THE CENTRE FOR INDEPENDENT STUDIES

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CIS Education Program

Failing to teach the teacher: An analysis of mathematics Initial Teacher Education

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Susan McKinnon Foundation

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Executive summary

Australian student achievement in the OECD-run Programme for International Student Assessment (PISA) has declined more steeply and consistently than in any other country, other than Finland. This decline has been greatest in mathematics, where the average Australian 15-year-old is around 14 months behind, compared to their counterpart in the early 2000s.

Policymakers' concerns about the performance of the education system are increasingly being centred around initial teacher education (ITE). In 2021, the federal government initiated a new Quality Initial Teaching Review, in part to better prepare graduates to be more effective teachers.

Numerous reviews into the sector have exposed generally poor standards and an unsatisfactory integration of evidence-based practice in ITE.

Partly to blame for this is an ideological preference for generally student-led, 'constructivist', rather than teacher-led 'instructivist' teaching approaches. As a result, teachers aren't equipped with a full range of practices that will be effective in teaching all learners. Of special concern in mathematics teaching is a lack of explicit instruction (a set of practices that place a central role in teacher-led instruction) and an overemphasis on constructivist-inspired approaches (a set or practices that place a central role in facilitating student-led inquiry).

ITE courses do not provide maths teachers the tools to employ explicit instruction

Based on an analysis of 90 mathematics units from the Bachelor of Education (Primary) courses of 31 universities, there is virtually no evidence of ITE where explicit instruction is clearly emphasised.

Of those universities, 27 clearly emphasise constructivist approaches, while 4 are either ambiguous or emphasise a range of teaching approaches. No mathematics units from any of the universities in the analysis appear to have a clear emphasis on explicit instruction.

This appears to be the result of an ongoing ideological bias — against explicit instruction, and in favour of constructivist teaching approaches — among education academics and ITE providers.

Given the significant evidence that supports the use of explicit instruction, graduate teachers cannot be considered classroom-ready unless they have appropriate knowledge and skill in implementing explicit instruction.

There is reason to believe that poor classroom-readiness of beginning teachers is directly the result of inadequate preparation during ITE.

Explicit instruction is not sufficiently practiced in Australian mathematics classrooms

Compared to mathematics classrooms of high-performing education systems — such as Singapore, Hong Kong, Shanghai, and Taiwan — Australia's are much more likely to employ constructivist-inspired teaching practices.

A lack of teacher-led instruction in Australia has contributed to declining student achievement. It's estimated that the average 15-year-old would be around 10 months ahead of where they currently are if they received mostly teacher-led instruction, with only occasional student-led practice.

It is reasonable to conclude that increasing preference for constructivist teaching approaches in recent decades has significantly contributed to the achievement decline of Australian teachers. This ideological preference originates from ITE.

Greater practice of explicit instruction would lift student achievement in mathematics

Education research shows there are important benefits from explicit instruction in mathematics. While the impact is found to be especially positive for struggling learners and those with learning difficulties, there is evidence that all learners benefit from at least some form of consistent explicit instruction.

There are some specific practices that are regularly found to be among the most effective for all learners:

- Clear teacher demonstrations that recognise implications of cognitive load.
- Guided, scaffolded practice opportunities that allow students to verbalise.
- Immediate corrective feedback to clarify and confirm students' progress.
- Spaced and interleaved practice to facilitate cumulative review of content.

Effective teaching doesn't employ explicit instruction alone, but a great deal of explicit instruction is often necessary before students have sufficient expertise for constructivist approaches to be introduced. Teachers who employ constructivist approaches alone are unlikely to provide optimal learning for their students.

Ineffective ITE places excess demand on costly and limited professional development

Teachers who are underprepared for the classroom during ITE later require professional development to meet their needs.

While this professional development does exist, it is limited and is often provided beyond the traditional, university-based ITE providers. It is also very costly to rely on professional development alone because it results in a significant delay in teachers accessing the knowledge needed to be effective from the start of teaching.

It's regularly outlined that the greatest need for professional development is in behaviour and classroom management. A greater focus on explicit instruction during ITE would significantly help beginning teachers maintain order, because many of the salient features of the pedagogy align with evidence-based behaviour management strategies.

Policymakers must ensure that evidence-based practices are included in ITE for prospective mathematics teachers

An effective Primary ITE programme would provide a graduate teacher with at least one unit dedicated to explicit instruction in the context of mathematics, and provide the tools to design and deliver curriculum and explicit instruction lessons that manage cognitive load and embed knowledge in students' long-term memories using strategies that are aligned with current evidence.

Content that would support beginning teachers to implement explicit instruction includes:

- Cognitive Load Theory and its applications.
- Strategies for gaining, maintaining and focusing student attention during whole-class instruction (e.g. choral response, student whiteboards, pair share).
- Questioning and checking for understanding.
- Explicit lesson design, including the use of worked examples.
- Strategies to facilitate spaced retrieval practice (e.g. Daily Review, Warm Ups).
- Practice breaking down complex skills into smaller instructional units.

The most effective quality assurance of ITE graduates is to directly observe their performance, and the practices of ITE providers.

While policymakers have introduced measures intended to improve alignment of ITE courses with evidence-based practice, it is clear from this analysis that it hasn't had the intended impact on ITE providers.

Rather than redesign their mathematics units to include evidence-based instructional approaches, some universities appear to have simply labelled constructivist approaches with the terms 'evidence-based' or 'research-based'.

An inspection approach may be the only reliable way to assess the quality of ITE programmes. To guide these inspections, a more detailed, specific framework should be developed; outlining exactly what should be taught in ITE, including the evidence-based practices listed above.

An inspection approach would, among others things, determine the effectiveness of ITE programmes based on assessment of preservice teachers' ability to implement explicit instruction, based on an agreed observational checklist or rubric.

Introduction

Despite decades of continuously increasing education funding, Australian student achievement trends in mathematics and numeracy are no better than mixed. Although some tests such as the Trends in International Maths and Science Study (TIMSS) and National Assessment Programme – Literacy and Numeracy (NAPLAN) show relatively static outcomes, achievement trends in the OECD's Programme for International Student Assessment (PISA) have shown consistent declines.

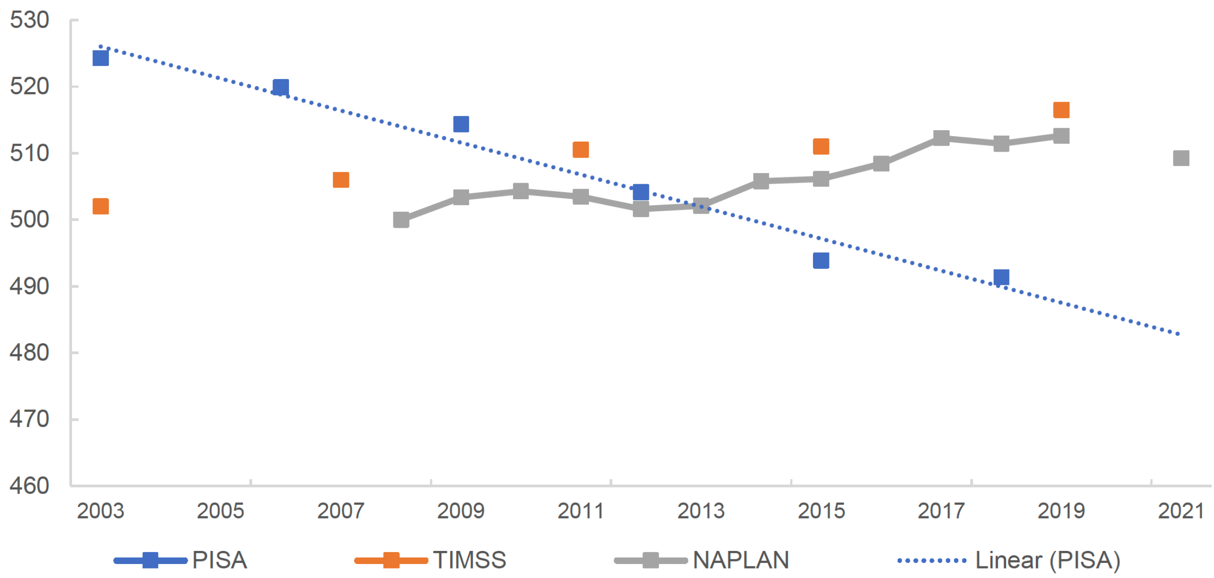
PISA is one of the most, if not the most, important educational achievement measure available. Unlike TIMSS and NAPLAN — which are curriculum based — PISA measures competency in the fields assessed. Its relatively long time series and international significance, together with the fact that it is based on the achievement of students approaching school-leaving age, make PISA crucial to assessing the performance of Australia's school system.

Student achievement in mathematics has been in steady decline for decades

Unfortunately, across all domains that are assessed, Australia's achievement decline in PISA is more consistent and steep than any other OECD country, other than Finland. The decline has been greatest in mathematics, with implications that extend to senior secondary and tertiary participation in mathematics.[1] The findings in the most recent round of PISA are particularly stark:

- Australian students' achievement fell to the equivalent of the OECD average for the first time;
- Compared to the average Australian student in 2003, an Australian student in 2018 is the equivalent of around 14 months behind; and
- 46 per cent of 15 year-olds don't achieve at the national standard of proficiency in mathematics.

