THEMATIC CASE STUDY

Numeracy

What works and why: emerging evidence from INOVASI on effective practice in early grades numeracy

June 2020

INOVASI
Innovation for Indonesia's School Children
Australia Indonesia Partnership

KEMENTERIAN PENDIDIKAN DAN KEBUDAYAAN

Australian Government

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Suggested citation: van der Heijden, Mary. 2020. What works and why: emerging evidence from INOVASI on effective practice in early grades numeracy. Jakarta: INOVASI. https://www.inovasi.or.id/en/publication/numeracy-what-works-and-why-emerging-evidence-from-inovasi-on-effective-practice-in-early-grades

Acknowledgement: The author would like to acknowledge and thank the INOVASI MERL team for the analysis of the program's survey data relating to numeracy – particularly Rasita Purba, George Sukoco, Robertus Sodo and Senza Arsendy; the Education Program Development (EPD) team: Lynne Hill, as the lead education advisor in INOVASI for key advice and support throughout the study development; Afifudin and Muhtar Ahmad, for their central and key role in implementing the video study of teaching and interviews, and in the analysis of the teaching episodes together with Feiny Sentosa, Rasita Purba, Dyah Puspitasari and Zainul Fadilah; Stephanie Carter and Annisa Rachmawati for organising the videoing and development of the transcripts; INOVASI program managers for supporting the study in many different ways, and colleagues involved in the development of the other thematic studies for their contributions to the study methodologies. Mostly importantly the study acknowledges and thanks the three teachers and their schools who generously allowed the recording of their teaching and their reflections of it, and the further analysis of it for the case studies section of the study, so that others could benefit from the exploration of their practice.

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The governments of Australia and Indonesia are partnering through the Innovation for Indonesia's School Children (INOVASI) program. INOVASI seeks to understand how to improve student learning outcomes in literacy and numeracy in diverse schools and districts across Indonesia. The first phase of the program (AUD49 million) began in January 2016 and will continue until June 2020. Working with Indonesia's Ministry of Education and Culture, INOVASI has formed partnerships with 17 districts in four provinces namely West Nusa Tenggara, East Nusa Tenggara, North Kalimantan, and East Java.

INOVASI is an Australia-Indonesia Government partnership, managed by Palladium

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List of Acronyms, Abbreviations and Bahasa Indonesia Terms

AKM	students' minimal competence assessment
AKSI	Indonesian students' performance assessment
EGRA	early grade reading assessment (from Papua New Guinea)
EPD	education program development
EQUIP-T	Education Quality Improvement Programme in Tanzania's
HOTS	higher-order thinking skills
INAP	Indonesia National Assessment Program
MERL	monitoring evaluation, research and learning
MoEC	Ministry of Education and Culture
MoRA	Ministry of Religious Affairs
OECD	Organisation for Economic Co-operation and Development
PDIA	problem-driven iterative adaptation approach
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
SIPPI	Indonesian education and learning innovation survey (*Survei Inovasi Pendidikan dan Pembelajaran Indonesia*)
SLA	students' learning assessment
TIMMS	Trends in International Mathematics and Science Study

Executive summary

This study was designed and conducted by INOVASI to explore the impact of two main pilot teacher training programs on the teaching and learning of early grade numeracy concepts. These 'short courses' were implemented in partner districts in Indonesia. The process was underpinned by the program's theory of change based on a problem-driven iterative adaptation approach (PDIA). The study discusses what works in INOVASI's partner districts and potentially in other Indonesian contexts to develop the numeracy knowledge, skills and behaviours, including fluency and flexibility with numbers, that students and teachers need.

Over the last ten years, the results for 15-year old Indonesian students participating in the Programme for International Student Assessment (PISA) show little improvement and about 40 per cent of the students scored below the lowest level in the international standard. In 2018, the results in mathematics show Indonesia ranking 70th out of 77 other countries, with a persistently and particularly low achievement level in thinking ability, mathematical inquiry and reasoning. This means that if students do not develop these basic competencies in numeracy then the prospect of a highly skilled and relevant workforce remains slim.

Although factors such as curricula, leadership, funding, family interest and involvement all contribute to student achievement, the most influential factor is the teacher. INOVASI's two numeracy pilot studies in Indonesia consisted of two main teacher training programmes involving over four hundred teachers and over 10,000 students in grades one to three.

Training

The training programs that INOVASI designed and conducted had to be practical, engaging and reflective in order to develop teachers' own understanding of the curriculum content and how young children learn basic concepts. The 'short courses' took place in district cluster teachers' working group (KKG) meetings and were presented by locally-trained facilitators who also supported teachers through mentoring sessions in the classroom.

Methodology

The study collected both quantitative and qualitative data to establish what works in INOVASI's partner districts and to investigate to what extent training teachers in specific areas will result in improved student learning outcomes. The emphasis was on teaching methods, providing and using appropriate materials and improving students' higher-order thinking skills in applying their newly developed knowledge and skills.

The mixed method approach discussed in the study includes: teacher observations; student and teacher assessments; teacher interviews; and in-depth video observations.

Findings

Our overall findings suggest that teachers improved their own understanding of the mathematical content and the pedagogy needed to support children's understanding of basic numeracy concepts. The quality of teachers' knowledge and skills in teaching numeracy progressed significantly. This in turn led to gains in students' ability in both conceptual knowledge and understanding in number and in their ability to demonstrate their reasoning and apply their knowledge. Teachers used relevant concrete and visual materials effectively to scaffold students understanding towards more abstract concepts. They also asked students more open-ended questions, although students needed more exposure and experience in explaining the processes and thinking about how they arrived at a solution.

Teachers also organised the classes so that students were in groups and, in the video studies, teachers had used pre-assessment data to organise the groups.

Students overall progressed in understanding and applying numbers. The use of materials to aid learning was evident in the videod lessons and teachers reported that the students were more engaged as a result. Both students and teachers needed more support in understanding how the use of materials helped them to learn specific concepts and be able to explain them. However based on the endline assessments, students progressed in reasoning and application. While the baseline showed that boys were often behind girls in mathematics, after the training pilots the boys progressed as much as and in some cases more than the girls.

Recommendations

This study provides evidence from INOVASI's first phase that suggests more time and emphasis should be given in the curriculum for teachers to focus on early conceptual knowledge, skills and understanding. This will ensure a solid basis for more abstract learning later on.

Teachers have not been exposed to the methods that are essential in developing a deeper understanding of number and the students have not had adequate time to practise and explore number concepts. The training in the teachers' working group meetings means that teachers can continue to learn with and from others and will be able to build on their teaching practices. Differentiated training for teachers and principals would also create awareness and support for new aproaches.

Teaching and learning materials that fit the context, and are manageable and appropriate for the varying levels need to be provided and should be aligned with the students' learning needs.

Teachers also need to conduct varied and regular assessments so they can use the outcomes effectively to organise the class. These assessments will give them insights into any difficulties or misconceptions the students may have so they can better meet individual, group and whole-class learning needs.

1 Introduction

INOVASI is a joint education program in partnership with the Indonesian Ministry of Education and Culture (MoEC) funded by the Australian government. This report presents the actions and findings of the teacher training pilots for early grade numeracy in Indonesian provinces over the period 2018–2020.

1.1 Purpose of the study

This study is a compilation of what we learned about improving numeracy outcomes in the course of INOVASI phase one. It provides emerging evidence of what works to improve numeracy skills in Indonesian contexts. 'Emerging evidence' means the evidence-base of promising local solutions in classrooms, schools, clusters and districts that may support further development of policies and programs in districts and at national level.

At this stage of the INOVASI program, emerging evidence also means evidence that is credible – in other words plausible, persuasive and convincing to policymakers. It derives from baseline–endline comparisons of quantitative data on students' achievement levels and teachers' knowledge. It also comes from classroom observations and qualitative case study data of classrooms, schools and district management of teaching and learning in numeracy. It is evidence that is still to be tested with robust methodologies in the next phase to reach the standards of certainty of randomised control trials or experimental studies.

The outcomes of the studies provide policy recommendations for Indonesian national and sub-national governments and the Australian government. This meets INOVASI's third program outcome: *National and sub-national stakeholders have access to emerging evidence of what does and does not work to improve student learning outcomes.*

1.2 Study focus

This study, designed and conducted by INOVASI, evaluates the impact of two pilots, Numeracy 1 and Numeracy 2, to answer the overarching evaluation question: What works in INOVASI's partner districts?

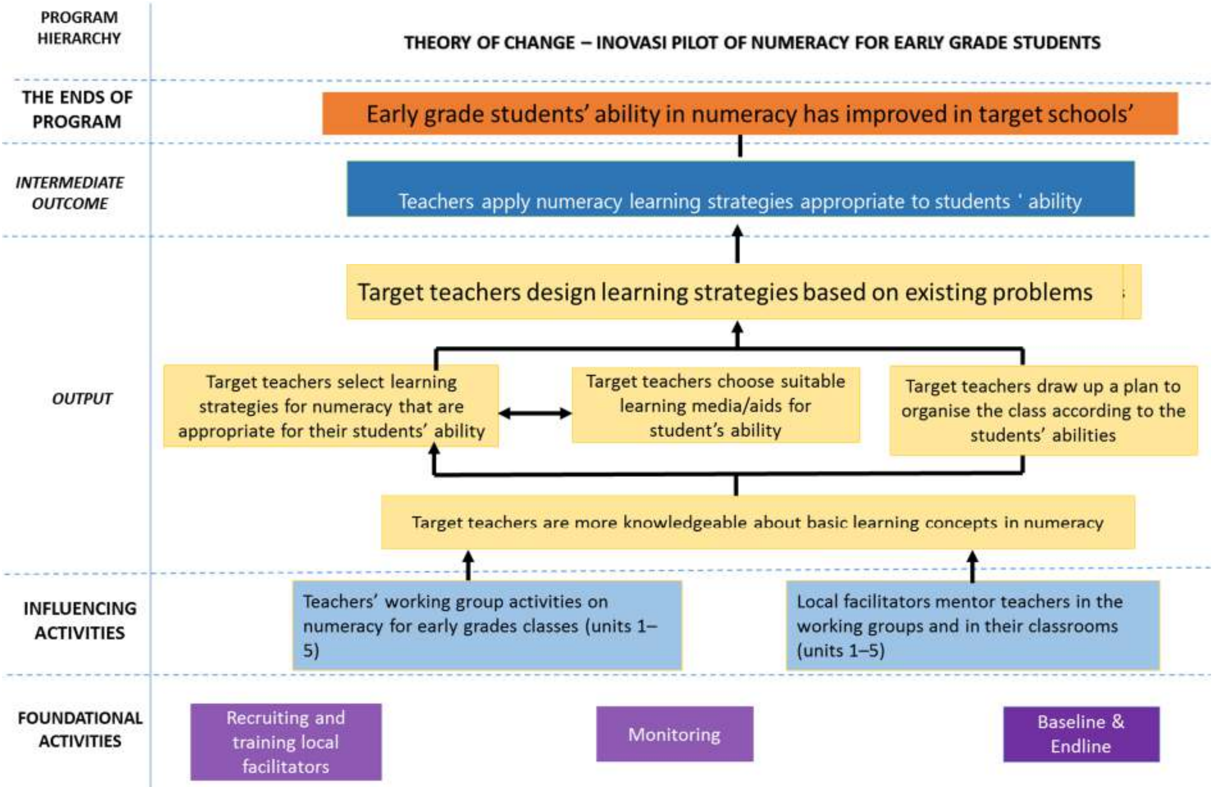
Three questions underpin this overarching evaluation question:

1. To what extent does training teachers to teach early grade numeracy result in improved outcomes?
2. To what extent does provision and use of appropriate materials improve children's numeracy outcomes?
3. Is there any evidence that improvements in numeracy resulting from the pilots will lead to better learning outcomes at higher levels or better higher-order thinking skills?

The second inquiry assesses the effectiveness of INOVASI's systemic improvements to conditions for teaching and learning numeracy at both the national and district levels. The key question for this inquiry is: *What works to bring about system improvements for numeracy teaching and learning in INOVASI's partner districts?*

After studying key international practices, INOVASI called on national and international expertise and experience to develop the training material. INOVASI uses the iterative approach, known as problem-driven iterative adaptation (PDIA), to continuously assess needs, review progress and adapt to learning. We do this by planning, implementing and evaluating the pilot activities in a politically-informed way. This means working with stakeholders to identify their problems, selecting and trying out different solutions that may be appropriate in these contexts and then iterating this process to discover 'best-fit' solutions, given local political, cultural and technical realities. Figure 1 shows the process underpinned by the problem-driven iterative adaptation theory of change for the Numeracy 2 pilot. Numeracy 1 followed a similar pathway with influencing activities including ten units. This study centres around outputs, intermediate outcomes and the desired outcomes.

Figure 1:Theory of change applied to numeracy



Source: INOVASI MERL team (2019)

Throughout the report, the term **numeracy** refers to the **knowledge, skills and behaviour** that students and teachers need in a wide range of contexts that include fluency and flexibility with numbers.

1.3 Study outline

After this brief introduction, section 2 analyses the policy and situational context of numeracy teaching and learning in Indonesia, at the national level and specifically in INOVASI's targeted provinces. After a review of the literature in section 3 we go on to outline the scope of INOVASI's intervention in numeracy in section 4. This includes its development strategies and the kind of data and information the program collected from each of these. Section 5 presents the methodology we used. This consists of a review of the evidence on effective numeracy teaching and learning and its applicability in Indonesian contexts. We also review a contextually relevant analytical framework against which we can address the key evaluation questions. The section on evidence sets out the program evidence used for the analysis. Discussion of the findings then follows leading to the culminating section of the study: the implications of the findings for practice, policy and management at the level of the classroom, school, community, district, province and nationally.

