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ARTICLE

Supporting successful outcomes in mathematics for Aboriginal and Torres Strait Islander students: a systematic review

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ABSTRACT

Research driven by government policy in mathematics education has focused on determining teaching and learning strategies to promote engagement for Aboriginal and Torres Strait Islander students. The aim of this study is to systematically review empirical research from 2008–2017 that examines ways to promote engagement and support successful outcomes for Aboriginal and Torres Strait Islander students in mathematics. A total of 28 articles were included in the review, and they were examined in relation to research design and the theoretical framework of engagement. Findings indicate that the majority of research conducted are qualitative studies focusing on primary school teachers changes in learning content knowledge and pedagogical content knowledge to teach mathematics. There are limited studies with regards to students' behavioural and emotional engagement in mathematics. Finally, teaching strategies that support learning in mathematics including, focusing on language and mathematical patterns and representations are identified.

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Introduction

Quality education for all students, and in particular improving the educational outcomes for Aboriginal and Torres Strait Islander students has been a focus of policy documents in Australia since the early 1980s (e.g., NSW Aboriginal Education Policy 1982 revised and launched in 1996). Despite this, there continues to be disparities between Indigenous and non-Indigenous students in particular school subject areas such as mathematics. In 2008, as a means to address these disparities, there were specific policy (e.g., Closing the Gap) targets to address student achievement in mathematics. A number of government-funded research projects were carried out to address key issues in schools with respect to the teaching and learning of mathematics in the hope that this would address the education outcomes. This systematic review examines research that has been undertaken in Australian during this time period (2008–2017), to seek to identify particular teaching and learning strategies that promote engagement that has the potential to lead to

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successful outcomes in mathematics for Aboriginal and Torres Strait Islander students. The systematic review reported in this paper is part of a larger study, *the Aboriginal Voices project*, that examines 10 critical areas in education for Aboriginal and Torres Strait Islander learners (Lowe et al., 2019).

Young Australian Indigenous students have been identified as one of the most disadvantaged groups in education (Gonski et al., 2011). We emphasise that this is not of reflection of Indigenous people or students themselves, rather a system of education that is yet to build on the strengths and knowledges of Indigenous peoples so that young Indigenous students are empowered in schooling. It is from this strengths-based perspective that we emphasise that young Indigenous students need to be positioned for mathematical success; as understanding and having success in mathematics empowers and assists all students (both Indigenous and non-Indigenous) future life decisions (e.g., social and economic) (Council for the Australian Federation, 2007). Despite the number of education policies and initiatives that focus on supporting and improving mathematical achievement for Indigenous students, the outcomes are yet to reach the targets projected. Past studies have explored the reasons why these initiatives have been unsuccessful and conclude that: (a) the mathematics curriculum impacts on student learning (Howard, 1997); (b) students have difficultly negotiating between cultures and seeing the value of what is being taught (Aikenhead, 2001; Cooper, Baturo, & Warren, 2005); and (c) at times, teaching practices fail to be inclusive (Howard & Perry, 2005). Hence, to date, there is a limited understanding of how teachers can engage students in mathematics, that promotes success and capitalises on the mathematical knowledge Aboriginal and Torres Strait Islander students bring to the classroom.

Theoretical framework of engagement

Engagement has been shown to have the largest effect on students' academic growth and is a predictor for school success (Reschly & Christenson, 2012). However, while many papers claim that students are engaged as a result of participating in particular mathematical programmes, few studies have considered this from both the teachers' and students' perspectives as well as across the three aspects of engagement as defined by Fredricks, Blumenfeld, and Paris (2004) *behavioural, emotional* and *cognitive* engagement (e.g., Durksen et al., 2017; Miller, Warren, & Armour, 2019; Skilling, Bobis, Martin, Anderson, & Way, 2016). For the purpose of this paper, we draw on this theoretical framework (Fredricks et al., 2004) as a tool to better understand the research in relation to Aboriginal and Torres Strait Islander students learning in mathematics. While, this framework provides a construct to understand student engagement, we adopt this framework to conceptualise engagement for both teachers and students across the three constructs (behavioural, emotional and cognitive) (Miller et al., 2019). *Behavioural engagement* pertains to the notion of participation, partaking in academic, social or extracurricular activities. For example, in particular students' conduct in class and their time on-task during mathematics instruction (Peterson, Swing, Stark, & Waas, 1984) or teachers teaching more mathematics. *Emotional engagement* encompasses the reactions (both positive and negative) that students have to teachers (and vice versa), classmates, and school (Stipek, 2002) and also in relation to reactions to the content that they are learning (feeling positive or negative about mathematics). We would also suggest that emotional

engagement for teachers is their reactions (positive or negative) about the subject and teaching the subject. *Cognitive engagement* incorporates the effort required to understand complex tasks and master difficult procedures and concepts. It is exhibited by students' motivation to work hard, their ability to cope with failure, and their flexibility when solving problems (Connell & Wellborn, 1991). For the purpose of this paper, this is also considered to be the case for teachers.