Achievement trends in international and national assessments.



Source: Programme for International Student Assessment (PISA) 2018 (15-year-olds), Trends in International Maths and Science Study (TIMSS) 2019 (average Year 4 and 8), and National Assessment Program – Literacy and Nuemracy (NAPLAN) 2021 (average Year 3, 5, 7, and 9).

There are a number of factors that have contributed to this decline. Perhaps the most important has to do with the flawed way maths is taught — both to prospective teachers at university, and to students in the classroom.

This paper provides a review of the teaching of mathematics in Australian classrooms. It will examine how teachers are taught to teach mathematics and how closely those courses follow the evidence of best teaching practice. It will look at how flaws in Initial Teacher Education (ITE) flow through into poor practices in the classroom. Finally, it will make recommendations about how to improve ITE and how we teach mathematics in Australian Schools.

What is ITE?

Initial teacher education (ITE) is responsible for providing beginning teachers with the knowledge, skills, and characteristics to prepare them for the classroom. Typically, ITE involves beginning teachers enrolling and completing an undergraduate or postgraduate degree at a university by an approved ITE provider. In an ITE course, preservice teachers complete a combination of courses that include pedagogical, subject matter, and — in some cases — subject-particular pedagogical knowledge. Enrolments are typically for either primary or secondary education.

There are 367 programmes, 48 ITE providers, and 91 locations preparing around 92,000 enrolled ITE students across Australia. Teaching graduates typically complete a standalone Bachelor of Education, or complete an undergraduate degree followed by a teaching course. Many more teachers now pursue two-year postgraduate teaching degrees, rather than one-year diplomas — with 39 per cent of graduating teachers having completed a postgraduate degree.[2] Less than half of enrolled ITE students complete their undergraduate degree.

More so than most other professions, the ITE sector is highly complex, with considerable overlapping federal and state and territory policies and regulations departments, along with compliance with professional, accreditation, and registration standards — all impacting on the work of prospective teachers, schools, and ITE providers.

In common with other countries,[3] Australian policymakers have increasingly viewed improvements to ITE as being necessary to improve education outcomes.[4] This has been motivated by concern for the quality of the delivery of ITE, wider concerns for education system performance, and changing composition of the teacher workforce (including ongoing attrition of teachers).

However, the potential problems with ITE extend beyond competency of the system. Rather than a strict dedication to evidence-based practice, ideological preferences can shape ITE content.[5 6 7] In mathematics, this has meant a focus on 'constructivist', rather than 'instructivist' teaching approaches.[8]

Instructivists promote teacher-led, explicit instruction, while constructivists promote student-centred approaches that allow students to construct their own meaning and understanding. Moreover, instructivisits tend to stress an emphasis on developing students' procedural knowledge, while constructivists emphasise developing students' conceptual knowledge.

While both are ultimately essential for any student to succeed in mathematics, there are critical implications for how to teach based on each goal. An emphasis on procedural knowledge means more time and effort placed on rehearsing and memorising arithmetic facts and procedures. An emphasis on conceptual knowledge means more time and effort placed on the insights of how to solve problems and discovering the principles underlying problems.

As a result, teachers may not receive a full range of practices that will be effective in teaching all learners.

Box: Instructivists and constructivists in mathematics teaching

At the heart of the divide is the relative emphasis for teachers to place in providing students with *procedural* knowledge for mathematical problem-solving — largely through an *instructivist* approach, generally supported by a focus on rehearsing and memorising arithmetic facts and procedures — or on constructing students' *conceptual* knowledge — largely through *constructivist* teaching approaches, with a focus on providing students with insights into how to solve problems and discover the principles underlying problems. [9]

Constructivist approaches in mathematics are generally student-directed; motivated by a view that students should discover their own ways to solve open-ended problems — often through applied rather than abstract contexts — as the primary means of understanding core principles and the relationships among them.

Proponents argue that students with procedural knowledge alone may know rules, recognise arithmetic, and correctly carry out known procedures in familiar problems, but may be limited in correctly applying procedures to different or unfamiliar problems, struggle to draw connexions between concepts, and lack a 'deep' understanding of mathematical relationships. As a result, they label a focus on procedures as 'shallow teaching syndrome',[10] that results in students lacking "curiosity, risk-taking, and negotiation."[11] Accordingly, they argue for greater emphasis for teachers on developing students' 'reasoning'.[12]

On the other hand, instructivists note that students who engage in inquiry, without sufficient foundational knowledge or procedural fluency, can become easily overwhelmed (among other reasons, due to excess cognitive load, as discussed further in a later section).[13] This has led to the emphasis on ensuring foundations are properly established for students achieve 'procedural fluency' — the ability to retrieve and interpret familiar arithmetic, representations, number combinations, and the like from long-term memory (without drawing heavily on limited 'working memory'[14]).[15] [16]

How maths teaching is being taught in Australian ITE

In order to identify the contents of ITE programmes, an analysis of course outlines of Australian ITE courses was conducted, to identify which pedagogical practices are being emphasised in ITE Mathematics courses. This included analysis of key words that relate to relevant theory (such as constructivism, cognitive load theory) and teaching practices (such as inquiry, open-ended tasks, explicit instruction), as well as details of prescribed textbooks, where applicable.

The analysis was limited to undergraduate primary courses. The AITSL Approved Programmes search function was used to identify accredited courses. Information about the mathematics units in these courses was then collected from the website of each university. While some universities provided extensive detail about their units, others provided none. Units for which no information could be located were excluded from this review. Some mathematics units were solely dedicated to developing the mathematics knowledge of pre-service teachers as opposed to pedagogical knowledge.

There is virtually no evidence of explicit instruction being emphasised in ITE

Based on an analysis of 90 Mathematics units from the Bachelor of Education (Primary) courses of 31 universities, there is virtually no evidence of ITE where explicit instruction is clearly emphasised.

Of the 31 universities, 27 clearly emphasise constructivist approaches, while 4 are either ambiguous or emphasise a range of teaching approaches. No mathematics units from any of the universities in the analysis appear to have a clear emphasis on explicit instruction.

There were just two mentions of explicit instruction and its associated terms across the 90 unit outlines analysed.

Of these mentions, however, there appears to remain a strong emphasis of constructivism. For instance, an assignment in one unit required pre-service teachers to plan a 5-week sequence of activities that included open-ended tasks, games, and "explicit teaching and learning experiences (*based on socio-constructivist learning approaches*)."[17] Another unit outline listed direct/explicit instruction alongside other approaches and theories, including "constructivism, humanism, socio-constructivism and constructionism."[18] This cursory treatment of explicit instruction is not sufficient to adequately prepare beginning teachers to implement the pedagogy.

There are many, and varied, references made to constructivist approaches in ITE

Analysis of key words used in ITE course outlines shows that the most commonly made references are to "real world/life", "inquiry", and "constructivism/ constructivist".

Count of key words found in examined ITE courses

	Courses	Units
constructivism/constructivist	6	11
inquiry	10	11
discovery	0	0
problem-based	7	7
student-centred	3	5
open-ended	7	7
real-world/life	9	12
rich tasks	6	7
games	4	4
play	5	5

	Courses	Units
explicit teaching	0	0
direct/ explicit instruction	2	2
teacher-led/directed	0	0
worked examples	0	0
guided practice	0	0
retrieval practice	0	0
cognitive load	0	0
working memory	0	0
long-term memory	0	0
I do, we do, you do	0	0

Analysis revealed that, much like the whole-language approach to beginning reading, constructivist approaches to teaching mathematics are referred to by a range of interchangeable terms. In addition to the term 'constructivist', the approach is also commonly labelled 'inquiry', 'student-centred' and /or 'problem-based'.

Several unit outlines do not make direct reference to constructivism or one of its synonyms; however, evidence that constructivist approaches are being privileged in these units can be found in the teaching and learning activities that are outlined. These include references to 'open-ended', 'rich' and 'real-life/world' tasks as well the use of 'play' and 'games'.

Keywords that are associated with explicit instruction are not found in the analysed course outlines. These include: worked examples; guided practice; retrieval practice; cognitive load; working/long term memory. As discussed in this paper, these are important terms for new teachers to know and be able to apply in the context of mathematics because they align closely with current understandings of human cognition and are practical strategies that have proven efficacy.

Some ITE courses are dismissive of explicit instruction and evidence-based practice in mathematics

Not only do ITE courses clearly not provide an emphasis on explicit instruction, there's also evidence that explicit instruction is disparaged in favour of constructivism.

For instance, one unit outline states: '*Students will develop capabilities as designers of learning, utilising authentic inquiry-based contexts*'.[19] Another unit outline states that pre-service teachers will: '*develop student-centred inclusive approaches for teaching mathematics in Foundation to Year 6*.'[20] The use of this loaded language appears to imply that non-constructivist approaches, such as explicit instruction, must be inauthentic and non-inclusive.

