leadership to teachers:

- What expertise is available within the school (for example, the numeracy lead teacher)?
- What external expertise can our leadership team access to go to the next level?
- How can our leadership team build upon this expertise to support effective professional learning?

• What role will the principal play in ensuring the success of the professional development?

What use are we making of the tools that are already available to help school leaders build their own knowledge and support further professional learning for teachers (for example, the *Effective pedagogy in mathematics/pāngarau BES*, the NDP resources)?

How can we take advantage of the new knowledge arising out of the research and development described in this exemplar?

Is there consistency in the kinds of talk promoted by our teachers across the school?

How can we ensure that there is coherence in the ways in which students are encouraged to participate as members of mathematical learning communities as they move between teachers?

Appendix A. The Mathematics Communication and Participation Framework¹⁶

An outline of the communicative and participatory actions teachers facilitate students to engage in as they (the teachers) scaffold the use of reasoned, collective, mathematical discourse.

		Phase One	Phase Two	Phase Three
Communicative actions	Making conceptual explanations	Use problem context to make explanation experientially real.	Provide alternative ways to explain solution strategies.	Revise, extend, or elaborate on sections of explanations.
	Making explanatory justification	Indicate agreement or disagreement with an explanation.	Provide mathematical reasons for agreeing or disagreeing with solution strategy. Justify using other explanations.	Validate reasoning using own means. Resolve disagreement by discussing viability of different solution strategies.
	Making generalisations	Look for patterns and connections. Compare and contrast own reasoning with that used by others.	Make comparisons and explain the differences and similarities between solution strategies. Explain number properties, relationships.	Analyse and make comparisons between explanations that are different, efficient, sophisticated. Provide further examples of number patterns, number relations, and number properties.
	Using representations and inscriptions	Discuss and use a range of representations or inscriptions to support an explanation.	Describe inscriptions used to explain and justify conceptually as actions on quantities, not manipulation of symbols.	Interpret inscriptions used by others and contrast with own. Translate across representations to clarify and justify reasoning.
	Using mathematical language and definitions	Use mathematical words to describe actions.	Use correct mathematical terms. Ask questions to clarify terms and actions.	Use mathematical words to describe actions (strategies). Reword or re-explain mathematical terms and solution strategies. Use other examples to illustrate.
	Participatory actions	Active listening and questioning for more information. Collaborative support and responsibility for reasoning of all group members. Discuss, interpret, and reinterpret problems. Agree on the construction of one solution strategy that all members can explain. Indicate need to question during large-group sharing. Use questions that clarify specific sections of explanations or gain more information about an explanation.	Prepare a group explanation and justification collaboratively. Prepare ways to re-explain or justify the selected group explanation. Provide support for group members when explaining and justifying to the large group or when responding to questions and challenges. Use wait time as a think time before answering or asking questions. Indicate need to question and challenge. Use questions that challenge an explanation mathematically and draw justification. Ask clarifying questions if representation and inscriptions or mathematical terms are not clear.	Indicate need to question during and after explanations. Ask a range of questions including those that draw justification and generalised models of problem situations, number patterns, and properties. Work together collaboratively in small groups, examining and exploring all group members' reasoning. Compare and contrast and select most proficient (that all members can understand, explain, and justify).

Appendix B. Moana's chart for the ground rules for talk

How do we kōrero in our classroom?

We make sure that we discuss things together as a whānau. We listen carefully and actively to each other.

That means:

- We ask everyone to take a turn at explaining their thinking first.
- We think about what other questions we need to ask to understand what they are explaining
- We ask questions politely as someone is explaining their thinking; we wait until they have completed their explanation.
- We ask for reasons why. We use 'what' and 'why' questions.
- We make sure that we are prepared to change our minds.
- We think carefully about what they have explained before we speak or question.
- We work as a whānau to reach agreement. We respect other people's ideas. We don't just use our own.
- We make sure that everyone in the group is asked and supported to talk.
- We all take responsibility for the explanation.
- We expect challenges and enjoy explaining mathematically why we might agree or disagree.
- We think about all the different ways before a decision is made about the group's strategy solution. We make sure that as we 'maths argue', we use "I think ... because ... but why ..." or we use "If you say that, then ...".