Aim of this study

The aim of this study is to systematically review literature related to teaching and learning strategies that promote engagement in mathematics for Aboriginal and Torres Strait Islander students. The following research questions are pursed:

- What research designs and methods are used to determine engagement that promotes positive mathematical outcomes for Aboriginal and Torres Strait Islander students?
- In what ways are the three aspects of engagement being studied? Which aspects are missing from this data set of papers?
- What professional learning support is most effective for teachers to help them develop the teaching and learning strategies including the necessary knowledge and skills for improving engagement for Aboriginal and Torres Strait Islander students?

Method

This paper reports on a protocol-driven and quality-focused systematic review (Bearman et al., 2012; Gough, 2007; Lowe et al., 2019) undertaken to examine teaching and learning strategies that promote engagement and successful outcomes for Aboriginal and Torres Strait Island students in mathematics. A systematic review of empirical research was conducted across 10 databases (A+ Education, AEI-ATSI, EBSCo, ERIC, Family ATSI, Indigenous Australia database, Indigenous collection database, MathEduc, Scopus, Web of Science). The initial search was driven by four key research concepts that underpinned the research question: (1) identifying cultural group; (2) numeracy and/or mathematics; (3) school type; and, (4) teaching and learning. Each of these research concepts had specific search terms (keywords; subject headings) as defined by the database. Table 1 provides an example of the keywords used in the initial search. These specific terms were

Table 1. Example of keywords for each concept used to search databases.

Concept 1: Cultural group	Concept 2: Numeracy and/mathematics	Concept 3: School type	Concept 4: Teaching and learning
Indigenous	Numeracy	Early childhood	Pedagog*
Aborigin*	Math*	Primary	Teach*
Torres Strait Australia		Secondary	Learn*

NB – * By using truncation characters at the end of terms (*) it is specified that the search algorithms of databases includes all possible word endings (e.g. learns, learner or learning).

searched across the titles, keywords, and abstracts in the selected databases with no defining parameters for publication dates.

In total, the results of the initial search yielded 551 publications. Each concept was individually searched and then combined at the end. Not all databases had keywords for each concept. In addition, some concepts were not necessary to search in particular databases. For example, concept one (identifying cultural group) was not searched in ASI-ATSI, Family ATSI, Indigenous collection database, and Indigenous Australian database as these databases only contained literature pertaining to Aboriginal and Torres Strait Islander people. Table 2 displays the initial outcome of the search with respect to each database/hand search and concept.

Exclusion criteria

The publications that were retrieved from the initial search were then examined against the exclusion criteria developed as part of the protocol for the study. The following provides the clear exclusion criteria used:

Exclusion criteria 1: Any duplicate publication was removed (124 excluded; 479 remaining).

Exclusion criteria 2: The publication must have been in print between the dates 1 January 2008 and 31 December 2017 (266 excluded; 213 remaining)

Exclusion Criteria 3: The publication must report on empirical data. These publications must be peer-reviewed. Hence, government reports, editorials (narrative) literature reviews, discussion papers, theoretical articles or commentaries were excluded (17 excluded; 196 remaining).

Exclusion Criteria 4: The participants of the study are not Australian (e.g., participants from Canada and Hawaii) (84 excluded; 112 remaining)

Exclusion Criteria 5: The review focuses on the teaching and learning of mathematics in either early childhood, primary or secondary settings. Thus, articles relating to mathematics and health outcomes, mathematics in other subjects (e.g., science) and tertiary settings were excluded (55 excluded; 57 remaining).

Table 2. Search outcomes for each database.

Database	Concept 1	Concept 2	Concept 3	Concept 4	Final
A+ Education	6535	14,305	63,455	8206	40
Ebsco	793	37,159	-	-	28
Scopus	24,306	291 828	-	-	152
Eric	3706	10,759	-	-	20
AEI-ATSI	-	164	-	216	24
Family ATSI	-	53	141	-	18
Indigenous Collection database	-	128	88	-	88
Indigenous Australian Database	-	44	-	-	44
Web of Science	77,790	64,943			102
MathsEduc	35	-	-	-	35
Proquest					2
Hand search by team*					50
TOTAL					603

NB: A hand search was also conducted by the researchers for key publications including past reviews in mathematics education (e.g., RiMEA). This yielded further 50 articles.

Exclusion Criteria 6: Where there were conference papers which had been further developed into journal articles by authors; the journal articles were selected for the systematic review (29 excluded; 28 remaining).