Further analysis also finds that some ITE courses promote outdated ideas about how students learn. For instance, three universities make reference to developmental stages or theories. This is despite evidence that shows cognitive development does not progress through a fixed progression of age-related stages.[21]

In addition, two unit outlines from one university state that students have 'different learning styles' that must be catered for.[22] [23] This is despite conclusive evidence that, to the extent that students have particular learning styles, this should not influence the practice of educators[24] — particularly as this tends to reinforce a bias in processing information in one way or another. There is, in fact, no scientific evidence to support the claims and implications made by proponents of the 'learning styles' theories.[25] Despite this, educators frequently employ classroom practices to accommodate learning styles, and regularly misunderstand theories of learning with 'learning styles'.[26]

A clear theme in the items recorded in course outlines is the use of strategies intended to increase the engagement of students.

While there is some evidence that when teachers more intensively aim to develop 'deeper learning' capabilities (such as critical thinking and collaboration), students may record higher levels of engagement and self-efficacy, there is no evidence of higher academic achievement in mathematics.[27]

Relatedly, it is often claimed that promoting positive attitudes towards mathematics — typically through real-world applications, attempting to make maths more fun,[28] or introducing more word-based, rather than abstract, problems[29] — can drive improvements in student achievement. However, research has shown that it is generally achievement that predicts attitudes toward mathematics, not the other way around.[30] Moreover, success in mathematics is found to beget further success and confidence in maths,[31] including at an early age.[32 33 34 35]

Another observation is the promotion of games and educational technology in ITE.

Game-based learning is inspired by constructivist theories — namely that students need experiential learning via social interaction with the environment and peers[36] — and is viewed by some as an alternative instructional approach.[37]

However, the research shows that only some — but by no means all — applications and integration of technology into maths education is found to benefit students.[38] There is mixed evidence that educational technology applications are an effective support for students' learning[39 40 41 42 43 44], including low-achieving students,[45 46] nor for substantially lifting motivations and attitudes to learning.[47] While there's some evidence that educational technology tends to suggest it may better to enable development of conceptual rather than procedural,[48] there is little documentation in ITE course outlines that teachers are developing the skills required to confidently provide students with procedural knowledge they will need as a precursor before use of technology for learning.

There is also evidence that educational technology applications, such as games, can result in students being less focussed on assigned learning tasks,[49] particularly beyond an initial novelty period.[50 51] It's been observed that while some educational technology can offer some corrective feedback for students, a weakness is that practice opportunities are rarely matched with overt demonstrations and explanations of content that students need[52] — implying that better incorporations of principles of explicit instruction would improve effectiveness of educational technology applications.[53 54 55 56 57]

Prescribed textbooks for maths teachers promote constructivist teaching approaches

Supporting texts commonly used in ITE courses clearly promote constructivist approaches to teaching mathematics. For example, Helping Children Learn Mathematics by Reys et al., the most commonly prescribed textbook in the units that we studied, states:

> *'…there is a definite shift towards constructivist approaches. Learning is seen less as information being 'poured-in' through direct instruction, and more about the development of concepts and processes through facilitation of rich learning experiences.'* (Page 30, 3rd ed.)

The second most commonly prescribed text, Teaching Primary Mathematics by Booker, Bond, Sparrow and Swan, also privileges constructivist approaches:

"When children construct their own mathematics, that knowledge is both personal and owned; something over which they have control so that their learning experiences empower them rather than leave them relying on procedures that have been developed by someone unknown, in response to problems that are no longer remembered, from a time and situation that no one can recall." (page 17, 5th ed.)

The rhetoric that surrounds constructivist approaches has seemingly contributed to a lack of progress towards approaches that are in line with current theoretical and empirical evidence.

There is no evidence in reviewed prescribed textbooks that explicit instruction is sufficiently described in detail.

Further problems with ITE in Australia

It is not just the course analysis above that should give rise to concerns over ITE in Australia. This analysis confirms a worrying trend identified in other areas as well.

Concerns about ITE extend beyond mathematics to other fundamental skills

Concerns for pre-service teachers' ability to teach reading[58] resulted in a 2019 report into the sector.[59] Examining 116 literacy units in 66 ITE degrees across 38 universities, the report found that only 4 per cent of ITE programs had a specific focus on early literacy and reading instruction. The vast majority allocated insufficient time and coursework to pedagogical strategies, leaving a substantial gap between knowledge and teaching in practice.

Moreover, the review found that most commonly prescribed textbooks in ITE programs often failed to provide information on effective, evidence-based pedagogy. In particular, content rarely specified five core elements of reading instruction: phonemic awareness; phonics; fluency; vocabulary; and comprehension.

The findings reinforced the lack of rigour and limited extent of pedagogical knowledge and training provided by ITE programmes. In large part, ideological debates about how to effectively teach reading — commonly referred to as the 'reading wars' — contributed to the ITE landscape failing to properly embed evidence-based practices.

ITE is failing to prepare early career teachers

International surveys show Australia's teachers are generally less well prepared compared to other OECD countries, and especially compared to Singapore (see Figure below). At least partly, underprepared early career teachers contributes toward underperformance of Australian students, especially in mathematics.

ITE is of special interest because Australia has a larger proportion of early career teachers compared to most other countries. Around 24 per cent of Australian teachers have five years or fewer in experience, which is higher than the OECD average of 19 per cent. The biggest difference compared to other countries is that 40 per cent of teachers in rural areas are novice, compared to 21 per cent in the OECD.

Concerns remain despite repeated policy interventions in ITE

ITE has undergone a series of significant reforms over the past decade. By and large, this has centred on efforts to improve the 'quality' of *teachers*, and to a lesser extent, *teaching* quality.

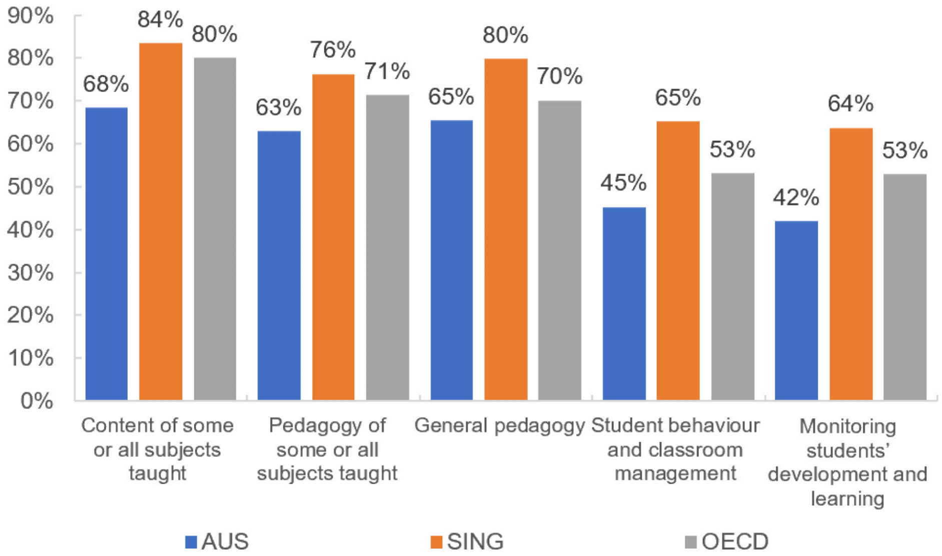
Despite this attention from policymakers, many education academics reject the concerns about ITE quality[60] as a contributor to declines to education outcomes,[61] and instead argue that it unnecessarily promotes a 'deficit framing' and 'negative discourse' around ITE.[62]

A major development has been the Teacher Education Ministerial Advisory Group (TEMAG) in 2014, which committed to improvement in five key areas:[63]

- stronger quality assurance of ITE programs;
- rigorous selection of entrants into initial teacher education;
- robust assessment of graduates;
- improved professional experience for pre-service teachers; and
- national research and workforce planning capabilities.

In 2015, the federal government established the Literacy and Numeracy Test for Initial Teacher Education Students (LANTITE).[64] The test has been introduced as the national means to ensure all beginning teachers meet the standard of achievement equivalent to the top 30 per cent of the adult population. While most teachers successfully pass LANTITE (84 per cent), 11 per cent fail to meet one of the two standards and 5 per cent meet neither.

Percentage of teachers who felt "well prepared" or "very well prepared" for the following elements from their ITE, Australia compared to Singapore and OECD average.



Source: Teachers and Learning International Survey (TALIS) 2018.

Another reform initiative is focussed on attracting high quality teacher candidates. In 2020, the High Achieving Teachers Program was introduced to offer alternative, including employment-based, pathways for individuals pursuing a career in education.[65]

Some measures within TEMAG have specifically targeted the quality and preparedness of ITE graduates — teaching performance assessments (TPAs) and requirements for ITE providers to demonstrate evidence-based practices are reflected in their course offerings.