The Numeracy 1 short course pilot covers the main areas of the curriculum while the Numeracy 2 short course pilot goes on to give teachers a concrete understanding of number and number operations in the early grades. The training was underpinned by a practical, reflective and collaborative approach.

As INOVASI is an adaptive and iterative program, the learning from the Numeracy 1 pilot culminated in the Numeracy 2 pilot in the second half of 2019. We collected and analysed data before and after the training, and midway through that period.

2 The context: teaching and learning numeracy in Indonesia

President Joko Widodo has identified 'human resource development' as a top priority for his second term. This includes an emphasis on increasing human capital, developing soft skills, national character-building and promoting religious tolerance. This partly reflects concerns about Indonesia's economic trajectory and the urgent need to lift productivity but also responds to growing political, religious and cultural polarisation, seen as a risk to Indonesia's democratic resilience, national security and stability. A new education minister has been appointed to help deliver on this agenda.

Developing a skilled work force relies on achieving the basic competencies in literacy and numeracy that underpin higher-order thinking skills (HOTS), such as critical thinking and problem solving. If students do not develop minimum competence in literacy and mathematics, the prospect for a skilled and relevant workforce remains slim.

As described in the following section, international test results across Indonesia indicate that students are failing to grasp mathematical concepts used in real-world problems (OECD PISA, 2015). These skill areas include: being aware of the relationship between numbers and quantity; understanding number symbols, vocabulary and meaning; engaging in systematic counting; being able to compare different number magnitudes; understanding number representations and number patterns; and being competent in simple mathematical operations.

While numeracy and literacy are equally vital for Indonesia, the recent focus has been on policy solutions for literacy. This may be because we can potentially improve literacy learning outcomes by providing appropriate reading books and building a reading culture, without having to revise the national curriculum. This is more difficult for numeracy. As observed from INOVASI's pilots and described in this report, the way the 2013 curriculum is interpreted in teachers' guides and students' workbooks prioritises the ability to perform mathematical calculations (sums), often without building understanding of how these apply in the real world (INOVASI, 2019).

Under the new minister, work on reviewing and updating the national curriculum has begun. While this process is at an early stage, initial information suggests that one focus will be early grades and foundational skills. INOVASI shared the findings from the phase one pilots reported in this study with senior officials and other influencers in MoEC and they appear to have contributed to the curriculum revision process. The findings highlight the overly fast pace in the current curriculum and the need to build solid understanding of numbers in the early grades as a basis for higher-order thinking and more complex computations and real-life applications of mathematical concepts in the higher grades.

The publication of this thematic study is timely and can further inform the curriculum and national policies as they evolve.

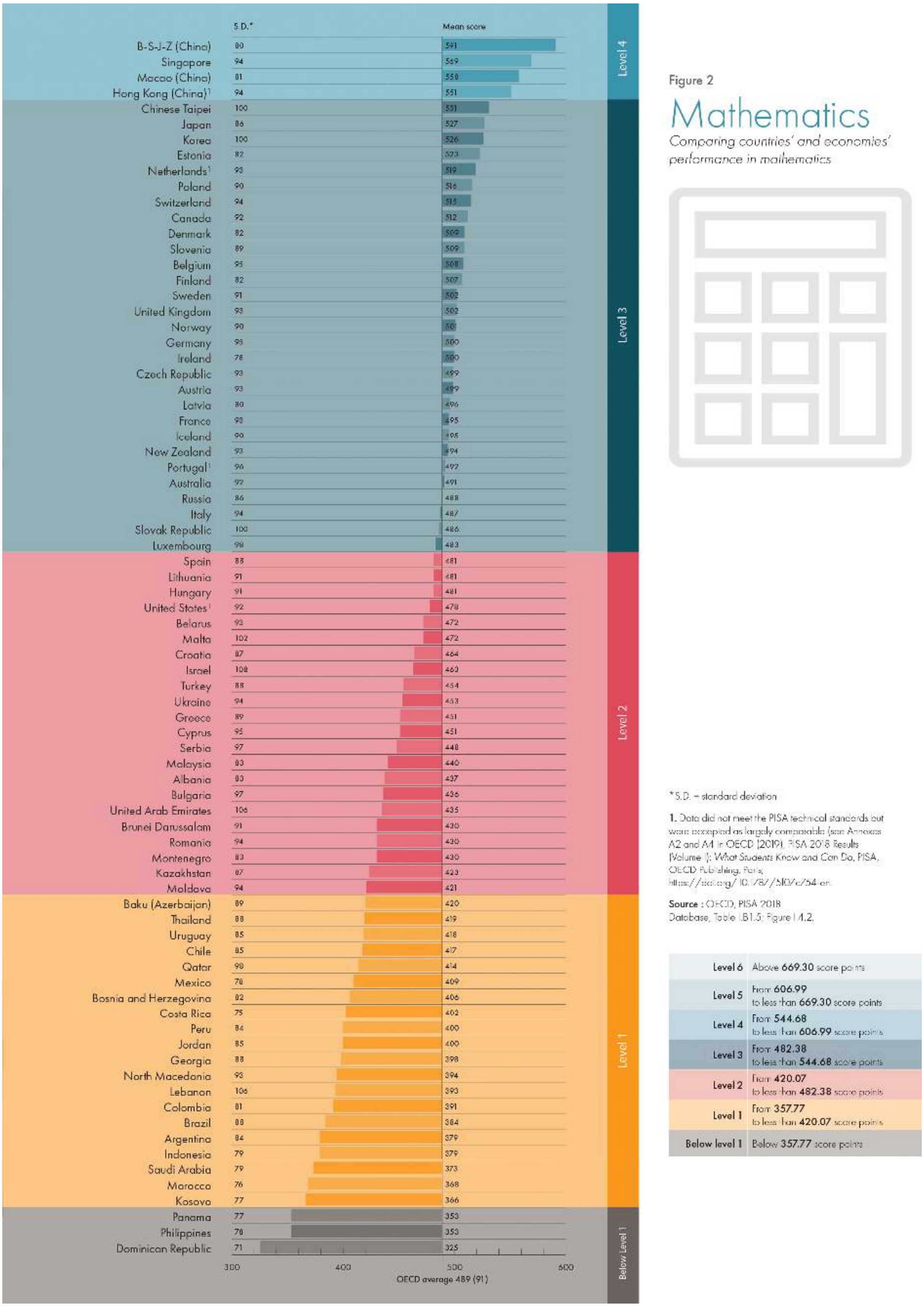
3 Effective practices in numeracy: review of research

A priority for Indonesia has been improving literacy and numeracy outcomes for students, not just to pass a test or an exam but to enable students to function and succeed as adults and to support the country's economic growth (Breakspear, 2012; Hanushek and Woessmann, 2009). While the emphasis has been on literacy, improving numeracy teaching and learning is a strong indicator of success in the future, not just in understanding mathematical concepts at school but in developing workplace skills and knowledge (Malloy, 2008; Nunes and Bryant, 1996; Steen, 2001; US Education Dept, 2008).

Although Indonesia was among the few countries that improved scores on the Program for International Student Assessment (PISA) between 2000 and 2012 (World Bank, 2018), it remains one of the lowest performing countries, both overall and among participating countries in the region. The 2018 PISA tests in mathematics ranked Indonesia 70th out of 77 participating countries with 379 points in level 1 (the lowest of six levels), significantly below the OECD average of 489. Compared to the overall OECD average of 76 per cent of students who attain level 2 or higher, just 28 per cent of Indonesian students reach this level, as shown in figure 2.

The PISA test measures the ability of 15-year olds in three categories – science, mathematics and reading – and in 2018 the performance of Indonesian students dropped in all three areas. In mathematics, the study gives Indonesian students a score of 379, a 7-point decrease from 2015, with science scores dropping to 396 points from 403 achieved in 2015. According to the PISA (2018) results, most students and in particular those from lower socioeconomic regions are able to master factual and procedural knowledge, while *mathematical inquiry and reasoning* have a much higher value for future employment and social empowerment.

Figure 2:Comparing PISA ranking in mathematics, 2018



Source: OECD (2019)

While students need to know the mathematical facts and procedures automatically, they also need to be able to communicate, reason, devise and apply strategies, use mathematical tools and develop higher-order thinking skills (as discussed later in this report). The 2015 PISA report indicated that Indonesian students' mathematical thinking ability (active cognition) was inadequate. Tanujaya *et al.* (2017) suggest from their research that students are not encouraged students to think and so they tend to merely regurgitate facts. The implication is that pedagogy has to adapt to meet the needs of a changing world. It is no longer sufficient for students to just know formulas or calculations by rote, they must also rationalise and reason how they helped them achieve the answer. This can begin at an early age whereby students talk about and demonstrate the different ways they can achieve a result. Furthermore, teachers themselves may need to be trained in ways of learning and teaching that are quite different from the way they were taught.

3.1 Number sense

A Research for Improving Systems of Education (RISE) working paper cites evidence from the Indonesian Family Life Survey (IFLS) that there is a gap between what students are supposed to learn and what they actually learn. The authors estimate that '*students in grade one have a 22 per cent probability of answering a maths question correctly*' (Beatty *et al.*,2018:29). This raises the question of which teaching methods and content need to change for all students to become numerate and reach their potential. The need for different ways of thinking and learning has surfaced recently with the rise of science, technology engineering and mathematics (STEM) education in the international world. Equipping students with embedded foundational mathematical concepts has become increasingly important in this context. Students need to think and apply their mathematical understanding past the traditional algorithms to develop **number sense** (Way, 2011). Learning in a less traditional way means students need to develop meaning, relationships, magnitude, operations and referents for numbers and quantities. Way (2011) suggests that it develops:

- mental calculation (Hope and Sherrill, 1987; Trafton, 1992);
- computational estimation (for example, Bobis, 1991; Case and Sowder, 1990);
- judging the relative magnitude of numbers (Sowder, 1988);
- recognising part-whole relationships and place value concepts (Fischer, 1990; Ross, 1989) and;
- problem solving (Cobb *et al*., 1991)

Education in number sense encourages students to think flexibly and efficiently through exploring numbers and visualising them in a variety of contexts. (Black, 2014) It is described as developing the following important knowledge, skills and understanding:

- An awareness of the relationship between number and quantity;
- An understanding of number symbols, vocabulary and meaning;
- The ability to engage in systematic counting, including notions of cardinality and ordinality;
- An awareness of magnitude and comparisons between different magnitudes;
- An understanding of different representations of number;
- Competence with simple mathematical operations;
- An awareness of number patterns including recognising missing numbers.

As suggested in Tsao and Lin's study (2012), creating opportunities for students to do the following will develop their number sense:

- Work with concrete materials and familiar ideas;

- Compose and recompose different arrangements and representations of number;
- Discuss and share their discoveries and solutions;
- Investigate the realistic uses of number in their everyday world;
- Explore number patterns and relationships.

The PISA 2018 results show that only 28 per cent of students in Indonesia achieve level 2 and beyond:

> *'At a minimum, these students can interpret and recognise, without direct instructions, how a (simple) situation can be represented mathematically (for example, comparing the total distance across two alternative routes or converting prices into a different currency)' (OECD, 2019: 2).*

This approach can be challenging for teachers and students in Indonesia as it asks for a new way of teaching and learning. INOVASI supported two numeracy training modules that incorporate an approach to higher-level reasoning skills. When INOVASI measured students' cognitive application in a *baseline* assessment, students' results ranged from 7.4 to 20.5 per cent in the four provinces before the pilot intervention (INOVASI, 2019).

3.2 Taking time and realigning priorities

Embedding concepts and skills in young children takes time and opportunities to practise and apply this learning in a range of situations. Pritchett and Beatty (2012) suggest that approaches used in developing countries often encourage 'shallow learning' partly because the curriculum moves too fast for children to grasp all the concepts. The danger is that superficially students seem to cope at an early stage and parents are pleased that their children can, for example, count up to 100 or write some numbers. However, they may have the mechanics of numeracy but not necessarily the understanding, for instance of cardinality or quantity, let alone computational skills. In their research across Asia and Africa, Pritchett and Beatty found that:

> *' …the learning, measured as the net addition in per cent correct, is only about 8 to 22 per cent per year. That is, of children lacking the ability to answer these simple curricular-based questions going into a typical grade, only about 1 in 8 demonstrate that skill after an additional year of schooling. This means that seven out of eight children made no progress on a typical item after an entire year of schooling' (Pritchett and Beatty, 2012:6).*

Although having an ambitious curriculum seems to be a positive move, Pritchett and Beatty (2012) argue that '*Paradoxically, learning could go faster if curricula and teachers slowed down*'. Apparently nearly 46 per cent of first graders could not solve the problem '49 minus 23' and even among 12th graders only 80 per cent answered this correctly (Beatty *et al.*, 2018). This implies that the most basic understanding of subtraction is not embedded. Allowing time for children and teachers to revisit and embed early concepts through application and inquiry prevents them from just acquiring facts at an abstract level where they do not connect to anything in their lives. This could impede their learning at a higher level and blur any opportunities to apply these concepts in relevant, real-world situations. The current curriculum means that once children can count orally to ten or complete worksheet problems like '4 plus 3' and '7 plus 2', teachers do not have time to relate these calculations to real life situations, as they have to move on quickly to the next part of the curriculum.