After applying these six exclusion criteria, there were remaining 28 papers to appraise.

Appraisal process

The remaining 28 papers were examined by three researchers to determine the relevance and appropriateness of the studies collated to answer the research question posed. Any disagreements between researchers that were raised were discussed until there was a consensus among the team. Each paper was reviewed and summarised by the researchers independently and then cross-check to determine consensus between the researchers. This process examined more closely the theoretical framework, research questions, sample size, participants, research design and methods, and main results of each of the 28 papers. All papers were considered appropriate for the systematic review.

Results

The following section presents the results of the systematic review answered in relation to the research questions posed. First, the research design and methods are analysed. Second, the findings are presented in relation to the three constructs of engagement aligned with participants. Finally, the papers have been analysed to identify the teaching and learning strategies that promote engagement in mathematics for Aboriginal and Torres Strait Islander students.

What research designs and methods are used to determine engagement that promotes positive mathematical outcomes for Aboriginal and Torres Strait Islander students?

Table 3 presents the studies included in the systematic review with descriptions of the participants, location, research design and methods employed.

Locations and participants

From the analysis of the papers identified, 36% of papers report studies that were conducted in Queensland, 25% from Western Australia and 14% from New South Wales. There appeared to be fewer studies identified in the systematic review from contexts such as Northern Territory (two studies) and no research from Tasmania, South Australia or Victoria. By no means does this mean that there has not been research conducted in these areas, rather there were no identified studies yielded in this systematic review.

There are a range of participants that were identified in the studies including, primary and secondary students, Indigenous and non-Indigenous teachers, Indigenous teacher assistants, principals, parents and community members. There appeared to be more studies focusing on primary school contexts rather than secondary school contexts. There were two studies that examined the teaching and

Table 3. Participants, research locations, research designs and methods employed for the studies.

	Author (Year)	Population studies	Location	Research design	Data collection instruments
1	Armour, Warren, and Miller (2016)	20 primary school Indigenous Teacher Assistants	Queensland	Qualitative	Semi-structured interviews
2	Baturo et al. (2008)	7 Primary and 4 secondary Indigenous Teacher Assistants	Queensland	Qualitative	Observations and informal interviews
3	Edmonds-Wathen (2014)	Senior Iwaidja language consultants, 5 caregivers (parents/grandparents) 8 children	Northern Territory	Qualitative	Task-based Interviews
4	Edmonds-Wathen (2015)	5 teachers	Northern Territory	Qualitative	Semi-structured interviews
5	Ewing et al. (2014)	4 teachers/trainers 1 principal 5 students	Queensland	Mixed methods	Questionnaire surveys Semi structure interviews
6	Grootenboer and Sullivan (2013)	56 Indigenous primary school students Years 3–6.	North-Western Australia	Quantitative	a task-based, one-on-one interview that focused on mathematical concepts related to measurement
7	Hurst and Sparrow (2012)	4 Aboriginal Education officers	Western Australia	Qualitative	Semi-structured interviews
8	Jacob and McConney (2013)	35 primary school teachers	Western Australia	Mixed methods	Pre- and post-questionnaires Follow up interviews.
9	Jorgensen (2015)	Teachers	Western Australia	Qualitative	Teacher interviews
10	Jorgensen (2016)	16 principals 1deputy principals 29 teachers 6 Aboriginal Education Workers	Region not identified (10 remote schools from 1 State)	Qualitative	Interviews
11	Jorgensen et al. (2013)	25 Teachers	North-Western Australia	Mixed methods	Data were collected through a questionnaire (n = 25) that was completed by all the teachers in the participating schools at the start of the project, and video-taped mathematics lessons over the first 2 years of the study (n = 16).
12	Kidman, Cooper, and Sandhu (2012)	3 Teacher aides (2 – Indigenous women; 1 man of African dissent)3 Secondary teachers	Queensland	Qualitative	General classroom observations Specific classroom observations Semi-structured interviews
13	Leder and Forgasz (2012)	89 Indigenous students from Kindergarten – Year 2	Not identified – part of the Make it count project	Mixed methods	Attitude Survey – multiple choice and open-ended items
14	McDonald et al. (2011)	40 primary school teachers	Queensland	Qualitative	Interviews
15	Miller (2015)	2 Year 3 students	Queensland	Mixed methods	Pre-test Lesson observations Interviews
16	Owens (2015)	16 teachers including principals 4 other staff 8 parents and elders 14 students	New South Wales	Qualitative	Interviews and yarning sessions

(*Continued*)

Table 3. (Continued).