Appendix C. Tumeke School's expansions of sections of the Mathematics Communication and Participation Framework

This chart illustrates the way Moana further elaborated sections of the Mathematics Communication and Participation Framework. She did this in two steps. She constructed the first step after she began exploring the framework, and she put the second step in place when she observed that her students were managing the first set of expectations and would not lose confidence when expected to engage at a higher level in the mathematical practices.

	Step 1	Step 1
Making conceptual explanations Use problem context to make your explanation experientially real.	<p>Think of a strategy solution and then explain it to the group.</p> <p>Listen carefully and make sense of each explanation step by step.</p> <p>Make a step-by-step explanation together.</p> <p>Make sure that everyone understands. Keep checking that they do.</p> <p>Take turns explaining the solution strategy using a representation.</p> <p>Use equipment, the story in the problem, a drawing or diagram, or/and numbers to explain another way or backing for the explanation.</p>	<p>Keep asking questions until every section of the explanation is understood.</p> <p>Be ready to state a lack of understanding and ask for the explanation to be explained in another way.</p> <p>Ask questions (What did you...?) of sections of the explanation.</p> <p>Discuss the explanation and explore the bits that are more difficult to understand.</p> <p>Discuss the questions the listeners might ask about the explanation.</p>
Making explanatory justification Indicate agreement or disagreement with an explanation and have a mathematical reason for the stance.	<p>Listen to each person in your group and state agreement with their explanation OR state disagreement with their explanation.</p> <p>Practise talking about the bits you agree with and be ready to say why.</p> <p>Ask questions of each other about why you agree or disagree with the explanation.</p> <p>Pick one section of an explanation and provide a mathematical reason for agreeing with it.</p> <p>Discuss the explanation or a section of the explanation and talk about the bits that the listeners might not agree with and why.</p>	<p>Provide a mathematical reason for disagreeing with the explanation or a section of the explanation.</p> <p>Think about using material or drawing pictures about the bit of the explanation that there have been a lot of questions about in the group.</p> <p>Ask questions of each other (Why did you...? How can you say...?)</p> <p>Question until you understand and are convinced.</p> <p>Explain and use different ways to explain until you are ALL convinced.</p>

Appendix D. Problem example using student misconceptions developed by the Tumeke School study group

Peter and Jack had a disagreement. Peter said that $\frac{5}{8}$ of a jelly snake was bigger than $\frac{3}{4}$ of a jelly snake because the numbers are bigger.

Jack said that it was the other way around, that $\frac{3}{4}$ of a jelly snake was bigger than $\frac{5}{8}$ of a jelly snake because you are talking about fractions of one jelly snake.

Who is right? When your group has decided who is correct and why, you need to work out lots of different ways to explain your answer. Remember you have to convince either Peter or Jack, and they both take a lot of convincing! Use pictures as well as numbers in your explanation.