TPAs, introduced from 2019, are intended to assess 'classroom readiness' of preservice teachers. The TPA requires all pre-service teachers to demonstrate appropriate skills, knowledge and practices prior to graduation. While this is an important development in assessing preservice teachers' practice and knowledge, there are concerns that the TPA process has already become highly bureaucratic. For instance, it is reported there is a 5-to-10-year process to validate and refine a TPA, and there is a complex process aligning TPAs with regulatory requirements. Furthermore, TPAs rely largely on student teachers self-reflecting and collecting evidence of their positive impact on students (such as providing samples of students' work, lesson plans, and self-reflection notes), rather than more directly observing this impact.

A key recommendation of TEMAG, and the national accreditation requirements, is that evidence must underpin the teaching practices taught within the ITE programs. However, national standards and procedures provide only a broad direction for quality teaching (such as demonstrating expert content knowledge and pedagogical content knowledge), without a specific articulation of what effective pedagogical approaches entail.[66]

Moreover, while the Australian Education Research Organisation (AERO) is tasked with "encouraging adoption and effective implementation of evidence in practice and policy", it is not clear there is any process that directly contributes to improving practice and knowledge for early career teachers, because there is no alignment between AERO and teacher training.

Since TEMAG, there has been some incremental improvements in ITE — with fewer low-ATAR course entrants, some consolidation of ITE programmes, and fewer underprepared teachers.[67] However, it is clear that policymakers remain rightly concerned about the sector.

Accordingly, in 2021, the federal government initiated a new Quality Initial Teaching Review. This has a two-fold focus: first, better attracting and selecting high quality candidates into teaching, and second, better preparing graduates to be more effective teachers.

How maths is taught in Australian schools

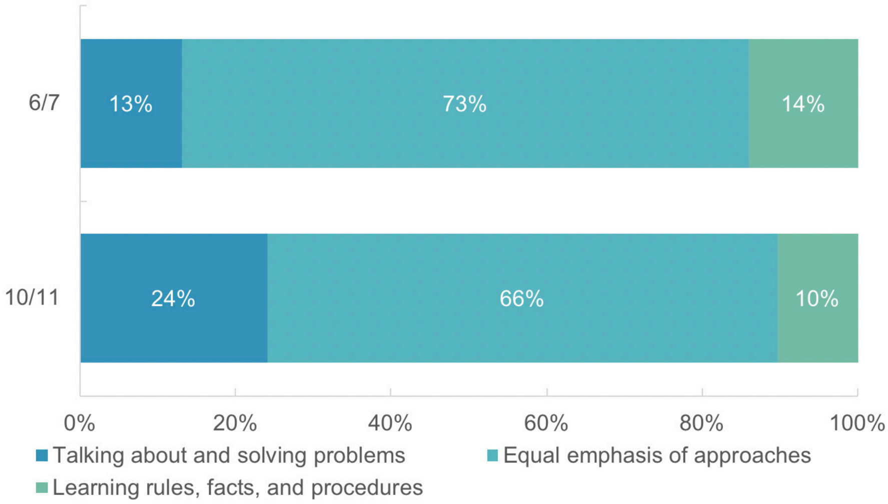
It is perhaps unsurprising that the analysis of ITE courses aligns with evidence from international comparisons of dominant mathematics teaching practices — which find that Australian mathematics classrooms are more likely to favour constructivism rather than instructivism.[68]

Australian policymakers have increasingly promoted inquiry-based approaches to mathematics against international trends

The way maths is taught in schools can also be influenced by policymakers' decisions beyond initial teacher training alone.

The vast majority of Australian teachers report that they employ a mixed emphasis of approaches — between explicit and inquiry-based — in teaching maths. However, by the age of 10, nearly 2.5 times more students receive instruction focussed on inquiry-based methods compared to procedural instruction.

Teachers' reported emphasis in teaching mathematics, students aged 6-7, 10/11.



Source: Longitudinal Study of Australian Children (LSAC); K cohort; Wave 2, Wave 4.

The Australian Curriculum Assessment and Reporting Authority's (ACARA) proposed draft national curriculum, presented in 2021, has also firmly steered towards an inquiry-based approach. Among others, the proposed draft curriculum references to students learning "through the approaches for working mathematically, including modelling, investigation, experimentation and problem solving."

Within the National STEM School Strategy are several associated programmes that appear to heavily preference inquiry-based approaches to mathematics. Among them is *reSolve: Mathematics by Inquiry*. In this national programme, teaching resources and professional development to promote inquiry-based teaching of mathematics is provided to teachers. In addition, over 300 volunteer reSolve 'Champions' are engaged to "promote a spirit of inquiry in school mathematics."

This trend is contrasted by practices in some similar countries and other high-performing school schools.

Trends in the United Kingdom and the United States

In the United States and United Kingdom, major government reviews have generally encouraged policymakers and educators to increase the use of explicit instruction in mathematics.

For instance, as far back as 2008, the National Mathematics Advisory Panel in the United States recommended that all struggling students should receive at least some explicit instruction regularly and that all students should consistently receive some explicit instruction.

Around the same time, in Australia, however, COAG's 2008 National Numeracy Review Report recommended:[69] "*greater emphasis be given to providing students with frequent exposure to higher-level mathematical problems rather than routine procedural tasks, in contexts of relevance to them, with increased opportunities for students to discuss alternative solutions and explain their thinking.*"

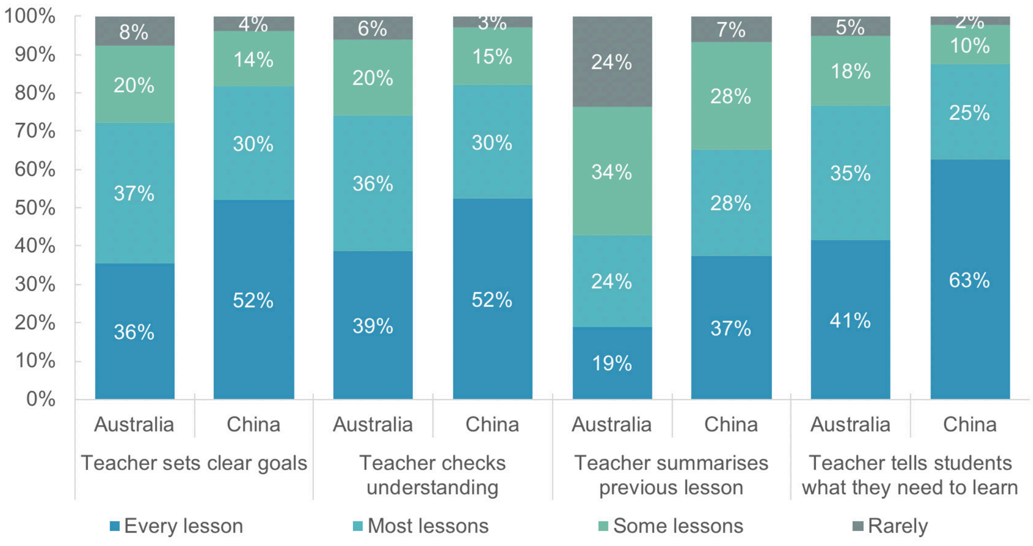
Recently, in the United Kingdom, new analysis and recommendations from the Office for Standards in Education, Children's Services, and Skills (OFSTED) in 2021 has made the case for additional incorporation of explicit instruction, along with a greater emphasis on developing foundational, procedural mathematical knowledge.[70]

Meanwhile, policymakers in the United Kingdom have taken a more direct approach to embedding expectations for the development of explicit instruction for graduate teachers during ITE. The Initial teacher training (ITT) framework specifically notes, for instance, that trainee teachers are advised to "introduce new material in steps and explicitly link new ideas to what has been previously studied," as well as specific reference for teachers to ensure "pupils have repeated opportunities to practice."

Trends in competing East-Asian nations

When comparing Australian maths lessons to those in Hong Kong, Australian lessons have been found to involve less teacher instructional time, more real-life connexions (rather than use of abstract, mathematical arithmetic only), less teacher-presented concurrent problem-solving, less use of procedures in problems, more reporting of solution results alone and less explicit making of connections, less time spent on repeating procedures, less time introducing and practicing new content, and more time spent on low complexity problems.[71] Another study of Hong

Indicators of teacher-led instruction, reported by 15-year-old students, Australia vs participating Chinese school systems.



Source: OECD (2013). PISA 2012 Results: Ready to Learn (Volume III) Students' Engagement, Drive and Self-Beliefs, OECD Publishing, Paris.

Kong classrooms observed greater teacher-directed instruction, greater exposure to instructional content, more advanced content, longer duration problems, detailed explanations of solutions, and more coherent lessons, compared to other countries.[72]

Compared to Singapore, Australian maths classrooms tend to practice more project-based and group activities, along with much higher use of technology for projects and classwork — all of which was associated with lower PISA scores for Australian students.[73]

PISA data shows that Australian teachers, on average, are less likely to employ evidence-based explicit instruction practices, compared to high-performing Chinese school systems.

Compared to Taiwan, TALIS data shows that Australian teachers less frequently: present a summary of recently learned content; set goals at the beginning of a lesson; and explain how new and old topics are related. By contrast, Australian teachers more frequently: have students work on critical thinking tasks; work in small groups; provide larger projects to work on; and (much more frequently) use ICT for projects and class work.