3.3 Active cognition

In schools where the teacher is responsible for telling the students everything, the skills of *thinking* can be treated as redundant or considered too time consuming. In these situations, the right answer to a number problem is the focus rather than the process or thinking required to work it out. As Geary (2005) suggests, students need the types of mathematical thinking that will help them survive in the world. Aptly described by Ollerton, Stratton and Watson (2020), developing this thinking entails engaging physically with objects, seeing parts and wholes, discerning, comparing, generalising and communicating. Students need to practise and apply these skills from a very young age to meet the needs of the future workforce in Indonesia and in the global community. Therefore we need to rethink what is important and not so important in our curriculum and adapt our pedagogy to incorporate these mathematical thinking skills in the numeracy lessons.

3.4 Student-centred learning

Hattie's (2009) synthesis of 800 meta-analyses relating to student achievement, based on 50,000 studies, is widely cited and he discusses the notion that what students do in the classroom matters. If they are passive recipients of the teacher's lesson, they are less likely to become independent thinkers and learners. The role of the teacher is to encourage students to be active in their learning. He cites Kember and Wong (2000) who found that *passive* students prefer teachers who organise, structure and share the learning goal but that *active* students prefer teachers who encourage interaction, vary their teaching approaches and are enthusiastic about the subject.

The challenge for many teachers around the world and in Indonesia is how to balance the blend of approaches where students do not depend on them all the time and do not always wait for approval, praise, correction or advice. This can be doubly challenging in a numeracy lesson where teachers' own understanding of learning and teaching mathematics has been about just getting a right or wrong answer. In addition, for a student-centred approach to be successful, students need opportunities to collaborate at appropriate times and learn with and from each other. However Hattie's (2009) research suggests that decisions on why and how this collaboration takes place need to be carefully thought out.

3.5 The use of learning materials

Learning materials, sometimes called 'manipulatives', are described as concrete models of abstract ideas. These materials are essential for young students and are used to show quantity, comparisons and complex mathematical systems and concepts. Materials for teaching and learning numeracy range from students' own fingers, shells and bottle tops to visuals including pictures, diagrams and number lines. These kinds of materials are used in classes around the world for that stage in the learning process that starts from concrete objects before moving on to abstract concepts. If we assume, for example, that students understand base 10 in an abstract form without giving them plenty of practice in parts and wholes of base 10, this will affect their conceptual understanding of other related concepts. The challenge is not only to provide the materials but for teachers to know how to use them to promote deeper thinking and understanding not just as a helpful crutch.

A large-scale literature review by Griffiths *et al.* (2017) discusses the qualitative and quantitative research around the use of materials over this and the last century. They describe how Mason and Johnston-Wilder (2006) built on Bruner's (1964) notion that the active use of materials helps memory, gives an iconic or visual representation to symbols and develops an overall understanding of numeracy. They develop this further by describing the different stages of manipulating objects and getting a sense of patterns and relationships to generalise using words and symbols.

Griffiths *et al*. (2017) cite Boulton Lewis (1998) who suggests that children need to be able to use manipulatives (learning materials) with some automaticity before they use them to learn new procedures or concepts. This implies that teachers need to monitor children's fluency with different materials and give them the opportunity to practise and use the learning materials. In addition, teachers must observe how children solve problems and calculate and discern what feedback and instruction they need next.

Susilowati (2014) outlines how using learning media helped children better understand basic number concepts. The children responded more quickly to teachers' questions and became enthusiastic and even passionate during the learning process. One issue has been that adults often perceive mathematics as difficult and this mindset, also found among teachers, is passed on to the children. If children are not given the opportunity to manipulate materials, visualise, make mental models and get to grips with early concepts, they may lose motivation and interest. Graven (2016) describes an example of this dilemma from South Africa where many students in upper primary and middle school still relied on their fingers to solve many computation problems and lacked opportunities to learn effective strategies to transition to more abstract thinking. Too often children are forced to tackle abstract concepts, trying to unravel what 'ten' means, for example, so they miss out on the practical process of breaking apart numbers and building them up.

3.6 Feedback

Moving backwards and forwards through these worlds of experience, between manipulable objects, mental imagery, drawing and abstract symbols helps children and adults to develop mathematical thinking and reasoning. The talk accompanying these worlds offers another layer in the complex process that allows teachers to hear what the children are thinking and learning. This may be challenging for schools that believe that quiet classes mean that learning is happening or that teachers should do all the talking. In simple terms, we miss the opportunity to assess how students are processing and communicating their learning and we cannot give them feedback.

Hattie's (2009) meta-analysis found that feedback was one of the most powerful influences on achievement. He discusses how feedback is not merely from teacher to student but also from student to teacher. Through this two-way communication, teachers know what students can do and understand by hearing and seeing any of their misconceptions and errors. Effective feedback is not about giving rewards or just affirming right answers, it is about gaining information about the learning that then leads to next steps. As he puts it, the purpose of feedback is *'to reduce discrepancies between current understandings/ performance and a desired goal'* (Hattie, 2009:176).

Shahrill (2013), citing Burns (1985), pointed out that teachers usually just nod and affirm when students give a correct response and only question students when they make an error. Teachers who are not confident in their own mathematical abilities don't want students to make mistakes and prefer not to address them. Students need to be able to describe the process they used to find a solution whether it is wrong or right and learn through discussion or demonstration. The teacher (and other students in the class) can help and suggest different solutions. Knowing how children learn mathematics and what kind of knowledge they need next is a critical element in giving them appropriate feedback to help them progress.

3.7 Assessment

Assessment is key in establishing whether or not learning has taken place and for whom. Summative assessments check progress over time but teachers also need to assess learning over shorter periods of time. Assessing whether children understood something is challenging in a busy classroom, particularly in more traditional classrooms where assessment means ‘testing’ knowledge at the end of a semester or even at the end of the year.

William and Leahy (2015) describe that when students talk about or demonstrate their learning, teachers tend to listen for the correct answer rather than for what they can *learn about the students’ understanding* in order to act on it, either immediately or in a future lesson. In two surveys prior to training, INOVASI found that just over a quarter of teachers checked whether the students had understood the intended learning at the end of the lesson (SIPPI teacher survey 2019/20). Therefore the notion of addressing misconceptions, adjusting future lesson plans or giving next steps does not take place. In INOVASI’s training, the teachers pre-assessed the class before each module. They then used this as a way of assessing the whole class on a specific concept and strategy and brought this to the teachers’ working group meeting.

3.8 Teachers’ mindset

Two aspects of teachers’ mindsets may have an impact in the Indonesian context. Firstly is teachers’ own attitudes towards numeracy (and possibly learning in general) and how they affect students’ mindsets and attitudes. Secondly, how confident teachers are about numeracy and their pedagogical knowledge, skills and understanding. Haylock and Cockburn (2003) report on a survey of 500 adults conducted by Swain that identified three myths adults have about maths: they believe mathematics is difficult, only for clever people and that it is a male domain.

They also found that teachers were often muddled in their own thinking about mathematics and aware of their own inadequacies and this translated into the three myths Swain identified in the classroom. This is a challenge as shown by INOVASI’s own data where 55 per cent of teachers perceive numeracy as a difficult subject for students (INOVASI, 2019). In addition, when teachers in 67 primary schools were tested using the Trends in International Mathematics and Science Study (TIMSS) from 2011 and earlier, the average score was 70–80 per cent and, in a recent cohort, the teachers scored just over 60 per cent.

If teachers’ own level of numeracy is not high, their beliefs about mathematics are unlikely to be positive and they may not have the knowledge to make numeracy meaningful. Siswono *et al.*(2019) examined the beliefs of Indonesian teachers and their findings suggest that primary teachers in particular need professional learning to improve their problem-solving knowledge (content and pedagogy). Their findings suggested that teachers’ beliefs were influenced by their own learning experience in school for content, and also by current curriculum reforms in terms of pedagogy.

In addition, for the context of our schools in Indonesia, Baumert *et al.* (2010) reported that:

'One of the major findings of qualitative studies on mathematics instruction is that the repertoire of teaching strategies and the pool of alternative mathematical representations and explanations available to teachers in the classroom are largely dependent on the breadth and depth of their conceptual understanding of the subject' (2010:138).

Giving teachers and students time to explore and extend their understanding of numeracy concepts in different ways may help in the first instance to adapt mindsets both in terms of mathematical content and with regard to teaching and learning. INOVASI investigated the limitations and experiences of some teachers by interviewing them after the pilot training and after a videoed lesson, one teacher said:

'I have never used this way before because I was not aware of the possibility. I also didn't know about using this ten frame so I still use my fingers.'

Teachers need time and support to make these changes.

4 The scope of INOVASI's numeracy interventions in the pilot districts

The total numbers of schools, teachers and students taking part in the numeracy pilots are presented in table 1.

Table 1: Participants in INOVASI's Numeracy 1 and Numeracy 2 pilots

Districts	Pilots	Number of schools	Number of targeted teachers			Number of targeted students		
			Female	Male	Total	Girls	Boys	Total
Sidoarjo	Numeracy 1	31	108	10	118	1,869	2,093	3,962
Sumbawa	Numeracy 1	17	50	11	61	805	846	1,651
Sidoarjo	Numeracy 2	11	48	5	53	702	796	1,498
Sumbawa	Numeracy 2	8	24	2	26	244	268	512
Bulungan	Numeracy 2	12	31	3	34	311	374	685
Malinau	Numeracy 2	13	63	7	70	569	706	1,275
Southwest Sumba	Numeracy 2	6	31	4	35	293	451	744
Central Sumba	Numeracy 2	6	17	5	22	152	178	330

4.1 Scope and content: Numeracy 1

Using the competency framework from the Indonesian 2013 curriculum, the INOVASI Numeracy 1 module focused on the developmental sequence of learning for the relevant numeracy concepts. It included some theory, some practical examples and relevant assessments to support teachers' knowledge of teaching numeracy in the main curriculum areas at primary level. INOVASI project staff and representatives from the Ministry of Education and Culture (MoEC) and Ministry of Religious Affairs (MoRA) developed the ten training units. These were conducted through ten teachers' working group sessions for grades one, two and three teachers, each lasting two to three hours (table 2). The training was followed by mentoring sessions with facilitators and reflection sessions.

Table 2: Numeracy 1 module: the ten unit topics

Unit number	Unit Title
Unit 1	Introduction: understanding mathematical concepts
Unit 2	Numbers
Unit 3	Place value
Unit 4	Addition and subtraction
Unit 5	Multiplication and division
Unit 6	Fractions
Unit 7	Fraction operations
Unit 8	Measurement
Unit 9	Shape and space
Unit 10	Story problems/word problems

4.2 Scope and content of Numeracy 2

The INOVASI Numeracy 2 pilot focused on early number concepts and skills aiming to build a stronger foundational understanding by introducing teachers to concrete, visual and enjoyable learning methods. The units were completed in collaboration with an international expert and key members of the education program development (EPD) team who worked in each of the four provinces. A member of Tanoto Foundation also formed part of the writing team.

As an adaptive program, the findings in Numeracy 1 suggested the need to further focus on early conceptual development for teachers' pedagogical knowledge and skills. Hence, Numeracy 2 was developed to improve teachers' own understanding of number sense and allow children to manipulate and use numbers in a flexible and efficient way. The module is designed so that teachers use the materials and learned mathematical concepts in the same way as their students would in the classroom. The content also built teachers' understanding of base 10 and its application in the four operations. The initial collaborative design included a module with ten units: number and number sense, pattern, pattern and number, number exploration, word problems, place value and two units on addition and subtraction, multiplication, multiplication and division.

INOVASI worked closely with the districts to organise and implement the training sessions in the teachers' working group meetings. However, due to limited time owing to exams and local needs, the units were reduced and combined for a one-semester time frame, as shown in table 3.

Table 3: Numeracy 2 adapted module to fit teachers' working group sessions

Unit number	Unit Title
Unit 1	Introduction: number and number sense
Unit 2	Pattern and pattern and number
Unit 3	Exploring number
Unit 4	Place value
Unit 5	Addition and subtraction

The structure of each unit followed this model:

1. *Pre-assessment for learning*: Results from a short assessment based on the topic of the unit (for example, place value) were collected from three students and brought to the teachers' working group to share with the group. The three students were chosen to represent the high, middle and low achiever cohorts. This meant that teachers could identify the problems the children might have and could already plan the most appropriate strategies for the students they assessed.
2. *Application*: Over the 120 minutes of the four or five main activities the teachers became students themselves, completing tasks in student mode combined with interactive theoretical tasks to aid knowledge acquisition of the concepts and pedagogy.
3. *Reflection:* Teachers used a short form to aid their reflection on strategies and their ways of working.
4. *Short action plan*: The plan included key 'takeaways' from the session that they could enact back in the classroom.

5 Analysis

This section is divided into the quantitative studies conducted under the supervision of INOVASI's monitoring, evaluation, research and learning (MERL) team and the qualitative teaching practice case study.

5.1 Quantitative studies

The quantitative data was analysed to provide evidence towards answering what works in INOVASI's numeracy pilot training. It focuses on student learning outcomes and teacher practices in the classroom. The data sets we analyse are mostly program-wide and include:

- Program-wide baseline–endline comparison of numeracy scores in the student learning assessments from INOVASI's education and learning surveys, SIPPI, carried out for the INOVASI pilots;
- Analysis for each grade level for the whole number – in the knowing and applying domains;
- Program-wide baseline–endline comparison of the SIPPI survey and spot-check results on the teacher practice index in INOVASI's numeracy pilots;
- Program-wide baseline–endline comparison of teachers' numeracy scores on the SIPPI student learning test from the SIPPI and pilot-specific tests before and after the modules.