Appendix E. BES Exemplar 1 implementation alerts

Not recommended	What the research shows about more effective implementation
Taking a ‘top down’ approach	Establish an open, safe, and supportive learning community within the teacher group to support professional discussion, resource sharing, video viewing and critiquing, and reading and discussing research articles.
Bypassing the professional learning gains made through involvement in the Numeracy Development Project (NDP) or Te Poutama Tau	Start from where the teachers are by making explicit connections to the teachers’ prior professional learning. For example, many New Zealand teachers have participated in the NDP and integrated aspects of this into their practice. Build from their experiences and their knowledge of the NDP strategies and framework within a collaborative partnership that aims to extend their classroom practices and put in place the next steps towards building an inquiry community.
Bypassing teacher’s current knowledge and expertise	Help the teachers to use their own social and cultural knowledge and their knowledge of their students to support students to engage in new mathematical practices. For example, model to teachers how they can use that knowledge to structure collaborative groups and then to support their students to explain, justify, and question.
<p>‘Protecting’ teachers from research evidence</p> <p>Being unprepared and unfocused</p> <p>Expecting teachers to read large amounts of research that is not directly relevant to their practice</p>	<p>Provide the teachers with research articles and/or videotaped examples of practice, using your judgment to select when each item will be of most benefit. The articles and videotapes should provide models of how other teachers have scaffolded their students to participate in and contribute to communities of mathematical inquiry, responded to student reasoning, and prepared and planned for learning in inquiry communities. They may also be used as a way to promote dissonance in teachers’ thinking about their current practices and challenge them to consider alternative practices, using the research to support their decisions. (For example, they could be used to prompt teachers to consider using complex instruction or to stop using strategy grouping.)</p> <p>Provide the teachers with time and space to read the articles independently. As a group, read and discuss strategically selected sections of the research (most teachers enjoy analysis of teacher–student actions and dialogue) and view and discuss video examples.</p>
<p>Expecting immediate outcomes</p> <p>Failing to provide time or space for change</p> <p>Taking a ‘one size fits all’ approach</p>	Begin slowly and provide teachers with time, space, and multiple ways to enact change in their classrooms. Encourage teachers to use the Communication and Participation Framework (Exemplar 1, Appendix A) and other relevant resources to map out their own pathway that fits within the contexts of their own classrooms. Ensure that the teachers are aware that the change is an ongoing long-term process and that, like them, their students will need time to process the shift in classroom interaction norms. It is to be expected that students will resist the change in social norms and will need carefully structured guidance to gradually develop mathematical practices, inquiry, and mathematical argumentation.
Placing the initial focus on student outcomes in terms of NumPA, GloSS, or other normative test results to the exclusion of other valued outcomes	Place the initial focus on growing students’ ability to communicate and participate in the mathematical discourse. The valued student outcomes should include students growing their ability to use different mathematical practices (including explaining, representing, justifying, and generalising) and to ask the questions that support mathematical sense-making. Make sure that the teachers understand that the way students appropriate and use these practices impacts on both their dispositions as users of mathematics and their ability to make sense of the mathematics. It is this that leads to improved achievement outcomes.
Using NDP or other mathematical materials as if they provided a strict recipe for implementation	<p>Support the teachers to collaboratively construct and use group tasks based around problems that are appropriate for this group of students in this context. Successful ‘group-worthy’ tasks:</p> <ul style="list-style-type: none"> • require the perspectives of different students; • can be solved using different methods; • emphasise important mathematical concepts and principles; and • are sufficiently challenging and open to allow different students to contribute their ideas. <p>Use the NDP material (particularly the number properties section) as a resource for writing problems that support the emergence of a range of strategy solutions.</p>
Not explicitly addressing some important elements of a community of mathematical inquiry	Discuss and explore the Communication and Participation Framework as a way to develop teacher understanding of key mathematical practices (for example, explanations, justification, representations, and generalisations). Include as part of this focus the use of culturally appropriate talk-formats and ground rules that are adapted to the immediate classroom community.

Deficit theorising by blaming the students, their ethnic origins, or their home or community environment for low achievement	Directly address, learn about, and affirm the linguistic, cultural, and pedagogical differences between different communities (including different Māori and Pasifika communities) and between those communities and the school and teachers. Help teachers to become aware when deficit theorising is applied and address it in ways that emphasise student achievement and potential.
Using streamed groups	Encourage teachers to use a flexible grouping model and cater to individual differences within this model. This should include the construction of small, heterogeneous, collaborative groups that work together to solve open-ended group-worthy tasks. Consequently, there should be a multiple ways in which students can contribute and in which their contributions can be valued.
Carrying out video recordings of classroom practice without first negotiating their use, ethics, or ground rules	<p>Communicate early and clearly about the purpose of the videos so that the school leaders, teachers, parents, and students understand their purpose – for schooling improvement – and agree to their use for that purpose.</p> <p>Establish a rule that anyone can ask for a video recording to stop if recording is inappropriate.</p> <p>Ensure the use of the videos is structured and professional and serves the professional learning focus.</p>
Accepting teacher resistance to being video and audio recorded	<p>Video and audio records are valuable tools to support change and growth but they need to be used judiciously. Teachers need time to view and analyse their own records and to select sections they want to share with a wider audience. Listed below are some approaches for enabling the objective use of video records to enable teacher professional learning:</p> <ul style="list-style-type: none"> • A group of teachers could view a videotaped sharing-back session. The group could record all questions asked by both teacher and students during the session and discuss why the questions were asked and what resulted mathematically from each of the questions. This approach helps teachers learn about the kinds of questions that support different mathematical practices and how they can scaffold their students to ask those questions. • Teachers could view a small group at work in their own or a colleagues' class, focusing their attention on the support provided by the teacher. This can alert teachers to the need to scaffold some students to access the reasoning through a better understanding of the mathematical content discussions and/or the social discourse process (that is, when and how to explain, question, agree, disagree, or challenge). It can help teachers understand how the talk-format is being used and the questions the students are asking. It can also prompt teacher awareness of the need to use a form of complex instruction that affirms effort over ability and explicitly assigns competence through raising student status (through public recognition of the intellectual value of their reasoning) and values multiple ways of contributing. • Use video clips to provide teachers with examples of the use of interactional strategies such as re-voicing, repeating, rephrasing, and requiring students to explain in different ways, to take a position on the mathematical thinking under discussion, and to discuss what their next steps might be. • Use video clips to provide teachers with examples of ways they can make 'on-the-spot' assessments of students' current reasoning and of ways the reasoning can be extended.
Not having proactive support and involvement of the principal and management staff	Involve the principal, members of the senior management team, and other staff members through staff meetings and other forms of professional meetings. Actively involve senior management members in all aspects of the project and make copies of the research readings available for all staff members regardless of their involvement. This encourages ongoing conversations in the staff room and across the staff.