Broader international comparisons of dominant teacher practice in mathematics show that Australia, like other Anglosphere countries, is labelled as favouring 'routine independence'._[74] Among the characteristics of countries included in this category are:

- Low frequency of listening to the teacher explain how to solve problems.
- Low priority to memorisation of rules, procedures and facts.
- High frequency of independent/group work.
- Low use of textbooks as the basis for instruction, instead relying on a variety of resources.
- High frequency of time addressing routine problems and comparatively little spent on complex problem solving.
- Written assessments and quizzes are used relatively infrequently.

This is contrasted with most East Asian countries, mostly labelled as favouring a 'learn, repeat, and check' method._[75] Characteristics of countries in this group include:

- High frequency of listening to the teacher and watching demonstrations of problem solving.
- High frequency of independent working and applying procedures to solve routine problems.
- Lower frequencies than other countries for explaining answers, relating to learning to daily lives or finding own solutions to complex problems.
- Testing is used fairly frequently.

In sum, there is increased emphasis in wider education policy in Australia to promote inquiry-based approaches in mathematics. ITE reform does not happen in a vacuum, with these wider developments clearly impacting on the ITE sector and early career teachers' practices.

How maths should be taught in Australian schools

A wide range of evidence — from experimental laboratory studies, correlational studies based on student achievement, and practice-based evaluations from classrooms — has demonstrated the effectiveness of explicit instruction approaches, especially in mathematics.

Overall effect sizes for explicit instruction are meaningfully large[76 77] — with studies finding very large effects of d=1.14 [78] and (g=1.22)[79], as well as moderate, but still significant, effects of d=0.57, d=0.46[80], d=0.38[81] — with some variation across different effect sizes across different age groups[82] and content areas[83].

This evidence base has most consistently found largest benefits for students with learning difficulties[84 85 86 87], and those academically at risk.[88 89 90 91 92 93 94] However, the research increasingly shows that the benefits of explicit instruction aren't limited to these students[95], but some practice is generalisable to all students.[96 97 98]

A critical conclusion emerging in the literature is that, even though students with mathematical difficulties tend to experience especially large effects from teacher-directed approaches (compared to alternatives), the same approaches are at least as effective, if not more so (compared to alternatives), for students *without* mathematical difficulties.[99] In other words, this provides strong justification for teachers to employ explicit instruction, not only for struggling learners, but for all learners.

To date, the application of explicit instruction in mathematics (and STEM more broadly[100]) has failed to gain the same level of attention from educators and policymakers as reading has over recent decades.[101] In part, this is because many more mathematics teachers often lack the resources and knowledge of how to effectively provide explicit instruction[102] and meet the needs of struggling learners in mathematics.[103 104]

Evidence shows a greater emphasis on explicit instruction would improve student outcomes

Evidence from correlational studies has found that students who receive mostly teacher-directed (with some student-directed) teaching record the highest achievement.[105 106] At the very least, there is also no evidence that mostly inquiry-based instruction is associated with any greater achievement overall.[107]

It is estimated that average PISA scores would increase by the equivalent of around 10 months of schooling, by the age of 15, if students received teacher-led instruction in most or all lessons, and only some student-directed instruction. The same analysis shows that students, on the other hand, who receive inquiry-based instruction in many or all lessons, but teacher-led instruction in none or only some lessons fall over two years of schooling behind. That is, there is significant room to improve overall student achievement in PISA by ensuring all students benefit from teacher-directed instruction in most or all classes.

Other analysis from international assessments shows that students who receive more memorisation and lecture-style teaching in mathematics record higher achievement, while students who receive more daily life examples of content record lower achievement.[108 109 110]

OECD research provides further insight by identifying different effects of teacher-directed instruction based on the nature of problems students are required to solve. For instance, greater exposure to teacher-directed instruction is associated with more success in solving simpler problems, but receiving teacher-directed instruction alone is associated with lower success in solving difficult problems.[111] Accordingly, this implies that most students will benefit most when there is at least some dosage of inquiry-based approaches.

The practice of evidence-based explicit instruction in mathematics

While it's becoming increasingly recognised that there are benefits of explicit instruction as a complete set of practices,[112] researchers have also sought to identify the relative benefits of each specific component of explicit instruction.[113 114 115 116] This has produced evidence of several practices teachers can be confident in applying in classrooms.

Clear teacher demonstrations that manage cognitive load

Effective teacher demonstrations provide concise and unambiguous presentation of concepts and step-by-step models of how to perform operations, along with reasons for the procedures.[117] This frequently takes place at the beginning of lessons and involves the teacher explicitly verbalising the steps to solve mathematical problems.[118 119 120]

Making the thought process public helps to ensure all students have the best chance of understanding the process of solving a problem.[121] Research suggests that students learn best when more explanations are provided for why certain steps are required during an example rather than presenting the solution steps alone.[122] It also appears that demonstrating a series of easy and hard problems with numerous examples is beneficial.[123] A clear contrast is found with inquiry approaches, which tend to downplay the role of the teacher in leading demonstrations.

The reasons that well-executied teacher demonstration is critical for students' learning are outlined in the understanding of cognitive load theory.[124] Simply put, learning is impeded when working memory — which is severely limited in duration and capacity — is overloaded. Constructivist approaches — because of the emphasis on initiating with exploration and the like — routinely impose a significant burden on working memory. Accordingly, there is strong evidence that new and complex material must be properly sequenced for students — with explicit instruction preceding students' inquiry, rather than the other way around.[125] [126]

Guided, scaffolded practice with student verbalisation to develop students' proficiency

Guided practice (as opposed to students' independent practice) involves teachers asking students to communicate the strategies they are using to complete each step of the process and provide reasons for their decisions.[127] [128] Practice opportunities can involve students completing written exercises, manipulating visual representations, and the like. Research on mathematics instruction indicates that frequent, well-designed, guided practice opportunities help students to attain automaticity with essential skills and procedures.

There's also evidence that 'more is better' when it comes to student opportunities to practice (rather than an implied assumption that there is a 'Goldilocks' amount of student practice[129]). There is some evidence to suggest that differentiating how teachers introduce practice opportunities (such as: "Say it with me, we solved this problem by ...") can assist in students' learning.[130] For some domains of maths learning, higher speed practice — such as quick responses and use of efficient counting procedures — is slightly more effective than non-speeded practice, where relations and principles are reinforced.[131] And, generally, increasing the rate of individual response opportunities during core mathematics instruction is found to better support early development of mathematical proficiency.[132]

Importantly, teachers should ask students to explain their solutions and to think aloud in solving problems. Compared to students who attempt to solve problems silently, those that verbalise their steps demonstrate better learning.[133] There's also evidence that students learn better when they verbalise responses back to teachers' questions.[134]

There is strong evidence that student verbalisation during practice can be highly effective when done as a group — in part because it supports the development of a shared language around mathematical problem solving.[135] When properly orchestrated, group student practice opportunities provide multiple students the opportunity to practice in unison. Choral responses can effectively engage all students in practice opportunities simultaneously.[136] Moreover, some research suggests that group practice is as effective, if not more effective, than individual practice in small groups — possibly because struggling learners may be disinclined and less confident to participate when in smaller groups.[137]

For the greatest instructional effectiveness, guided practice is a highly interactive process, involving the teacher working with students in a way to move them gradually towards independence. This process of scaffolding involves the transfer of control for problem solving from the teacher to the student.[138] [139] After solving problems together, students gradually complete more steps with decreasing guidance from the teacher, until students are ready to independently practice content. [140]

A specific instructional strategy that can be implemented during guided practice is worked examples.[141] [142] [143] [144] [145]Two types of worked examples are worked example-problem pairs[146] and faded worked examples.[147] Both approaches follow contemporary theory and are well supported in empirical evidence.[148]

When learning relatively unfamiliar mathematics content, explicit instruction is clearly superior to constructivist approaches. However, with increased familiarity, the advantage decreases, then disappears and finally reverses.[149] Constructivist approaches that emphasise students' inquiry are suitable only after students have developed a level of expertise so their working memories are not overloaded when solving problems.

Immediate corrective feedback to clarify and correct students

Immediate corrective feedback from teachers to students involves clarifying what students have done correctly and what they need to improve, based on students' attempts to solve academic problems.[150] Corrective feedback can, and should, also include reteaching or clarifying instructions when students are not able to respond to questions or their responses are incorrect.