Instruments

The term 'survey instrument' in this report refers to the Indonesian education and learning innovation survey (SIPPI) questionnaires that serve as the primary source of information on a given respondent. SIPPI uses separate and different questionnaires for students, parents, teachers, school principals, school supervisors and classroom observations. The instruments consist of: students' tests; students' surveys; parents' survey; teachers' survey; teachers' classroom observation; teachers' subject matter test; school principals' survey; school supervisors' survey; and school facility observation.

The data collection used two types of instruments: paper-based and computer-based. The early-grade student tests were administered one-on-one and conducted in a room or class that could be observed from outside to ensure students' safety.

This study mainly refers to the following instruments:

- Student interviews and tests (student learning assessment – SLA);
- SIPPI survey;
- Teacher subject matter knowledge before and after the pilot tests;
- Spot-check classroom observations.

We also refer to the other aspects of the SIPPI survey when relevant later in this section.

Student learning assessments

INOVASI used the student learning assessment (SLA) tool to capture students' learning outcomes. The tool covers mathematics and Indonesian language tests for primary schools. The instrument was developed by adapting national (Indonesia National Assessment Program – INAP; MoEC's Electronic Books) and international (the early grades reading assessment – EGRA; Trends in International Mathematics and Science Study – TIMMS; and Progress in International Reading Literacy Study – PIRLS) frameworks.

The test was administered with each student in a one-on-one situation with an adult. It was composed of two sections: a basic numeracy section and a numeracy comprehension section whereby students apply their knowledge and use reasoning skills. Students who passed the basic numeracy test moved on to the more difficult comprehension test. The basic test included recognising numbers, counting and noting quantities of objects. The comprehension test was graded in difficulty for grades one, two and three and students were expected to use higher-order thinking skills and reason in applying their knowledge.

Education and learning survey (SIPPI)

This instrument consists of two parts. The first part records basic information about the characteristics of the school as a precondition to all learning in schools. The second part is an observational tool to identify specific and immediate changes related to numeracy teaching and learning. For the findings, the focus will be on teachers' practices and students' progress.

Spot-check observations

The MERL team organised spot-check classroom observations once during every pilot cycle, conducted in a random sample of partner schools. The instrument was adapted from the Papua New Guinea early grade reading assessment (EGRA) classroom observation instrument, the Teach Philippines classroom observation instrument, the World Bank's *Teach* guide and the Education Quality Improvement Programme in Tanzania's (EQUIP-T) 2014 impact evaluation. The aim was to focus on changes in practices and the environment. The spot check provides a snapshot of classrooms in action.

SIPPI teacher test

The teacher test is one of INOVASI's instruments used to measure teachers' content knowledge. MoEC's assessment centre and the research and development agency adopted the instrument to use in the PIRLS 2011 for the reading test and in TIMSS 2011 and earlier years for the mathematics test. The test was originally developed for MoEC's assessment centre to assess the 250 best primary school teachers in Indonesia.

Numeracy 2 has an additional test targeting the areas of learning and teaching in the module. The questions were subdivided into attitude, knowledge (pedagogical) and behaviour of the teacher in the classroom.

5.2 Student learning assessments evidence and analysis

Student learning assessments were conducted at the beginning and end of the Numeracy 1 and Numeracy 2 pilots teachers' working group sessions. We begin by examining the Numeracy 1 data.

To answer the first question: *To what extent does training teachers to teach numeracy result in improved outcomes*, we consider what areas improved or did not improve across the two pilots for students in grades one, two and three.

Table 4: Numeracy 1 analysis framework

Question	Domains	Evidence Numeracy 1
Do students make progress overall in all domains?	Content domain: Whole number, fractions, geometry and measurement Cognitive domain: Knowing and applying	Student results baseline to endline in two partner districts in each content and cognitive domain
Does each grade make progress in the whole number content domain and applying domain?	Cognitive and whole number domain	Table 5 Overall combined grade level from partner districts
Do boys and girls make the same progress?	Cognitive and whole number domain	Table 6 Overall combined grade level data from partner districts
Has the students' attitude to mathematics changed?	Attitude and influence: friends, teacher, content and activity	Overall grade level data from partner schools

Table 4 outlines questions and evidence that focus on gains made at program and district level in Numeracy 1 in the content and cognitive domains, with a focus on number and the progress of boys compared with girls. We also measure if there has been a change in attitude and for what reason.

Numeracy 1 student learning assessment evidence

This data shows that the overall average score in each of the student numeracy learning outcomes increased in both districts after the Numeracy 1 was implemented. In Sidoarjo, the overall baseline score improved from 69.1 per cent to 78 per cent. In Sumbawa the gains were greater, with an average baseline score of 51.5 per cent and an endline score of 71 per cent. In order to gain more insight, table 5 indicates the average progress in each district and in each content and cognitive domain.

Table 5: Baseline and endline of student learning assessment data: all domains

	Content domain						Cognitive domain			
	Whole numbers		**Fraction and decimals**		**Geometry and measurement**		**Knowing**		**Applying**	
	Baseline	Endline	Baseline	Endline	Baseline	Endline	Baseline	Endline	Baseline	Endline
Sumbawa	55.1	78.8	42.3	61.5	61.0	73.3	56.8	74.6	35.9	63.0
Sidoarjo	72.6	82.0	55.9	68.1	69.4	80.2	74.3	84.5	49.7	60.1

Scores in the content domain increased in both districts (table 5). Students progressed significantly in the applying domain in Sumbawa where scores increased by more than 25 per cent while in Sidoarjo scores increased by around 10 per cent. In more detail, Sumbawa started at a lower percentage (35.9 per cent) and that may account for the difference. These indicators could signify that a change in pedagogy has an effect on students' thinking and reasoning abilities. Delving deeper, we can then consider how students performed in number as this underpins numeracy in all domains and was the focus in the Numeracy 2 pilot.

Using the combined scores of both districts, each grade level progressed for the whole number domain. In particular, grade three has a higher mean score in all areas (table 6).

Table 6: Baseline and endline results: student learning assessments for Numeracy 1, all districts, all grade levels for whole numbers

	Grade 1 (223 students)		Grade 2 (235 students)		Grade 3 (239 students)	
	Baseline	Endline	Baseline	Endline	Baseline	Endline
Whole numbers (mean)	55.2	70.9	60,9	80,5	77,8	90,2
Knowing (mean)	64.3	81,1	69,7	85,3	79,8	91,3
Applying (mean)	46.7	53,7	28,4	62,9	70,7	82,7

Overall, both boys and girls made progress (brackets indicate the improvement from the baseline) with girls achieving slightly higher than boys which corresponds with international data (table 7). However, boys made the most progress in the 'applying' domain. In one year, progress would be expected at some level but the results suggest that engaging boys using varied methods may have boosted their progress.

Table 7: Numeracy 1 student learning assessment: baseline and endline results, by gender

Only Numeracy 1 pilots (691 students-345 girls and 346 boys)						
	Baseline			Endline		
	All	Girls	Boys	All	Girls	Boys
Whole numbers (mean)	64,6	67,5	61,6	80,5 (15.9)	82,1 (14.6)	78,9 (17.3)
Knowing (mean)	71,2	73,8	68,9	84,9 (13.7)	86,3 (12.5)	83,5 (14.6)
Applying (mean)	48,4	51,7	45,0	66,4 (18.0)	68,1 (16.4)	64,8 (19.8)

Attitude to mathematics

The proportion of students who consider mathematics a favourite subject increased from 32 per cent to 42 per cent in Sidoarjo. From a regression summary conducted by the MERL team, the findings indicate that students who say that their favourite subject is mathematics do better than those who do not. The results were consistent across the sub-samples (excluding those students with special needs) and there was a significant magnitude, ranging from 2.5 – 35 points, with an overall effect size of 2.5. This would suggest that building students' confidence and enjoyment of numeracy leads to greater achievement. This question was not asked in Sumbawa for the baseline so the progress could not be measured (INOVASI regression document). The change in the way the teacher plans and then teaches in the classroom appears to be having an impact.

The two factors influencing the students most in considering mathematics as a favourite subject were *content* and *learning activities*, as opposed to *being the teacher or students' friend*. From the 233 grade one students, 63 per cent chose *content* as the reason why mathematics was their favourite subject, as did 84 per cent of the 235 grade two students and 54 per cent of the 229 grade three students. Interestingly, by grade three the number decreased from 63 per cent to 54 per cent. This could be because students, facing increasing challenges, have not had sufficient time to build their confidence or there may be greater pressure on them to think and show their learning, rather than be passive.

Numeracy 2 student learning assessment evidence

There were only three months between the baseline student learning assessment and the endline for Numeracy 2 so it is difficult to make claims about the impact of the pilot on students' improvements. The key is to establish if students progressed in number (content) along with applying that knowledge and reasoning development (cognitive).

Table 8: Analytical framework for Numeracy 2

Question	Domains	Analysis Numeracy 2
Do students make progress overall in all domains?	1 Content domain: Whole numbers	Table 7 Basic numeracy test
Does each grade make progress in the whole number content domain and applying domain?	Whole number, cognitive and cognitive number domain	Table 8 Overall combined grade level from partner districts
Do boys and girls make the same progress?	Cognitive and whole number domain	Table 8 Overall combined grade level data from partner districts
Has the students' attitude to mathematics changed?	Attitude and influence: friends, teacher, content and activity	Table 9 SIPPI baseline and endline data

The results of the baseline numeracy test look slightly different from the Numeracy 1 results where almost all students achieved a mean score of 97–100 per cent. In Numeracy 2, the grade one students' starting point was lower on recognising numerals (91 per cent) and this may indicate a lower ability in reading, less previous exposure and the fact that students had had only one semester in school (table 9). The additional districts in the Numeracy 2 cohort are also lower in terms of socioeconomic status than Sidoarjo and Sumbawa.

Boys' scores are lower than girls' scores but they made similar progress, although number discrimination remains an issue. This ability to understand quantities of numbers is essential and affects other areas of mathematical development.

Table 9: Numeracy 2: basic numeracy test, boys and girls data

Numeracy 2 pilots (936 students-452 girls and 484 boys)						
	Baseline			Endline		
	All	Girls	Boys	All	Girls	Boys
Basic numeracy (mean)	90%	91%	88%	94%	96%	93%
Number recognition (mean)	91%	92%	89%	96%	98%	95%
Number discrimination (mean)	98%	98%	98%	98%	98%	97%

This is often where the problem starts and continues. Students at this level may still need a lot more experience and practice with exploring numbers, discriminating patterns and understanding number bonds to ten (2 plus 8, 7 plus 3, 9 plus 1, and so on) as well as using this knowledge for higher numbers. However, as suggested by a grade one teacher after the videoed lesson, '*we move on to the next stage in the textbook*,' to 'cover' the curriculum before students have had time to internalise foundational knowledge and skills.

Similar patterns to Numeracy 1 testing can be seen with boys performing slightly below girls in the endline test, particularly with number discrimination (table 10). Again, we cannot draw too many conclusions from this in a three-month time span but given that Numeracy 2 is practical and hands on, the gap may narrow over time.

Table 10: Student learning assessment Numeracy 2 baseline and endline comprehension test

Numeracy 2 pilots						
	Grade 1 (297)		Grade 2 (338)		Grade 3 (301)	
	Baseline (Inovasi 2)	Endline (Inovasi 2)	Baseline (Inovasi 2)	Endline (Inovasi 2)	Baseline (Inovasi 2)	Endline (Inovasi 2)
Whole number	35,9	49,7 (14.80)	56,5	65,6 (9.1)	69,4	81,4 (12)
Knowing (mean)	47,1	61,0 (13.9)	66,3	73,5 (7.2)	77,2	83,1 (5.9)
Applying (mean)	22,2	33,2 (11)	44,8	41,5 (-3.3)	50,6	74,5 (23.9)

Progress similar to the trajectory in the Numeracy 1 progress data is already takng place despite the endline test being taken within three months. The most significant progress is in grade three with a mean increase of 23.9 in the applying area (table 8). As mentioned previously, this is an area in need of improvement in Indonesia and the 301 students made progress in using their reasoning skills and applying their knowledge. However, it should be noted that grade two decreased in the mean score. There are two 'applying' questions in the grade two test that are multiplication and division problems. This may be an issue in the test content as the timing for the Numeracy 2 training only allowed for addition and subtraction topics. As a result, the students had not covered multiplication and division.

Attitude to mathematics: Numeracy 2 and Numeracy 1

Students' attitude to mathematics changed positively (table 11) in Numeracy 2. The main points of interest are indicators 2 and 4. For grade one, there was a gain of 11 per cent in children who found mathematics the easiest lesson because of the content, in grade two, 14 per cent more and in grade three, 4 per cent more. Significant gains were made in the number of grade one students who perceive mathematics as the easiest subject. This would signify that a change in teaching practice that emphasises more exploratory hands-on tasks has aided this perception. Grade three students increased from 11 per cent to 21 per cent because of the learning activity which may indicate that the learning activities are more engaging and challenging.