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- 1 Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.
 - 2 'Mathematical argumentation' refers to the process of resolving mathematical disagreement by examining the premises of the different positions to establish which outcome is correct. There are constructive ways of doing this, and students need teacher guidance and modelling.
 - 3 Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.
 - 4 In the educational context, a smart tool is one that supports professional learning about how to advance student learning. Selecting, developing, and using smart tools was found to be a leadership practice that advanced valued student outcomes in the *School leadership/He kura rangatira BES*. Leaders select and design smart tools by ensuring they are based on valid theories and that they are well designed to serve their purpose. Tools are only designated 'smart' if the evidence indicates that they actually do advance valued outcomes for students.
 - 5 The exemplar explains how the teachers used the Mathematics Communication and Participation Framework to scaffold the development of mathematical communities of inquiry amongst the students.
 - 6 Mullis, I., Martin, M. O., & Foy, P. (2007). Findings from IEA's trends in mathematics and science study at the fourth and eighth grades. In collaboration with J. F. Olson, C. Preschoff, E. Erberber, A. Arora, & J. Galia (Eds.), *Index of students' perception of being safe in school (SPBSS) and trends*, (p. 367). United States: TIMSS & PIRLS International Study Center.
 - 7 This is not the school's actual name.
 - 8 The effect sizes are also in accord (in terms of order of magnitude) with the values of Cramer's V, a measure of the strength of association of the Chi-Square tests (given categorical data). For Ava's class, $V = 0.841$ (out of a possible 1) was calculated for the achievement gain. The achievement gain for Moana's class was $V = 0.907$.
 - 9 This section draws on *The New Zealand curriculum* and the parallel document, *Te marautanga o Aotearoa*. It includes quotes and paraphrases from pages 9, 14, 16, and 18 of *The New Zealand curriculum* and page 40 of *Te marautanga o Aotearoa*. Ministry of Education (2007). *The New Zealand curriculum*. Wellington: Learning Media.
Ministry of Education (2008). *Te marautanga o Aotearoa*. Wellington: Learning Media.
 - 10 An 'inscription' is a tool or artefact that symbolises an idea and helps organise mathematical thinking. Examples include graphs, diagrams, and the number system itself. See pages 127–135 of the *Effective pedagogy in mathematics/pāngarau BES* for further explanation.
 - 11 Alton-Lee, A. (2003). *Quality teaching for diverse students in schooling: Best evidence synthesis iteration*. Wellington, New Zealand: Ministry of Education. (See pp. 16–17). Available from www.educationcounts.govt.nz/goto/BES
 - 12 The students were attempting to solve the problem presented in BES Exemplar 1, Appendix D.
 - 13 Soft balls that did not roll but fitted into the students' hands.
 - 14 A 'solution strategy' is a strategy to solve a specific problem.
 - 15 Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.
 - 16 Hunter, R. (2007). The Mathematics Communication and Participation Framework: An outline of the communicative and participatory actions teachers facilitate students to engage in to scaffold the use of reasoned collective discourse. This framework was informed by the work of: Wood, T., & McNeal, B. (2003). Complexity in teaching and children's mathematical thinking. In N. L. Pateman, B. J. Dougherty, & J. Zilliox (Eds.). *Proceedings of the 27th Annual Conference of the International Group for the Psychology of Mathematics Education, Vol. 4*, pp. 435–443. Honolulu, HI: ME.