Where possible, teachers should also provide opportunities for students to correct their errors — especially with teacher support in guiding them to solve a problem correctly, often by asking simpler sub-questions. Another effective strategy is for teachers to first model an appropriate response if a student makes an error, then prompt students to correct the response; in turn, reinforcing the steps to solving the problem again. [151]

Research shows that corrective feedback is most effective for low-knowledge learners and in addressing procedural — more so than conceptual — outcomes,[152] but is generally highly impactful for all students (d=0.7).[153] There is evidence that high rates of feedback appear to result in better student learning, whether or not that feedback is corrective or affirming.[154]

By contrast, unguided inquiry encourages making mistakes and discourages correction. Based on the underlying constructivist approach toward pedagogy, student-led inquiry is considered critical to the learning process — meaning that students should be encouraged to try, and to fail, in the pursuit of solving problems and understanding concepts. Accordingly, it's argued that one way to improve teaching of mathematics is to change teachers' attitudes toward 'mistake culture', so that making mistakes isn't a disincentive to students.[155]

Spaced and interleaved practice to facilitate cumulative review

Cumulative review involves students being provided the opportunity to practice — including through reteaching and retesting — information previously covered.[156] [157] [158] Research shows that this review activity can ensure knowledge is maintained over time and helps students see connexions between various mathematical ideas[159] — including weekly and month review. This is contrasted with daily review activity, which focusses on students 'overlearning' basic and foundational material — particularly when it is to be drawn on subsequently in a lesson — so it is readily recalled automatically by students.[160]

However, instructional choices to promote review — particularly whether reteaching or retesting should be prioritised — should be informed by the complexity of information involved.[161] Generally, more complex content should involve reteaching first, followed by retesting, but for more basic facts and skills, retesting is suitable for retrieval practice.

Two evidence-based approaches to effectively facilitate cumulative review are spaced[162] and interleaved practice.[163] Both practices are employed to avoid excessive reliance on 'blocking' — continually practising similar content in one block — but work through different cognitive processes. [164]

Spacing deliberately leaves gaps between practice, in part to recover working memory, as well as an opportunity to partially forget, then recall the information as required. Generally, spacing involves practice of the same information over time. Interleaving involves not only spacing out practice, but also mixing up how information is ordered across different topics.[165] Generally, interleaving involves spacing practice out over time, but with different information across time.

By contrast, inquiry approaches encourage students to explore and make connexions between concepts themselves through their own reflexion, rather than requiring teachers to provide cumulative review activities.

How ITE should be managed

While policymakers have introduced measures intended to improve alignment of ITE courses with evidence-based practice, it is clear from this analysis that it hasn't had the intended impact on ITE providers.

Although Teacher Performance Assessments and ITE Accreditation procedures might be rigorous, the standards that are used to judge ITE programmes are vague and open to interpretation. This means that many ITE courses may notionally meet requirements based on compliance with formalities on paper.

It appears that current ITE assessment procedures appear to have only resulted in ITE providers making tokenistic changes to their programmes rather than the meaningful improvements to practices. Standard 2 of AITSL's Accreditation of Initial Teacher Education Programs in Australia: Standards and Procedures document states:

> *Evidence must underpin all elements of initial teacher education, from the design and delivery of programs to the teaching practices taught within programs. Evidence is the basis on which panels make accreditation recommendations.*

Our analysis shows that some universities, rather than redesign their mathematics units to include evidence-based instructional approaches, appear to have simply labelled constructivist approaches with the terms 'evidence-based' or 'research-based'.

An inspection approach may be the only reliable way to assess the quality of ITE programmes. To guide these inspections, a more detailed, specific framework should be developed which outlines exactly what should be taught in ITE, including the evidence-based practices listed in this paper.

An inspection approach would, among others benefits, determine the effectiveness of ITE programmes based on assessment of preservice teachers' ability to implement explicit instruction, based on an agreed observational checklist or rubric.

Box: ITE inspection in the United Kingdom

ITE providers are inspected for the quality of their curriculum and training annually by the external evaluation agency, the Office for Standards in Education, Children's Services and Skills (OFSTED).The annual inspection consists of a four-day onsite visit — involving observations and interactions with various stakeholders such as programme leaders, trainers, trainees, mentors and employers. ITE program's overall effectiveness is graded on a four-point scale: from inadequate through to outstanding.

The quality of education and training is assessed on the basis of the ITE curriculum, training on pedagogical approaches and assessment of trainees. The assessment includes examining the knowledge and skills taught by the program, how it is being taught, and whether preservice teachers can apply the learnt knowledge and skills into practice. ITE providers must also demonstrate that their curriculum is carefully crafted and based on scientific evidence.

Conclusion

Policymakers and educators alike have demonstrated growing concern about the quality of the ITE sector over recent years. The analysis in this paper validates this concern and puts a specific lens on ITE for beginning mathematics teachers. A special emphasis on mathematics is justified given the trajectory of student outcomes and the need to further develop the mathematics teacher workforce in light of current shortages.

Despite clear evidence of the efficacy of explicit instruction, it is not practiced consistently and regularly in Australia's mathematics classrooms. The analysis shows that high-performing countries more frequently apply the principles and priorities consistent with explicit instruction.

It is clear that a lack of explicit instruction contained in ITE contributes to a lack of explicit instruction in the classroom. For Australian students' mathematics outcomes to improve, ITE must improve with it. For this reason, ITE providers require clear and unambiguous expectations for genuinely incorporating evidence-based practices into their mathematics ITE courses.

Content that would support beginning teachers to implement explicit instruction includes:

- Cognitive Load Theory and its applications.
- Strategies for gaining, maintaining and focusing student attention during whole-class instruction (e.g. choral response, student whiteboards, pair share).
- Questioning and checking for understanding.
- Explicit lesson design including the use of worked examples.
- Strategies to facilitate spaced retrieval practice (e.g. Daily Review, Warm Ups).
- Practice breaking down complex skills into smaller instructional units.

For policymakers to better validate that ITE courses contain sufficient content, observations should be made of performance and capability of graduating teachers to demonstrate relevant practices. Some examples of practices that teachers should be able to demonstrate on completion of mathematics ITE include:

- Clear teacher demonstrations that recognise implications of cognitive load.
- Guided, scaffolded practice opportunities that allow students to students to verbalise.
- Immediate corrective feedback to clarify and confirm students' progress.
- Spaced and interleaved practice to facilitate cumulative review of content.

Appendix

Table A1. Key words identified in ITE course outlines.

ALPHACRUCIS COLLEGE	Bachelor of Education (Primary)	CRS214	• Constructivism • Direct / explicit instruction
ALPHACRUCIS COLLEGE	Bachelor of Education (Primary)	CRS314	• Social construction • Student-centred
AUSTRALIAN CATHOLIC UNIVERSITY	Bachelor of Education (Primary)	EDMA290	
AUSTRALIAN CATHOLIC UNIVERSITY	Bachelor of Education (Primary)	NMBR141	• Real world situations
AUSTRALIAN CATHOLIC UNIVERSITY	Bachelor of Education (Primary)	EDMA291	• Inclusive mathematics pedagogy • Open-ended tasks • Inquiry based learning • Real life contexts • Games • Explicit teaching • Socio-constructivist
CHARLES DARWIN UNIVERSITY	Bachelor of Education Primary	EMA100	
CHARLES DARWIN UNIVERSITY	Bachelor of Education Primary	ESC300	• Real-world problems
CHARLES DARWIN UNIVERSITY	Bachelor of Education Primary	EMA200	• Rich tasks • Open-ended questions
CHARLES STURT UNIVERSITY	Bachelor of Teaching (Primary)	EMM410	• Constructivist principles • Stage appropriate tasks
CHARLES STURT UNIVERSITY	Bachelor of Teaching (Primary)	EMM418	• Constructivist principles • Open-ended problems
CHRISTIAN HERITAGE COLLEGE	Bachelor of Primary Education	CR161	
CHRISTIAN HERITAGE COLLEGE	Bachelor of Primary Education	CR262	• Real-world contexts • Games • Real-world problem • Inquiry
CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDUC1031	• Constructivist approaches
CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDPR2004	• Social constructivist approaches

CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDPR3000	• Social constructivist approach to • Social cultural theories
CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDPR4000	
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	SIT106	
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	ESM211	
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	ESM310	
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	ESM410	• Authentic problem-solving experiences
EDITH COWAN UNIVERSITY	Bachelor of Education (Primary)	MAE1250	
EDITH COWAN UNIVERSITY	Bachelor of Education (Primary)	CUR6020	
EDITH COWAN UNIVERSITY	Bachelor of Education (Primary)	MPE6105	• Games
FEDERATION UNIVERSITY	Bachelor of Education (Primary)	EDBED1012	• Real world problems
FEDERATION UNIVERSITY	Bachelor of Education (Primary)	EDBED3112	
FEDERATION UNIVERSITY	Bachelor of Education (Primary)	EDBED4111	• Real world contexts • Inquiry
FLINDERS UNIVERSITY	Bachelor of Education (Primary), Bachelor of Arts	EDUC2422	
FLINDERS UNIVERSITY	Bachelor of Education (Primary), Bachelor of Arts	EDUC3625	
GRIFFITH UNIVERSITY	Bachelor of Education	2091EDN	
GRIFFITH UNIVERSITY	Bachelor of Education	2092EDN	
GRIFFITH UNIVERSITY	Bachelor of Education	4091EDN	• Real-life situations
LA TROBE UNIVERSITY	Bachelor of Education (Primary)	EDU1LNU	
LA TROBE UNIVERSITY	Bachelor of Education (Primary)	EDU2TPM	
LA TROBE UNIVERSITY	Bachelor of Education (Primary)	EDU4MFU	
MACQUARIE UNIVERSITY	Bachelor of Education Primary and Bachelor of Psychology	EDST2110	
MACQUARIE UNIVERSITY	Bachelor of Education Primary and Bachelor of Psychology	EDST3110	• Inquiry-based models