Table 11: Numeracy 2 baseline and endline enjoyment indicators

Numeracy 2						
	Grade 1 (297)		Grade 2 (338)		Grade 3 (301)	
	Baseline (INOVASI 2)	Endline (INOVASI 2)	Baseline (INOVASI 2)	Endline (INOVASI 2)	Baseline (INOVASI 2)	Endline (INOVASI 2)
Mathematics is the easiest subject	25%	44%	37%	48%	37%	41%
What is the main reason you think mathematics is the easiest subject?						
1. Because of the teachers	11%	5%	15%	6%	17%	4%
2. Because of the contents	68%	79%	66%	80%	71%	75%
3. Because of the friends	6%	0%	3%	6%	1%	0%
4. Because of the learning activity	15%	16%	16%	19%	11%	21%

5.3 SIPPI teacher survey baseline and endline

This section analyses the development of teachers’ capabilities in the classroom from the beginning of the pilot studies (baseline) to the end of the pilot studies (endline). Three main analyses of teacher practices are included in this section, using: the SIPPI teacher survey, the spot-check classroom observation and the teacher tests. For the SIPPI survey and the spot-check classroom observation a ‘teacher Index’ was created to measure technical competence and teachers’ skills of delivery in the classroom.

Table 12: Analytical framework for the SIPPI teacher survey and spot-check classroom observation

	Inquiry variables	Teacher practice index
Technical competency acquired through INOVASI training	• Learning objectives/activities • Teacher uses an appropriate teaching tool (for explaining a concept) • Student work displayed in classroom • Group/pair activities	1. Clearly explains lesson objective 2. Objective of the learning activity 3. Demonstrates with learning material (non-abstract) 4. Organises the class into groups/pairs for activities 5. Displays teaching aids (Num1 priority) 6. Examines what knowledge or skills are understood at the end of the lesson
Teaching skills of lesson delivery learnt through INOVASI	• Teacher provides learning materials for students to use • Teacher asks open questions • Teacher provides feedback	7. 75% of students use learning material 8. Teacher delves into student opinion (discourse) 9. Asks open questions 10. Checks on understanding 11. Summarises the learning

SIPPI baseline and endline data: Numeracy 1 and Numeracy 2

The baseline for teachers participating in Numeracy 1 was carried out over the period August–October 2018 in Sidoarjo and January–April 2019 in Sumbawa. The endline survey was conducted in August–September 2019 in both districts. The baseline for Numeracy 2 was carried out in schools in Sidoarjo, Sumbawa, Bulungan and Malinau (North Kalimantan), Southwest Sumba and Central Sumba. Pilot Numeracy 2 was implemented between August and December 2019. The initial survey was conducted in August–September and the endline was conducted in January–February 2020.

The intention here is not to compare the two numeracy pilots but to evaluate the impact on teacher practice using the variables in the teacher survey index. The SIPPI is used to establish which practices were used before and after the Numeracy 1 and 2 pilot courses. These were the variables most likely to impact on students actively learning, practising and embedding concepts in early grade classrooms.

Using the principal component analysis enabled the MERL team to create the teacher practice index to analyse complicated larger sets of quantitative data while preserving as much of the statistical information as possible (Jolliffe and Cadima, 2016). The data presented is at program level for each of the different cohorts.

Table 13: Teacher index for all schools completing Numeracy 1 and 2

All Numeracy 1 and 2 pilots (17)				
	Baseline (Numeracy 1)	Endline (Numeracy 1)	Baseline (Numeracy 2)	Endline (Numeracy 2)
Teacher index scores	22.44	62.31	62.31	66.20

Table 13 represents the cumulative data from all the teacher practices variables. Overall, using the principal component analysis, there is significant gain from 22.44 to 66.20. This increase suggests that teachers' participation in INOVASI's two training modules has had a significant impact on teacher practice in the classroom overall. In table 14, we consider the areas of improvement in detail.

Table 14: Teacher practices variables: Numeracy 1 and Numeracy 2

All Numeracy 1 and 2 pilots (17)				
	Baseline (Phase 1)	Endline (Phase 1)	Baseline (Phase 2)	Endline (Phase 2)
Clearly explains the learning objective at the beginning of the session	53%	71%	71%	71%
Conveys the new knowledge or skill that the students will obtain through this learning process	35%	65%	65%	59%
Uses an appropriate teaching tool	65%	94%	94%	47%
Around 75% of students use tools to understand the concept	35%	35%	35%	41%
Delves deeper into students' opinions	29%	53%	53%	59%
Teaching aid displayed in the classroom	88%	94%	94%	100%
Gives feedback to students	59%	6%	6%	88%
Brings up open questions	94%	82%	82%	65%
Checks on students understanding	53%	82%	82%	100%
Examines whether students understand the knowledge/skill in accordance with what was conveyed at the beginning of the learning	29%	47%	47%	12%
Summarises the learning activity and conveys it to all the students	35%	71%	71%	94%
Group/pair activities	35%	71%	71%	76%

There is significant progress in the variable measuring teachers who '*delve deeper into students' opinions*'. This improved from **29 per cent** of the teachers doing this in the baseline in Numeracy 1, to **59 per cent** in the endline for Numeracy 2. This is consistent with the spot-check classroom observation data where **75 per cent** of the teachers in the sample schools demonstrated similar practice in answering the question '*Did the teacher ask questions to provoke students to think more deeply about the numeracy concept*?'

Significant gains were also made in teachers' abilities to '*check on student understanding',* progressing from 53 per cent to 100 per cent. This links to the previous variable. However, we should be wary of drawing too much from this, as often teachers will ask 'do you understand?' and the class inevitably chants yes. There are different interpretations of checking for understanding and this will be discussed further in the qualitative section. Equally, summarising the learning activity for the students showed gains from 35 per cent of the teachers doing so to 94 per cent which was also seen in the video case study analysis. This suggests that in practice teachers are building this into the classroom context.

There is only a small gain in the percentage of '*students using tools/learning materials'* to help them understand a concept (35 per cent to 41 per cent) and a decrease for teachers from 65 per cent to 47 per cent. Comparing that with the SIPPI spot-check data, there was an increase from 83 per cent to 100 per cent of teachers using materials to demonstrate and students from 67 per cent to 100 per cent. This indicates that teachers are using materials to aid student learning. However, the learning materials may not always be used appropriately and teachers are likely to resort to traditional, abstract methods of teaching when unsure. In addition, we must acknowledge that teachers sometimes feel they have to perform when being observed and revert back to their original methods as security.

However, teachers have gained in the way they organise the class for learning activities (see table 15).

Table 15: Numeracy 1 and 2 classroom organisation

	Baseline Num 1 and Num 2	Endline Num 1 and Num 2	Baseline Num 1	Endline Num 1	Baseline Num 2	Endline Num 2
Group/pairs	35%	71%	39%	61%	27%	45%

The organisation of the class enables a more student-centred approach when teachers develop group and pair activities involving practical, concrete activities and dialogue. This can also be a challenge in some of the contexts teachers work in as some classrooms are small and groups can be 30 or more, making group work noisy and distracting. Managing a class that involves active, student-centred learning is more challenging than one where the teacher stands at the front of the class teaching (or telling) passive learners. Clearly teachers feel more confident and see the value in organising the class in a more student-centred manner.

SIPPI spot-check classroom observations

Classroom spot-check observations were conducted during Numeracy 1, with a sample of 19 teachers observed in 19 schools in Sidoarjo and Sumbawa. In Numeracy 2, 36 teachers were observed in 36 schools in Southwest Sumba, Central Sumba, Bulungan, Malinau, Sumbawa and Sidoarjo. This record of a snapshot midway through the training sessions provides evidence of uptake of new practices by teachers and enabled feedback to stakeholders.

For teachers in Numeracy 1 and Numeracy 2, the main teaching practices selected for analysis are shown in table 16.

Table 16: SIPPI spot check results for Numeracy 1 and 2, classroom practices

Teaching practice observed	All schools Numeracy 1	All schools Numeracy 2
1. Stating the lesson objective	63%	72%
2. Displays of numeracy learning materials (self-made and commercial)	100%	92%
3. Demonstrates how to use learning materials	89%	89%
4. Use of learning materials by the students	74%	100%
5. Feedback to students	100%	97%
6. Revision of the lesson and additional tasks	58%	75%

The results for the most part are either consistent with the SIPPI endline survey or higher. These variables are considered basic teaching practices in most current classrooms that follow the pattern of an introduction, tasks, feedback and reflection. In more traditional classrooms, students may not be told the learning objective as the task is often functional, such as ‘complete the page in the textbook’, ‘write down the two times table’, and so on, not about what the students are expected to learn.

There was a decline in using the classroom environment to display numeracy learning materials in the Numeracy 2 classes. The five units in the teachers' working group sessions emphasised creating and using materials that the *students could use* to support their learning rather than creating a numeracy environment with displays although both support student learning. In a written reflection of the Numeracy 2 course, teachers noted that while students benefitted from the materials, the process took time outside of school and they did not always have enough time for this. Also they did not have enough time to make sure that there were enough materials for every child.

As INOVASI is an adaptive program, Numeracy 2 focused on specific early grade numeracy teacher practices and these were added to the spot-check classroom observation. The aim was to observe how teachers had developed the focus on number sense, feedback and assessment, and had integrated word problems into their classroom practice. In table 17, we consider teachers who only participated in Numeracy 2 compared to those who participated in both Numeracy 1 and 2.

Table 17: SIPPI spot-check data on Numeracy 2, additional data, all districts

Teaching practice	Numeracy 2 only	Numeracy 1 and 2 (both training pilots)
Are learning resources or learning aids made by the teachers sourced from local ingredients and/or easily accessible materials?	92%	100%
Did the teacher ask a few questions that provoke students to think more deeply about the concept of numeration? (Example: Can you count in another way? How do you know how many items are in the bag? Asking students to explain the outcome)	74%	75%
Does learning involve group assignments?	94%	100%
Does the teacher pre-assess the numerical ability of the students? (Request preliminary pre-assessment of students)	74%	88%
Has the teacher compiled a stage of learning plan to respond to difficulties experienced by students?	80%	100%
Do teachers use word problems to build understanding of the numerical concepts?	51%	63%
If yes, does the teacher use a picture/concrete object/props to visualise the word problem so the child can easily solve the problem?	50%	39%

Overall, teachers participating in both training sessions seem to make greater changes in their practice. These teachers have had longer to practise and use these skills and behaviours in the classroom. The most significant for both groups is the availability of materials. Given the context in Indonesia, Numeracy 2 strategically built the workshops around using locally-made materials and not ones that were commercially manufactured. In each teachers' working group, INOVASI supplied a basic pack of resources for each school. This was made by the INOVASI team or collected as recycled items. The model could then be transferred and imitated in any district for any class. The main objective was that teachers would not have any barriers in locating materials to aid the concrete and visual approach before moving on to more abstract approaches of base ten, place value, pattern and addition and subtraction. The teachers learned how specific numeracy learning materials could help students develop number sense and understand place value and how to use these concepts. This included the use of ten frames, hundred charts and number lines, for example. Having these learning materials available is one thing but having them in the hands of students is the crucial aspect in helping them learn new concepts.

Table 18: Spot check 2 district-level student use of materials

Numeracy Pilots by Target District	Most of students (≥ 50%) Involved in making use of the tools/media available during the learning process							
	Yes		No		NA		Grand Total	
	#	%	#	%	#	%	#	%
Bulungan	12	100%					12	100%
Malinau	10	77%	1	8%	2	15%	13	100%
Sidoarjo	11	100%					11	100%
Southwest Sumba	6	100%					6	100%
Central Sumba	6	100%					6	100%
Sumbawa	10	91%			1		11	100%
Grand Total	**55**	**93%**	**1**	**2%**	**3**	**5%**	**59**	**100%**

In all districts apart from Malinau, 80 per cent of teachers were observed using concrete materials. Malinau has a lower per capita consumption than Bulungan and materials may not be as accessible. The analysis of student use of learning media also seems to support this, as Malinau has the lowest use out of the districts (table 18).

Materials used in schools

Photo 1: Ten frames with recycled bottle tops and 100 squares

Photo 2: Number cards 1–10, sticks, mini blackboards

For the ‘questioning’ variable, 74 per cent of teachers were observed communicating and asking students open questions. The open questions invited students to reason and explain. In the videoed lessons, while more open questions were asked by one teacher, students did not respond and teachers often resorted to giving the answer instead of waiting or scaffolding the response. Many of the activities in Numeracy 2 were aimed at a student-centred approach involving discussing, working answers out together or demonstrating their methods for working out a calculation. While 100 per cent of both cohorts of teachers provided group tasks, as was found in the videoed lesson, without targeted support, the students worked alone or the more able students did all the work. Some learning will still take place but discussion, trial and error and practical examples would support higher-order thinking and application.

SIPPI teacher tests

The SIPPI teacher test covers the same content and cognitive domains as the student test: knowing and applying mathematical content. The purpose is to gauge the level of the teachers’ own mathematical understanding. Overall, the teachers scored between 60 per cent and 70 per cent on the endline test. In principle, all teachers need to score higher than this. This would help in their confidence and mindset which would also be transferred into the classroom, as discussed in the literature review.

The five units in the Numeracy 2 module emphasised pedagogy in the classroom up to grade three rather than the teachers’ own content knowledge of mathematics, so the results would not have changed significantly. The additional pilot-specific numeracy test for Numeracy 2 explored the gains in teachers’ own understanding of teaching practice through the pre- and post- pilot tests.

Numeracy 2: pilot-specific numeracy test

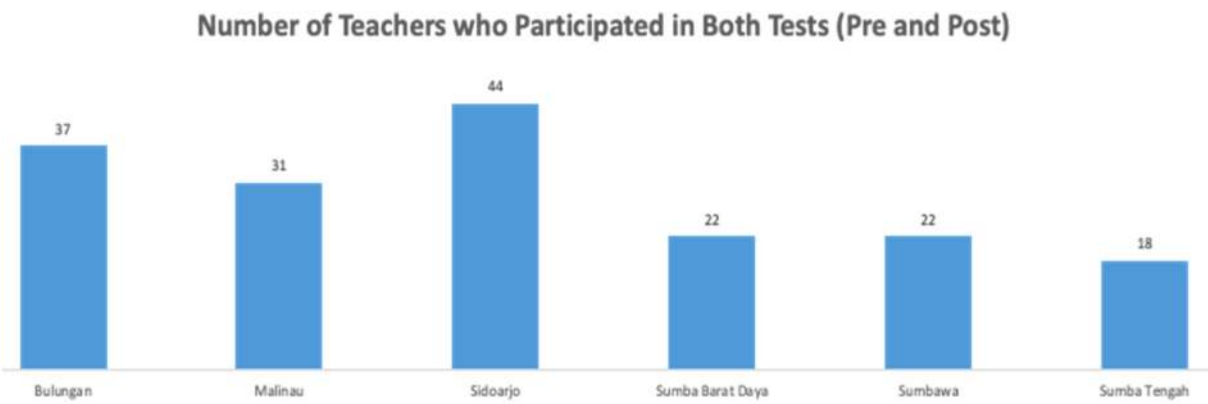
The Numeracy 2 pilot-specific tests contained 25 closed questions as we recognised that open questions were too difficult to score and analyse. Questions were categorised into different domains: attitude (8 items), knowledge (7 items) and behaviour (10 items) (see appendix 2 for the teacher test).

Table 19: Categories in the teacher practices test

Domain	Question
Attitude	2, 3, 7, 8, 12, 16, 20, 24
Knowledge	1, 4, 5, 10, 11, 13, 15, 17, 19, 22
Behaviour	6, 9, 14, 18, 21, 23, 25

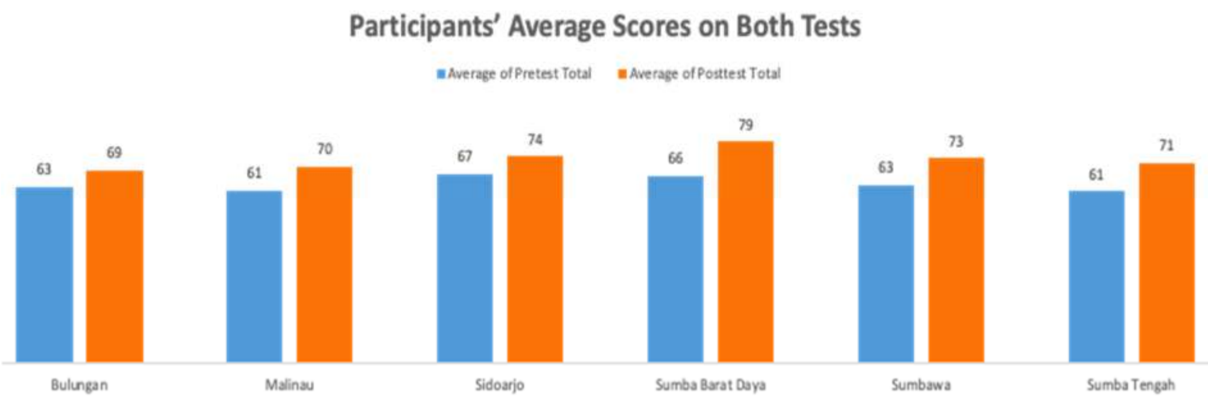
The number of teachers in each district is outlined in Figure 3.

Figure 3: Numeracy 2 pilot specific numbers of teachers participating



From the cumulation of scores from all three domains, the post-test shows that approximately 78 per cent of teachers improved their scores from the pre-test scores. Gains from the pre-test (orange) to the post-test occurred in all districts with an average increase of approximately 8 points in the teacher index.

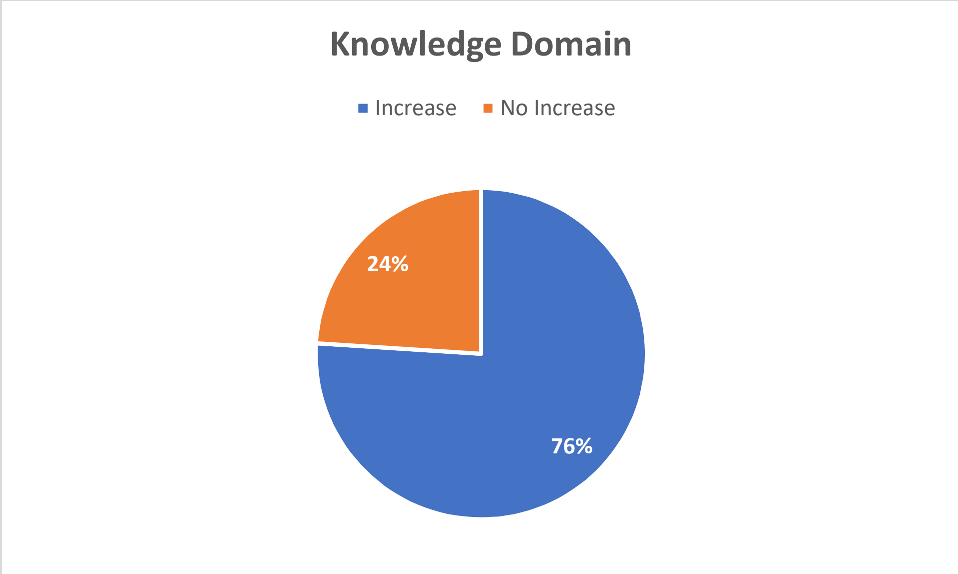
Figure 4: Numeracy 2 pilot specific test average scores on pre- and post- tests, by district



Domain-specific analysis

The knowledge domain grew from 24 per cent to 76 per cent, the highest rate of gain, suggesting that through the methodology of the teachers' working group training, teachers improved their knowledge of teaching methods.

Figure 5: Numeracy 2 knowledge domain teacher response



The three most improved items were: using the number line for teaching subtraction, pattern discrimination and place value. This indicates that the use of learning materials has helped develop teachers' pedagogical knowledge and also that the unit focusing on patterns has improved their awareness of *how patterns and relationships* should be encouraged. Patterns and relationships in numbers do not feature heavily in the Indonesian curriculum (competence 3.5) and this topic was mostly new to the teachers. Learning about this has impacted on teachers' knowledge of how young children learn and apply patterns in different aspects of numbers and in real life.

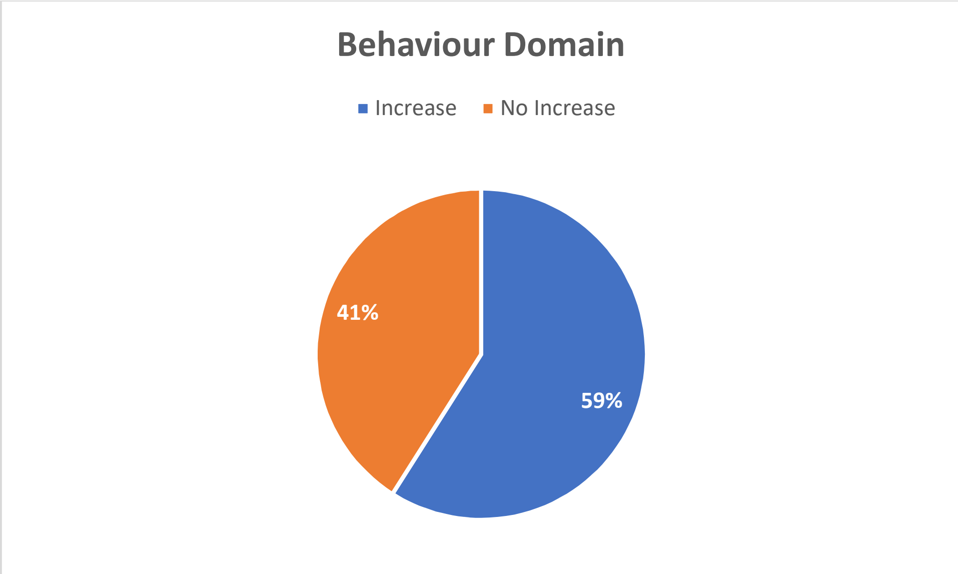
The behaviour domain

The behaviour domain concerns what teachers believe they do in the classroom to facilitate students' learning. Statements such as *'I ask students to show their understanding of place value by using learning media'* requires a different approach and thinking from telling students how to solve a problem and then just giving a score or marking it right or wrong. There was evidence of this new practice in all three of the videoed lessons but the teachers still tended to focus on the right answer and not the errors the students were making.

Another statement was '*I give students various short activities of less than 15 minutes to help them practise addition and subtraction.*' A number of factors may have influenced the lower gain in this domain. The addition and subtraction unit was intended to give teachers strategies to *teach* addition and subtraction. They were exposed to short lessons, often called 'mini lessons'. The notion was that teachers could still teach the curriculum but include these mini lessons. They could change the magnitude of the numbers in the activity but essentially the strategy once taught could be repeated for different levels. This adaptability of a strategy may seem an alien concept for Indonesian teachers who have themselves been taught one way, usually with a paper and pen. In addition, in the teaching practice videos, teachers taught for much longer than 15–20 minutes so the concept of a mini-lesson was new to them and possibly not as manageable.

However, although the least progress was seen in the behaviour domain, this is not surprising since the strategies and approaches needed in terms of number sense and practical strategies will take time to both process and practise. This is seen in the videoed teaching practice study where the teachers' behaviour varied, with two out of the three teachers confidently using the methods learned in the teachers' working group meetings.

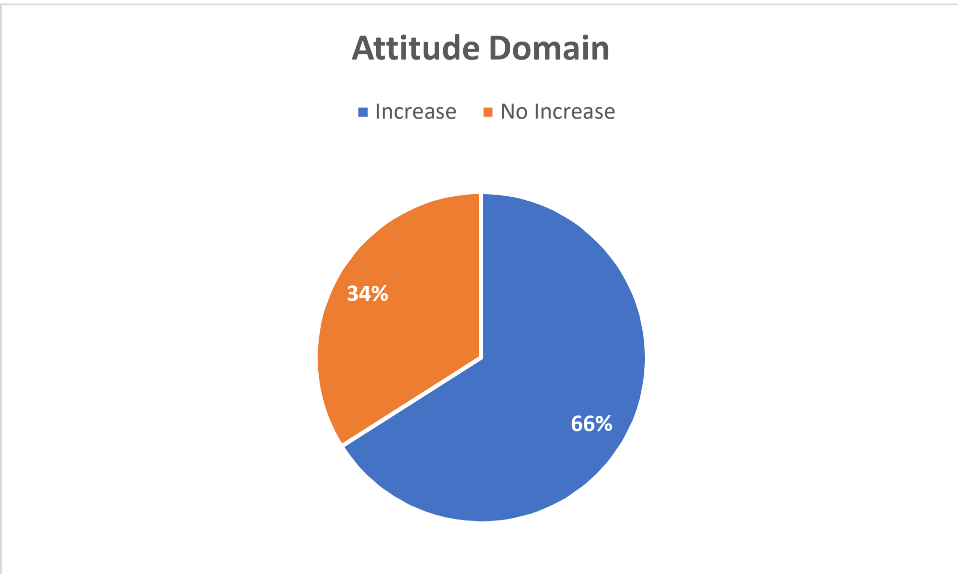
Figure 6: Numeracy 2 behaviour domain teachers' response



The attitude domain

The attitude domain progressed for 66 per cent of the teachers, reflecting the gains in the teachers' own attitudes towards learning numeracy. These questions broadly focused on beliefs around everyone's capacity – students and teachers' alike – to learn and improve. This result closely aligns with the results from the video case study where two out of the three teachers showed a positive attitude to all students learning.

Figure 7: Numeracy 2 attitude domain teachers' response



5.4 Conclusion

Through INOVASI's Numeracy 1 and 2 pilots, students progressed in the knowledge domains and significantly gained in the applying domain. This suggests that the improvements in pedagogy are having an overall impact on student learning. Boys still performed slightly below girls but gains were observed, particularly among boys. With a more student-centred approach where students used learning materials to meet a learning objective, they enjoyed mathematics and their perceptions of the subject were more positive, with a slight exception in grade three.

Teachers who took part in the Numeracy 1 and 2 teachers' working group sessions showed gains in most areas of their teaching practices and this impacted on student progress. They ask more questions and clearly benefitted from the pilot sessions where they had an opportunity to experience this, along with using the learning materials themselves. However, further development is needed on how to scaffold and support students' responses and give feedback on learning.

Teachers arranged the classes in groups to support a more student-centred approach and shared the learning objectives so that students knew what they were learning. This is a visible, tangible shift in teachers' mindsets, moving from a didactic teacher-centred approach to a more student-centred one. Teachers' own knowledge of numeracy content and processes also progressed, demonstrating a growth mindset towards learning new content and methods.

6 Qualitative studies

6.1 The numeracy teaching practice case study

The numeracy teaching practice case study was developed from in-depth studies of three teachers delivering a numeracy lesson in three different grades: grades one, two and three. These took place after the five teachers' working group sessions for Numeracy 2 were completed.

Purpose

The purpose of the case study was to make in-depth observations of classroom practice through videoed lessons to probe the teachers' practices, beliefs and understanding considering the knowledge and skills they had gained through INOVASI's Numeracy 2 pilot. The rationale of the activity was to contribute to INOVASI's evidence on teacher development in literacy and numeracy.

Selection of participants

The MERL team analysed the baseline SIPPI data from the teachers' teaching practice and the teachers' subject knowledge tests and selected teachers with moderate to high scores. The three teachers chosen, one each from grades one, two and three, also had high attendance rates at the teachers' working group sessions (86 per cent to 100 per cent). The teachers chosen included one teacher was from Sumbawa and two teachers from Sidoarjo.