MONASH	Bachelor of Education (Honours) in Primary Education	EDF1065	• Rich teaching and learning experiences
MONASH	Bachelor of Education (Honours) in Primary Education	EDF2066	• Open-ended tasks • Student-centred inclusive approaches
MONASH	Bachelor of Education (Honours) in Primary Education	EDF3067	• Student-centred inclusive approaches • Inquiry-based
MONASH	Bachelor of Education (Honours) in Primary Education	EDF4075	• Student-centred inclusive approaches
MURDOCH UNIVERSITY	Bachelor of Education (Primary Teaching)	EDN351	• Enable children to construct the knowledge
MURDOCH UNIVERSITY	Bachelor of Education (Primary Teaching)	EDN3102	
QUT	Bachelor of Education (Primary)	EUB111	• Real world contexts • Play
QUT	Bachelor of Education (Primary)	EUB208	
QUT	Bachelor of Education (Primary)	EUB307	• Inquiry • Real world
RMIT	Bachelor of Education	TCHE2458	• Open-ended questions • Rich tasks • Games
RMIT	Bachelor of Education	TCHE2479	• Problem solving tasks
RMIT	Bachelor of Education	TCHE2489	
RMIT	Bachelor of Education	TCHE2348	• Inquiry-oriented approach • Rich
SOUTHERN CROSS UNIVERSITY	Bachelor of Arts/Bachelor of Education (Primary)	MATH1002	
SOUTHERN CROSS UNIVERSITY	Bachelor of Arts/Bachelor of Education (Primary)	EDUC2014	
SOUTHERN CROSS UNIVERSITY	Bachelor of Arts/Bachelor of Education (Primary)	EDUC3012	
SWINBURNE UNIVERSITY	Bachelor of Education (Primary)	EDU10003	• Play • Real world
SWINBURNE UNIVERSITY	Bachelor of Education (Primary)	EDU20002	
SWINBURNE UNIVERSITY	Bachelor of Education (Primary)	EDU30066	
UNIVERSITY OF CANBERRA	Bachelor of Primary Education	9864.3	

UNIVERSITY OF CANBERRA	Bachelor of Primary Education	9883.2	• Learning styles
UNIVERSITY OF CANBERRA	Bachelor of Primary Education	9888.2	• Learning styles
UNIVERSITY OF NEW ENGLAND	Bachelor of Education (K-6 Teaching)	EDME145	
UNIVERSITY OF NEW ENGLAND	Bachelor of Education (K-6 Teaching)	EDME358	• Student-centred • Developmental teaching theories • Investigative activities
UNIVERSITY OF NEW ENGLAND	Bachelor of Education (K-6 Teaching)	EDME369	• Developmental learning sequences
UNIVERSITY OF NEWCASTLE	Bachelor of Education (Primary)	MATH1900	• Real world contexts.
UNIVERSITY OF NEWCASTLE	Bachelor of Education (Primary)	EDUC2749	
UNIVERSITY OF NEWCASTLE	Bachelor of Education (Primary)	EDUC3055	• Play • Problem based learning
UNIVERSITY OF QUEENSLAND	Bachelor of Education (Primary)	EDUC1720	• Problem-solving approach • Real-world
UNIVERSITY OF QUEENSLAND	Bachelor of Education (Primary)	EDUC2730	
UNIVERSITY OF QUEENSLAND	Bachelor of Education (Primary)	EDUC3720	• Authentic and open-ended
UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	167268	
UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	167263	• Children’s construction of mathematical and science understanding • Inquiry based learning
UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	167541	
UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	150267	• Play • Constructivist perspectives
UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EHM1200	
UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EDX3280	
UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EPM4100	

UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EPS2008	• Inquiry-based • Problem-based learning
UNIVERSITY OF SYDNEY	Bachelor of Education (Primary)	EDUP1015	
UNIVERSITY OF TASMANIA	Bachelor of Education (Primary)	EPR220	• Rich tasks • Problem solving • Appropriate pedagogies
UNIVERSITY OF TASMANIA	Bachelor of Education (Primary)	EPR320	• Appropriate pedagogies
UNIVERSITY OF WOLLONGONG	Bachelor of Education	EDMM101	• Problem solving strategies
UNIVERSITY OF WOLLONGONG	Bachelor of Education	MATH132	
UNIVERSITY OF WOLLONGONG	Bachelor of Education	EDKM201	
UNIVERSITY OF WOLLONGONG	Bachelor of Education	EDKM202	• Rich mathematical activities
VICTORIA UNIVERSITY	Bachelor of Education (P-12)	EEC2105	• Rich tasks • Open questions
VICTORIA UNIVERSITY	Bachelor of Education (P-12)	EEC4109	
EASTERN COLLEGE	Bachelor of Education (Primary)	ES611	
EASTERN COLLEGE	Bachelor of Education (Primary)	ES718	
EASTERN COLLEGE	Bachelor of Education (Primary)	ES713	
UNIVERSITY SUNSHINE COAST	Bachelor of Primary Education	EDU118	• Play-based • Inquiry
UNIVERSITY SUNSHINE COAST	Bachelor of Primary Education	EDU209	
UNIVERSITY SUNSHINE COAST	Bachelor of Primary Education	EDU400	• Inquiry based learning experiences

Table A2. Prescribed texts identified in ITE course outlines.

ALPHACRUCIS COLLEGE	Bachelor of Education (Primary)	CRS214			
ALPHACRUCIS COLLEGE	Bachelor of Education (Primary)	CRS314			
AUSTRALIAN CATHOLIC UNIVERSITY	Bachelor of Education (Primary)	EDMA290			
AUSTRALIAN CATHOLIC UNIVERSITY	Bachelor of Education (Primary)	NMBR141			
AUSTRALIAN CATHOLIC UNIVERSITY	Bachelor of Education (Primary)	EDMA291			
CHARLES DARWIN UNIVERSITY	Bachelor of Education Primary	EMA100	Simeon, D., Beswick, K., Brady, K., Faragher, R., & Warren, E. (2011). Teaching mathematics: Foundations to middle years.		
CHARLES DARWIN UNIVERSITY	Bachelor of Education Primary	ESC300	Skamp, K. and Preston, C. (2015). Teaching primary science constructively. 5th ed.		
CHARLES DARWIN UNIVERSITY	Bachelor of Education Primary	EMA200	Mason , J. & Johnston - Wilder , S. (2006) Designing and Using Mathematical Tasks		
CHARLES STURT UNIVERSITY	Bachelor of Teaching (Primary)	EMM410	Jorgensen, R & Dole, S., (2020) Teaching mathematics in primary schools: principles for effective practice	Van de Walle, J.A., Karp, K.A., & Bay-Williams, J.M. (2013). Elementary and middle school mathematics: Teaching developmentally	Cathcart, G (2015) Learning mathematics in elementary and middle schools : a learner-centered approach
CHARLES STURT UNIVERSITY	Bachelor of Teaching (Primary)	EMM418	Simeon, D., Beswick, K., Brady, K., Faragher, R., & Warren, E. (2011). Teaching mathematics: Foundations to middle years.		
CHRISTIAN HERITAGE COLLEGE	Bachelor of Primary Education	CR161			
CHRISTIAN HERITAGE COLLEGE	Bachelor of Primary Education	CR262			
CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDUC1031	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		

CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDPR2004	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDPR3000	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
CURTIN UNIVERSITY	Bachelor of Education (Primary Education)	EDPR4000	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	SIT106	John Mason, Leone Burton, K. C. Stacey Thinking mathematically		
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	ESM211	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics	Sullivan, P. (2018) Challenging mathematical tasks: unlocking the potential of all students	
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	ESM310	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics	Booker, G., Bond, D., Briggs, J., Sparrow, L., & Swan, P. (2014). Teaching primary mathematics (5th ed.).	
DEAKIN UNIVERSITY	Bachelor of Education (Primary)	ESM410	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics	Booker, G., Bond, D., Briggs, J., Sparrow, L., & Swan, P. (2014). Teaching primary mathematics (5th ed.).	
EDITH COWAN UNIVERSITY	Bachelor of Education (Primary)	MAE1250	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics	Budgen, F., & West, J. (2019) Foundations of Primary Mathematics Education: An Introduction	
EDITH COWAN UNIVERSITY	Bachelor of Education (Primary)	CUR6020			