Methodology

The methodology used drew broadly on the World Bank TIMMS mathematics teaching video study (Ragatz, 2013) and from Harvard University's Best Foot Forward project advice on leveraging video for learning (Centre for Education Policy Research). This method elicits reflection from the teachers and then layers the interpretation of the lesson using locally-informed mentors and subject specialists. The study consists of four steps:

1. *Video:* Video recording of a lesson by each of the three teachers based on learning from the addition and subtraction and or place value units in Numeracy 2.
2. *Interview 1*: Shortly after the video was taken in the classroom, the INOVASI staff in each district conducted a reflective interview with the teachers concerned to elicit their perceptions and thoughts about the lessons.
3. *Interview 2*: Two interviews were conducted face to face and one was conducted via Skype as the teacher was unable to travel. The interviews had two parts, one covering more general questions about their perceptions of the lesson and one more detailed appraisal where the video was stopped at key points. The aim was to probe the teachers' understanding of salient points of the lesson.
4. In January 2020, a team of education program development (EPD) staff with an international team worked on the analytical framework to share and contest interpretations, and to identify key emerging themes for the analytical framework for the teaching practices.

The study

The analytical framework has four dimensions that reflect the four aspects of INOVASI's developmental approach to improving learning outcomes in literacy and numeracy through its pilots. These dimensions with their accompanying inquiries are set out in table 20.

Table 20: Summary of the analytical dimensions for the case study lesson analysis

Dimensions	Inquiries
Competence acquired through INOVASI's technical approach in numeracy	The extent of the technical competence acquired through INOVASI
Improvement of relevant general skills and teaching behaviours that affect efficacy	How the teacher's skills of lesson delivery affect the efficacy of the lesson
Developing mindset – cultural beliefs about teaching numeracy	Teachers' beliefs about numeracy and the teaching of numeracy
The contextual fit of INOVASI's approach with teaching and school cultures affecting numeracy	4The fit of the INOVASI approach with the local teaching culture

Lesson contexts and description

Teachers were asked to choose a lesson related to the Numeracy 2 module that they felt confident to be videoed teaching. Each classroom had six large tables and groups of four children seated (mixed boys and girls) at each table.

Materials used

Ice cream sticks

10 frames and bottle tops

Photo 3: Ten frames

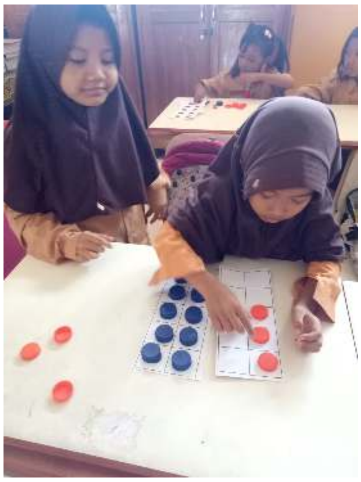


Photo 4: Collaborative learning using ten frames

Grade one lesson

Due to nervousness, the teacher taught the first part of the lesson without any materials and children worked on a worksheet. When she realised most children did not understand, she introduced the materials. She did have a detailed lesson plan prepared.

The first part of the lesson took 26 minutes and the main part of the lesson took 29 minutes. The details below are about the second part of the video.

Lesson scope and content

The teacher told the children, 'Today we will learn about addition, subtraction and place value.'

Table 21: Grade one lesson scope and content

Activity	Timing (approximate) and time on transcript	Content	Organisation whole class/ group/pairs/ individual
1	1.51 (15mins)	Worksheet 1 with 3 questions, addition/subtraction less than 30 Family/number bonds to 10 to complete	individual
2	16.40 (10 mins)	Worksheet 2 with 4 questions, similar concept addition/subtraction and family/number bonds to 8 and subtraction to make 10 (10 = 20 - ?)	individual
3	26.08 (14 minutes)	Teacher gives out materials to work out the answers on the same worksheet Students use materials	Individual
4	40.15 (12.00 minutes)	Using materials to show place value in 12 and 24	individual
	52.44	End of lesson/tidying up	

Grade two lesson

The lesson took approximately 30 minutes.

The teacher introduced the objective, 'We are going to learn addition and subtraction' (0.07).

After a brief question and answer session about the addition of dots on the two tens frames (8 on one and 9 on the other), the teacher distributed worksheets, a plastic bag with bottle tops, tamarind seeds and ten frames.

Lesson scope and content

Once the teacher had settled the class and after each point in the lesson, she went around the class to teach specific children.

Materials used

Ten-frame, tamarind seeds and bottle tops

Number lines

Whiteboard

Worksheets

Photo 5: Child demonstrating her calculation on the numberline.

Photo 6: Ten-frames with bottle top and seeds (addition example)

Table 22: Grade two lesson scope and content

Activity	Timing (approximate) and time on transcript	Content	Organisation whole class/ group/pairs/ individual
1	1.42 (8 minutes)	Addition and subtraction using ten frames (under 30) pair work	Pairs
2	11.30 (4 minutes)	Board demonstration 1 more than/ less than	Whole class
3	17.46 (5 minutes)	Addition and subtraction using a number line	Pairs
4	23.29 (2.30 minutes)	Whole class and individual contributions – teacher telling a word problem, three girls and one boy volunteered to tell their word problem to the class	Whole class/ individual
5	26.10 (1.20 minutes)	Board demonstration by a girl on solving 5+6 by using the number line 1.20 minutes	Whole class
	27.37 (2 minutes)	Teacher closure. Question from a girl, word problem and reminder about what the students had learned and used	Whole class

Grade three lesson

Students were seated at tables of four at single-gender tables and also worked in pairs.

The objective was to learn and find out various ways to add and subtract and to understand place value

Students could choose the materials to solve their problems from the following:

Materials used

Ten-frames, problem cards, 100 squares, 0-100 number line represented as a tape measure.

Photo 7: Subtraction number card, 100 square, measuring tape (number line replacement)

Once students settled, the teacher told them the objective: 'Today we are going to learn and find out various operations for addition and subtraction and place value' and then students quietly worked individually.

Table 23: Grade three lesson scope and content

Activity	Timing (approximate) and time on transcript	Content	Organisation whole class/group/ pair/individual
1	2.06 (15 mins)	Students worked individually and each child had a card with a calculation on it to solve such as: 90 - 21 =.	Individual
2	17.00 (5 mins)	The eacher demonstrated the 100 square and explained 73 - 49 and 78 +15 She made a connection between the use of the number line and the 100 square	Whole class
3	24.08 (15 mins)	Using learning media, most children focused on the 100 square to answer the five worksheet questions (addition, subtraction, skip counting/multiplication and use of word problems)	Individual
	(33.30)	The teacher asked one set of students to explain the process to the person sitting next to them	Pairs
	(39. 34)	End of lesson	

6.2 Findings and discussion

The extent of the technical competence acquired through INOVASI

All teachers planned their lessons using the strategies from INOVASI's Numeracy 2, units 4 and 5, as the basis for the lesson. The three teachers focused on students who were already identified as having difficulties with tens and units or, in the case of grades one and two, students who were able to rote count but not add and subtract numbers more than 20. Teachers all noted that they used the pre-assessments from the teachers' working group meetings, so they already knew who needed more support.

Supporting students with basic numeracy skills

A lot of time was taken with grade one and two teachers waiting while the students counted the numbers of items or numerals one by one and the students were not encouraged to skip count (see patterns) or to subitise (recognise sets of objects without having to count). This approach was new to both students and teachers, as the two teachers spoke about how they had only used fingers and then went straight on to visuals or abstract ideas. The grade two teacher reflected:

> *'Maybe my method (before) was to remember or imagine the sum or by using fingers. But usually they (students) stay quiet because the fingers are not enough. If we use the learning media they will be able to add more.'*

This suggests that teachers need more experience themselves in order to know when to prompt and suggest alternative ways to use the learning material.

The grade one teacher reflected:

> *'I used to use the old method of using fingers. It turned out that they practised using fingers for a long time but (then) they could not master (the higher addition problems) because there were only 10 fingers. Children need the learning media as they face difficulties moving beyond 10.'*

This was also noted in grade three where students used a 100 square for addition and subtraction but did not count in fives or tens to be efficient. The teacher did not instruct them in this process. She said in the interview:

> *'If the subtraction means to the left, he is only given (focused on) the direction, next time if he counted in tens it would be quicker.'*

Her reflection from the video already indicated she knew that the concept of patterns of 10 is another teaching point.

Learning materials

The grade two teacher used learning materials by showing two cards with 9 dots and 8 dots each. The students could mostly chorus the right answer. The teacher, on reflection, knew what her intention had been (moving one dot from the 8 to create 10 that would then make 1 ten and 7 units) (video grade two, 1.23) but she realised that she had not said this explicitly to the students.

After watching the video, all teachers recognised that students did not necessarily understand the concept they were teaching or that students were not able to apply the concept to the materials. The grade three teacher noted in her reflection interview that:

> *'Through the measuring tape to subtract, the smaller the value/number means a reduction but the greater the number means addition. He (the student) didn't know this.' (grade three video 36.23-37.40).*

The teacher reinforced this concept clearly.

Teachers were mostly able to use materials to support addition and subtraction calculations. The grade three teacher differentiated the use of the materials for a student to better understand place value (grade three, 10.01). Grade one students seemed to use the learning materials superficially and they were confused (grade one video, 9-12 mins). The use of the ten frames highlighted that both students and teacher had a rudimentary notion of its use for place value. The education program development team members noted that although an important turning point in the lesson for learning was to move away from just using fingers to compute two numbers, students and teachers needed more time to practise and to explore the concept of addition and subtraction and base ten.

Demonstration

Grade two and three teachers both used the strategy of demonstrating the process of how the learning materials were to be used for addition and subtraction. The grade two teacher encouraged individual students (a girl each time) to demonstrate to the class after her as a follow up before the students then went to the next set of problems. The grade three teacher taught the use of the number square in a clear way which she then supported with individual attention. However, the teachers clearly felt more confident teaching the whole class in a more traditional way. They blended approaches of direct teaching as a whole class with giving attention to students who needed support the most.

The grade two teacher was the only teacher to relate the addition and subtraction concept to word problems. She modelled a simple problem and then the four students (three girls and one boy) made up word problems at the end of the lesson. The word problems were formulaic but the oral presentation of this helped to give more meaning as to why the lesson focused on addition and subtraction. Nesher and Teubal (1975) also conducted research with seven year-olds to analyse the difficulties they had with applying their knowledge of addition and subtraction to problems. The results suggested that there were difficulties for children to recognise the correct operation needed. One reason was the lack of linguistic skills. For instance, the mathematical understanding of 'less' and 'more' is problematic but often teachers did not take into account the children's own real-life experiences. The grade two teacher had used the learning from the Numeracy 2 pilot to teach the language often found in word problems, 'more than, and less than' (although she did not explicitly say this to students) and also to practise addition and subtraction word problems orally with the students.

Strategies to support the development of number sense

All teachers monitored the learning when students were on a task during an activity. The teachers tended to repeat or clarify the question for content or procedural purposes, particularly for students who seemed to have difficulties. For example:

> *T: 'What is the question, read it please?' (grade one, 4.13).*
>
> *T: 'How many do you want to add? Adding 5? Take 5 tamarind seeds' (grade two, 3.25).*
>
> *T: 'What number do you add or subtract? OK subtraction'*
>
> *T: 'So how do you work on that?'*
>
> *S: 'Finding out number 98 subtracted by 52'*
>
> *T: 'Subtracted by 52, how do you do that? (Teacher shows student) 98, then it is subtracted. We count not to the right but to the left. So please try doing that again. Show me' (grade three, 7.31).*

Teachers tended to ask a procedural question and then answer the question themselves as students were mostly reluctant to give much detail about the process they had tried or were about to try. The response of only one-word answers that were often correct would indicate a lack of practice in having a dialogue, rather than a lack of knowledge.

The grade two teacher frequently asked the students more open questions such as 'how' questions that could have been interpreted as metacognitive questions but the students answered them as procedural ones. For example, when asking two students who had difficulties with addition and subtraction:

> *T: '... your result for 12 plus 5 is 17. How did you solve this?'*
>
> *S: 'We counted them'*
>
> *T: 'How did you count them?'*
>
> *S: 'Using bottle tops and tamarind seeds.'*

The question itself is fairly simple and the thinking involved is not particularly demanding but there was an opportunity for the students to explain numerically rather than functionally. The teacher had observed the process but did not pursue or explain further for them. For example, to explain that the students had first completed the ten frame with 10 bottle tops, then added two more on to the next ten frame, making 12. After that they had added five seeds to make 17. The teacher might have added extra details: two full number frames are two tens, 20, three less than 20 is 17, and so on. This would have extended the thinking beyond recall.

There was an example of one teacher requiring a student to think about the process when considering a word problem. First, the teacher modelled an addition word problem and then, after the class had arrived quickly at the answer of 13, the teacher asked a further question about the problem (grade two, 23.36):

> *T: 'How do you know that they both had ice creams?'*
>
> *S: 'By adding them'*
>
> *T: 'What do you add?'*
>
> *S: '6 to 7.'*

The intention to promote thinking was also present in the written problems for grade three, requiring students to find the solution in two different ways, but there was not sufficient time left in the lesson for this to be completed.

How the teachers' skills in delivering the lesson affect the efficacy of the lesson

Teachers were clear about the intention of each activity. The grade one teacher organised the children to work in pairs, based on the pre-assessments that they had been introduced to in the INOVASI pilot sessions. In interview 2, the grade one teacher said that she grouped the children:

> *'Based on the results of the pre-test, each group consists of one higher, medium and lower [achiever].'*

The grade two teacher also organised students in pairs of mixed ability. Only the grade three teacher had paired lower ability students together because she '*could then give them more attention*'. Students appeared comfortable to sit in small groups. In grades one and two, the students co-operated in taking turns to use materials and to answer a question. One teacher commented:

> *'Based on the results of yesterday's pre-test, there were those who could master it [addition and subtraction] and those who did not answer at all.'*

This then helped her to organise the learning and the class the next day. The spot-check class observation results also indicated that 88 per cent of the teachers who had participated in both training sessions pre-assessed their students. Being given the specific tools and guidance on what to do next from INOVASI's Numeracy 2 training helped the teachers organise their classes accordingly. This can be a challenge in Indonesia where teachers often feel pressured to teach the next item on the curriculum when students have not fully grasped the concept. The curriculum is so full that often there is no time to re-visit or interleave concepts and skills.

Generally speaking, from the videos, the noise level was reasonable and students were largely well managed. Grade three students were focused and the teacher was respectful and calm towards them. She used terms of endearment and apologised when she made a slight mistake. Grade two students were enthusiastic to volunteer (from what was evident) and a student demonstrated the number line, then later the word problems and was confident to try. All three teachers talked about engagement with the materials and how this motivated the students.

As the emphasis was on getting the 'right answer' as the priority, at times the grade one teacher repeated questions, for example:

> *'What is the answer? What is the answer, 20. What is the answer?' (grade one, 39.34).*

Students in all classes seemed anxious to get the right answer and on one occasion when the grade three teacher asked students to show their partners how to work out a problem, they did not seem to know what to do (grade three, 35.00). This emphasis on correct answers influenced how teachers gave feedback and for what. In most cases there was no 'wait time' (apart from grade three who waited calmly) and prompts were not given to help students think.

Teachers gave praise when students were successful by clapping, saying phrases like *'good job', 'well done', 'that's right' 'try again*'. This affirmed the correct answer but did not go far enough to be specific about anything else, for example, how students worked the problem out, used materials, focused and so on. Balancing between being positive about the correct answer, taking the time to give next steps and being specific about other aspects of the process helps young learners to develop their higher-order thinking.

Teachers' beliefs about numeracy

The evidence in the video suggests that getting the correct answer is of paramount importance. Teachers only asked for an explanation of an answer when the answer was correct. Once a student made an error, the teachers immediately went back to direct teaching mode to repeat the correct way, as if to rectify the situation by retelling the student the mechanics of the operation. This meant that students ended up copying the teacher and not explaining their thinking about the process.

Overall, teachers did prompt students with questions, such as: '*Can you prove it*?', '*How do you solve it?*', but they tended to guide the answer by explaining or implying the steps. This is understandable as students themselves did not seem to have the tools to articulate their thinking. Given that the learning materials were new to students, this may take time and the idea of students explaining their understanding, not just writing an answer on a worksheet to be corrected, is one yet to be embedded.

Notable was the omission of any specific feedback in all three lessons. In grade one and three, the teachers asked for an answer and if it was correct, they moved on. If it was incorrect, they asked the question again and mostly just gave the answer and then expected the students to carry on. The grade two teacher in contrast attempted to give the students an opportunity to describe what they were learning and then supported them while they tried again to find the correct solution.

In both interviews, all the teachers confirmed that they found the use of learning materials, other than counting with fingers, important for students learning numeracy concepts.

> *'In order to make it easier for children to understand through using the 10 frame, the hundred square and the measuring tape (number line)' (grade three teacher).*

This teacher understood from watching the video that the students were not at a stage where they could choose which learning material was best for a given calculation. Some of the students in grade three were overwhelmed with the choice of three learning materials and were unable to start. In addition, it was clear that while the adaptation of the number line to a 100 cm tape measure for the context was a good initiative, the measure itself moved and it was harder to make specific 'jumps'. The measure could be attached to cardboard to make it less malleable.

The grade two teacher also noted:

> *'When a number is more than ten, I believed that students just can imagine the number. Using fingers just for the initial steps is okay but some students are already in an advanced stage, so they can do additions and subtractions … but they are still using their fingers.'*

Although the students could count and possibly complete addition and subtraction formulas, they still did it with the aid of their fingers and could not see the patterns that are gained through using materials. This was an insightful reflection from watching the video itself:

> *'I can see the success of my students, so they know the results they make. With this learning material children do not need to imagine the result and they are happy because they can practise directly in front of them, It helps them be more aware of the concept' (grade one teacher).*

The teacher reflected on the difference between the first half of the lesson and the second half and could see the advantages of the use of concrete materials before going to the abstract form.

Teachers encouraged a more student-centred environment by arranging the students in small groups so they were facing each other and were not in rows facing only the teacher. From the second interview, grade two and three teachers believed that there are opportunities for students to learn from each other by being in groups. However, this was the only reason cited by the teachers and they showed lack of depth of understanding as to *how* this would help students. They both said the reason was '*that the more able students would support the less able ones*'. Only the grade three teacher said she had put two less able students together and as all her tasks were individual tasks, no collaborative learning was evident. She did, however, give extra challenges by asking more questions of a child that needed support (she had prepared them for the lesson but the exchange is not included in the video).

The fit of the INOVASI approach with the teaching culture

The final part of the analysis was conducted with literacy specialists who had analysed the case study of three videoed reading lessons using the same methodology. There were six common overall findings in both content areas:

- Teachers' use of learning material
- Teachers' ability in questioning
- Teachers' understanding of the purpose of the strategies and assessment instrument applied
- Teachers' awareness of individual learning levels
- Managing learning
- Active and student-centred learning

The context and content for numeracy and literacy were different. The literacy study involved a small guided reading session with a group of students of the same grade level. The numeracy study centred around full-class lessons in three different grades. Despite the contrasting settings and content, the themes arising indicate common features of teaching practice.

Table 24: Collaborative numeracy and literacy analysis

Common Findings	Differences in the findings	Recommendation
Use of media	Literacy: The use of books to broaden children's horizon Numeracy: The use of learning media to acquire and support conceptual understanding of base ten Numeracy: The use of learning media to deepen teachers' understanding of how children learn foundational numeracy skills	L: Develop teachers' ability to select appropriate books according to students' reading ability and needs N: Create opportunities for teachers to practice using the learning media/practical material to support conceptual development
Teachers ability in questioning	Literacy: Tendency to ask questions with one word answers (closed questions) Numeracy: Tendency to ask questions with only one possible answer (closed questions)	L/N: Strengthen teachers' abilities to formulate HOTs questions N: Strengthen teachers' abilities to formulate HOTS questions and how to scaffold students' answers about how they solved a problem (Correctly and incorrectly)
The purpose of strategies and assessment processes	Literacy: The confusion of using strategies in reading (guided reading, shared reading) and Instruments (running record) Numeracy: The lack of depth understanding the reasons applying appropriate strategies	L/N: Strengthening teachers' ability and knowledge through training and mentoring L/N: Using video recordings of lessons to analyse learning and assessment processes
Teachers' awareness of individual learning levels	Literacy: Addressing different needs depending on students' ability Numeracy: Addressing different needs depending on students' ability	L: Using updated data of students' ability in order to plan for learning opportunities N: Developing teacher's skills to use evidence of students' learning to plan for and improve learning in the lesson
Managing learning	Literacy: Organising groups according to the learning needs	N: Videoing of lessons

Common Findings	Differences in the findings	Recommendation
	Numeracy: Organising groups according to the activity and the learning needs, such as pairs, group work, individual work	N: Videoing the lesson and using the lesson in KKG sessions/school meetings to analyse and give feedback as to why and how students are organised
Active and student-centred learning	Literacy: Teachers dominating during learning; Students are less proactive Numeracy: Students are active but not encouraged to be responsive Aligning more student-centred learning with the needs/demands of the curriculum	L: Strengthening the teachers' ability to apply active learning through training and mentoring N: Deepening of understanding of the practical application and purpose of student-centred learning, towards student's conceptual understanding aligned with the needs/demands of the curriculum through training and mentoring

In each of the six areas of practice, there were differences in the degree this was observed in the lessons. In terms of numeracy, each teacher demonstrated a basic level of competency or understanding that could be built on. A challenge for the teachers we observed in these two different provinces was to balance the need to teach content in a rigorous way but still allow students to make errors and learn from their mistakes by teachers using careful scaffolding in their language and instruction. The traditional model of 'tell and the student will learn' leaves students behind at later levels. However, as the grade one teacher noted, there is pressure to get on to the next part of the curriculum regardless of the level or understanding of the students. Under this pressure, teachers often rely only on traditional methods of teaching and rush through essential foundational learning.

Teachers tended to find it challenging to reflect on their own practice, even when they watched the video to look at specific moments in the lesson. Both Indonesian and international educators in the literacy and numeracy analytical teams identified the use of video as a tool for professional development whereby teachers have time to watch their own and their students' performances and reflect on it in teams. Teachers' mindset takes time to change; there may be cultural implications and previous experiences to be taken into account before this can take place.

INOVASI's student tests indicate improvement in student learning outcomes resulting from INOVASI's numeracy pilot training, even at this level of teacher's competency. Aptly cited by Perry and Ketterlin-Geller (2018):

> *'Because foundational mathematics skills are predictive of future academic success, including reading achievement (Duncan et al., 2007), as well as economic well-being in adulthood (Richie & Bates, 2013), the importance of improving mathematics teaching and learning cannot be overstated. Because of this, mathematics is increasingly being considered a focal area within global contexts.'*

It is apparent that teachers recognised their students' lack of basic understanding in numeracy and have started to consider ways to help them understand better. This is a crucial stage for early grades teachers where they need to establish their students' foundational numeracy skills.

7 Conclusion

Overall, teachers in this study became more aware of what students do and do not understand in early number concepts like addition, subtraction and place value. The use of the videos helped to demonstrate this issue more clearly as often 'in the moment' busy teachers do not have time to observe learning patterns. Video or voice recordings may be a way to capture learning for reflection and development.

Teachers gave attention to students with difficulties but did not always have the skills to give them formative feedback. As the teachers mostly focused on students attaining the correct answer, once that was achieved and teachers moved on, they did not take the opportunity to develop the students' metacognitive skills.

While teachers asked students many questions, more work needs to be done on how to help silent children to engage confidently in dialogue, either with a teacher or with a fellow student so they learn to apply the higher-order thinking skills needed in mathematics. This implies that teachers need to develop their practice and modelling of scaffolding and eliciting responses in different ways.

Teachers talked about using textbooks as a guide to the curriculum content and our findings suggest that the content of the textbooks tends to be for written and visual practice. The textbooks need to match with practical, concrete classroom approaches.

Teachers have become more student-centred by seating the class in groups and, in some cases, arranging students to work together in pairs, depending on ability. More work needs to be done on when, why and how teachers should implement working together and when they should not. In particular, teachers and students should know why this way of working is important in developing students' numeracy skills. The same applies to knowing when to use concrete materials and considering when, why, what and for whom they should be used.

8 Recommendations

INOVASI's phase one work in the numeracy area suggests a number of recommendations for government. At the national level, these include the following:

1. The current review of Curriculum 2013 provides an opportunity for the findings of this and previous studies to inform Indonesia's national curriculum. We understand that the review will focus initially on the early grades and the revised curriculum should allow more time for concrete, fun challenges that build a solid understanding of number in these grades. The curriculum could be slowed down and aligned more effectively with the emerging assessment framework, rather than with the current Curriculum 2013. This should provide the basis for more abstract maths in higher grades. In addition to changing the content, an updated curriculum should change the way mathematics is taught in the classroom (stipulated in teachers' guidebooks and students' textbooks and workbooks).
2. MoEC's work on new assessments (the students' minimal competence assessment – AKM – that was formerly the Indonesian students' performance assessment – AKSI) should be aligned to changes in curriculum and school-based assessments should be implemented and used to inform local and national policy decisions. School and class based assessments can then be used by teachers, schools and district government as formative assessment to inform teaching and identify training needs for teachers' continuing professional development.
3. MoEC should ensure that mathematics units are appropriately covered in continuing professional development training and resources for primary school teachers. Teachers should receive professional development in subject areas where they are weakest.
4. A second phase of INOVASI can work with MoEC and MoRA to support this process through developing and piloting further teacher training modules and effective approaches to changing practices and improving learning outcomes in different contexts. This may provide opportunities for longitudinal studies to determine the effects of changes to the content and ways of teaching numeracy in the early grades on students' performance in higher grades, including on PISA tests and in higher-order thinking skills.

Policy recommendations and priorities at the district level include:

- Ensure that all teachers are equipped with the knowledge and skills to develop and implement new and appropriate approaches to teaching numeracy in the early grades. This should include using readily-available concrete learning materials to engage and motivate students to make meaningful representations of their learning.
- Provide training for teachers in formative assessment so they can implement simple and timely strategies to track students' progress and meet the different learning needs of early grade students.
- Provide opportunities for continued targeted professional learning meetings on specific numeracy knowledge, skills and concepts to improve teachers' questioning, inquiry, reflection and planning to meet student's development of higher-order thinking skills in the early grades.
- District education offices need to strengthen school leaders' understanding of the curriculum. In practice, changes occur and succeed in schools if the principal displays effective curriculum leadership. Principals could provide teachers with the time and

resources to plan learning, create appropriate resources and check formative assessments. This could include teachers learning from having time to reflect on classroom practice, possibly using recordings of lessons.

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