EDITH COWAN UNIVERSITY	Bachelor of Education (Primary)	MPE6105	Budgen, F., & West, J. (2019) Foundations of Primary Mathematics Education: An Introduction	Serow, P., Callingham, R. and Muir, T. (2019) Primary Mathematics: Integrating Theory with Practice	
FEDERATION UNIVERSITY	Bachelor of Education (Primary)	EDBED1012	Booker, G., Bond, D., Briggs, J., Sparrow, L., & Swan, P. (2014). Teaching primary mathematics (5th ed.).		
FEDERATION UNIVERSITY	Bachelor of Education (Primary)	EDBED3112			
FEDERATION UNIVERSITY	Bachelor of Education (Primary)	EDBED4111			
FLINDERS UNIVERSITY	Bachelor of Education (Primary), Bachelor of Arts	EDUC2422	Van de Walle, J.A., Karp, K.A., & Bay-Williams, J.M. (2013). Elementary and middle school mathematics: Teaching developmentally (8th ed.). Boston, MA : Pearson.		
FLINDERS UNIVERSITY	Bachelor of Education (Primary), Bachelor of Arts	EDUC3625			
GRIFFITH UNIVERSITY	Bachelor of Education	2091EDN			
GRIFFITH UNIVERSITY	Bachelor of Education	2092EDN	Jorgensen, R & Dole, S., (2020) Teaching mathematics in primary schools: principles for effective practice		
GRIFFITH UNIVERSITY	Bachelor of Education	4091EDN			
LA TROBE UNIVERSITY	Bachelor of Education (Primary)	EDU1LNU			
LA TROBE UNIVERSITY	Bachelor of Education (Primary)	EDU2TPM	Booker, G., Bond, D., Briggs, J., Sparrow, L., & Swan, P. (2014). Teaching primary mathematics (5th ed.).		
LA TROBE UNIVERSITY	Bachelor of Education (Primary)	EDU4MFU	Booker, G., Bond, D., Briggs, J., Sparrow, L., & Swan, P. (2014). Teaching primary mathematics (5th ed.).		

MACQUARIE UNIVERSITY	Bachelor of Education Primary and Bachelor of Psychology	EDST2110			
MACQUARIE UNIVERSITY	Bachelor of Education Primary and Bachelor of Psychology	EDST3110			
MONASH	Bachelor of Education (Honours) in Primary Education	EDF1065			
MONASH	Bachelor of Education (Honours) in Primary Education	EDF2066			
MONASH	Bachelor of Education (Honours) in Primary Education	EDF3067			
MONASH	Bachelor of Education (Honours) in Primary Education	EDF4075			
MURDOCH UNIVERSITY	Bachelor of Education (Primary Teaching)	EDN351	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
MURDOCH UNIVERSITY	Bachelor of Education (Primary Teaching)	EDN3102			
QUT	Bachelor of Education (Primary)	EUB111			
QUT	Bachelor of Education (Primary)	EUB208			
QUT	Bachelor of Education (Primary)	EUB307			
RMIT	Bachelor of Education	TCHE2458			
RMIT	Bachelor of Education	TCHE2479			

RMIT	Bachelor of Education	TCHE2489	Simeon, D., Beswick, K., Brady, K., Faragher, R., & Warren, E. (2011). Teaching mathematics: Foundations to middle years.		
RMIT	Bachelor of Education	TCHE2348			
SOUTHERN CROSS UNIVERSITY	Bachelor of Arts/Bachelor of Education (Primary)	MATH1002	Angel, AR, Abbott, CD & Runde, DC, 2019, Foundations: mathematics and numeracy,		
SOUTHERN CROSS UNIVERSITY	Bachelor of Arts/Bachelor of Education (Primary)	EDUC2014	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
SOUTHERN CROSS UNIVERSITY	Bachelor of Arts/Bachelor of Education (Primary)	EDUC3012	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
SWINBURNE UNIVERSITY	Bachelor of Education (Primary)	EDU10003			
SWINBURNE UNIVERSITY	Bachelor of Education (Primary)	EDU20002	Brady, K. & Winn, T., (2017). Maths skills for success at university.		
SWINBURNE UNIVERSITY	Bachelor of Education (Primary)	EDU30066			
UNIVERSITY OF CANBERRA	Bachelor of Primary Education	9864.3	Brady, K. & Winn, T., (2017). Maths skills for success at university.	Simeon, D., Beswick, K., Brady, K., Faragher, R., & Warren, E. (2011). Teaching mathematics: Foundations to middle years.	Peter Sullivan, Pat Lilburn (2017) Open Ended Maths Activities
UNIVERSITY OF CANBERRA	Bachelor of Primary Education	9883.2	Simeon, D., Beswick, K., Brady, K., Faragher, R., & Warren, E. (2011). Teaching mathematics: Foundations to middle years.	Sullivan, P., Lilburn, P. (2017) Open Ended Maths Activities	
UNIVERSITY OF CANBERRA	Bachelor of Primary Education	9888.2	Simeon, D., Beswick, K., Brady, K., Faragher, R., & Warren, E. (2011). Teaching mathematics: Foundations to middle years.	Sullivan, P., Lilburn, P. (2017) Open Ended Maths Activities	

UNIVERSITY OF NEW ENGLAND	Bachelor of Education (K-6 Teaching)	EDME145	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
UNIVERSITY OF NEW ENGLAND	Bachelor of Education (K-6 Teaching)	EDME358	Serow, P., Callingham, R. and Muir, T., Cambridge University Press 3rd ed. 2019 Primary Mathematics: Integrating Theory with Practice		
UNIVERSITY OF NEW ENGLAND	Bachelor of Education (K-6 Teaching)	EDME369	Van de Walle, J.A., Karp, K.A., & Bay-Williams, J.M. (2013). Elementary and middle school mathematics: Teaching developmentally (8th ed.). Boston, MA : Pearson.		
UNIVERSITY OF NEWCASTLE	Bachelor of Education (Primary)	MATH1900			
UNIVERSITY OF NEWCASTLE	Bachelor of Education (Primary)	EDUC2749			
UNIVERSITY OF NEWCASTLE	Bachelor of Education (Primary)	EDUC3055			
UNIVERSITY OF QUEENSLAND	Bachelor of Education (Primary)	EDUC1720	Haylock, D., & Manning, R 2018, Mathematics Explained for Primary Teachers,,		
UNIVERSITY OF QUEENSLAND	Bachelor of Education (Primary)	EDUC2730	Van de Walle, J.A., Karp, K.A., & Bay-Williams, J.M. (2013). Elementary and middle school mathematics: Teaching developmentally (8th ed.). Boston, MA : Pearson.		
UNIVERSITY OF QUEENSLAND	Bachelor of Education (Primary)	EDUC3720	Van de Walle, J.A., Karp, K.A., & Bay-Williams, J.M. (2013). Elementary and middle school mathematics: Teaching developmentally (8th ed.). Boston, MA : Pearson.		

UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	167268	Van de Walle, J.A., Karp, K.A., & Bay-Williams, J.M. (2013). Elementary and middle school mathematics: Teaching developmentally (8th ed.). Boston, MA : Pearson.		
UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	167263	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	167541	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
UNIVERSITY OF SOUTH AUSTRALIA	Bachelor of Primary Education	150267	Van de Walle, J.A., Karp, K.A., & Bay-Williams, J.M. (2013). Elementary and middle school mathematics: Teaching developmentally (8th ed.). Boston, MA : Pearson.	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics	
UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EHM1200	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EDX3280	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics		
UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EPM4100			
UNIVERSITY OF SOUTHERN QUEENSLAND	Bachelor of Education (Primary)	EPS2008	Booker, G., Bond, D., Briggs, J., Sparrow, L., & Swan, P. (2014). Teaching primary mathematics (5th ed.).	Haylock, D., & Manning, R. (2018) Mathematics Explained for Primary Teachers	Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J., Frid, S., & Bennett, S. (2019). Helping children learn mathematics
UNIVERSITY OF SYDNEY	Bachelor of Education (Primary)	EDUP1015			

UNIVERSITY OF TASMANIA	Bachelor of Education (Primary)	EPR220			
UNIVERSITY OF TASMANIA	Bachelor of Education (Primary)	EPR320			
UNIVERSITY OF WOLLONGONG	Bachelor of Education	EDMM101			
UNIVERSITY OF WOLLONGONG	Bachelor of Education	MATH132			
UNIVERSITY OF WOLLONGONG	Bachelor of Education	EDKM201			
UNIVERSITY OF WOLLONGONG	Bachelor of Education	EDKM202	Booker, G., Bond, D., Briggs, J., Sparrow, L., & Swan, P. (2014). Teaching primary mathematics (5th ed.).		
VICTORIA UNIVERSITY	Bachelor of Education (P-12)	EEC2105			
VICTORIA UNIVERSITY	Bachelor of Education (P-12)	EEC4109			
EASTERN COLLEGE	Bachelor of Education (Primary)	ES611			
EASTERN COLLEGE	Bachelor of Education (Primary)	ES718			
EASTERN COLLEGE	Bachelor of Education (Primary)	ES713			
UNIVERSITY SUNSHINE COAST	Bachelor of Primary Education	EDU118	Goos, M., Geiger, V., Dole, S., Forgasz, H., & Bennison, A. (2019). Numeracy Across the Curriculum		
UNIVERSITY SUNSHINE COAST	Bachelor of Primary Education	EDU209	Jorgensen, R & Dole, S., (2020) Teaching mathematics in primary schools: principles for effective practice		
UNIVERSITY SUNSHINE COAST	Bachelor of Primary Education	EDU400	Jorgensen, R & Dole, S., (2020) Teaching mathematics in primary schools: principles for effective practice		

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