	Author (Year)	Population studies	Location	Research design	Data collection instruments
17	Papic (2015)	217 students from 13 Australian Aboriginal Community Children's Services	New South WalesAustralian Capital Territory (1 centre)	Quantitative	One-on-one pre-test interview
18	Papic (2013)	15 Aboriginal children attending an Aboriginal Children's Service 3 Teachers	New South Wales	Case Study	One-on-one student interview Documenting student learning Focus group session with teachers
19	Papic, Mulligan, Highfield, McKay-Tempest, and Garrett (2015)	From 15 Australian Aboriginal Community Children's Services, 66 early childhood educators 255 children aged 4–5 years in the year prior to formal school (125 children in 2011 and 130 children in 2012)	New South WalesAustralian Capital Territory (1 centre)	Qualitative	Photos, observations, children's drawing and teachers' documentation supported the progression data. Teachers' planning documentation – daybooks and planning documentation throughout the duration of implementation.
20	Pegg and Graham (2013)	453 Middle school Aboriginal and Torres Strait Islander students. There are also non-Indigenous students and comparison participants.	North Coast Region and the New England Region of New South Wales (NSW), and the Northern Territory	Quantitative	Pre-post testing with students. PATMath – NSW cohort NT Department designed test – NT cohort
21	Sarra and Ewing (2014)	6 children aged 2–4 years old 1 Principal	New South Wales	Mixed methods	Diagnostic task-based interviews Interview with principal Photographic evidence School observations
22	Sullivan et al. (2013)	16 primary school teachers	Western Australia	Qualitative	Video-taped classroom lesson observations (32 lessons)
23	Treacy (2013)	47 Aboriginal students from Kindergarten to Year 3	Western Australia	Quantitative	Interviews (in English and Kriol)
24	Treacy et al. (2015)	18 Aboriginal students from Year 1- Year 11	Western Australia	Qualitative	Interviews
25	Warren and DeVries (2009)	7 Teachers 125 Students (14 Indigenous students) Seven Prep schools	Queensland	Mixed Methods	Pre- and post-intervention tests Student portfolios classroom Observations teacher interviews
26	Warren and Miller (2013)	230 Indigenous students from Prep – Year 1	Queensland	Mixed methods	Pre-post mathematics test Pre-post mathematical language test
27	Warren and Miller (2016)	1738 Students (660 Indigenous students) 21 Teachers 19 Indigenous Teacher Assistants	Queensland	Mixed Methods	Pre-post mathematics test Semi-structured interviews
28	Warren et al. (2010)	17 Teachers 24 Indigenous Teacher Assistants 430 students (280 Indigenous students)	Queensland	Mixed Methods	Teacher Surveys Diagnostic mathematics tests for students Attitude surveys for students Observations of classroom practices and student responses Semi-structured interviews Discussions with teachers and teacher assistants Artefacts – unit plans, lessons examples of student work

learning of mathematics with children from early childhood settings (prior to formal schooling) (e.g., Papic, 2015; Sarra & Ewing, 2014).

There were nine studies that focused on more than one participant group, for example, Indigenous teacher assistants, teachers, students and parents/community members. Of the remaining studies, seven papers focused on students, six papers focused on teachers, and three papers focused on Indigenous teacher assistants. It is apparent from the studies that have been conducted and published between 2008–2017 there was a focus on multi-participant as a means to better understand the teaching and learning strategies that are needed to support positive engagement in mathematics. In addition, different sample sizes were apparent from the analysis, with a case study presenting two students mathematical thinking (e.g., Miller, 2015) through to a study which measured the pre and post-test results of 660 Indigenous primary school students (e.g., Warren & Miller, 2016).

Research design and data collection instruments

Studies differ with regard to the types of research design and data collection instruments used for the studies. Majority of papers used a qualitative design (13 studies, 46%), followed by mixed methods (11 studies, 39%), followed by quantitative methods (4 studies, 14%). Majority of the qualitative and mixed methods studies used interviews (79%) as a basis to collect data (e.g., semi-structured interviews, task-based interviews) which can be seen in Table 3. Studies also utilised video-taped classroom observations (e.g., Jorgensen, Grootenboer, & Niesche, 2013; Sullivan, Jorgensen, Boaler, & Lerman, 2013); pre and post-testing (e.g., Pegg & Graham, 2013; Warren & Miller, 2016, 2013); and attitude surveys (e.g., Leder & Forgasz, 2012; Warren, Cooper, & Baturo, 2010).

In what ways are the three aspects of engagement being studied? Which aspects are missing from this data set of papers? The term "engagement" is often used in mathematics education to encapsulate the way in which students may participate in the classroom. Applying Fredricks et al. (2004), framework for engagement to each of the papers, provides insight as to the types of engagement discussed in Australian research literature focusing on the improvement of teaching and learning for Indigenous students. For the purpose of this paper, each of the research articles were examined in relation to the following six categories: teacher behavioural, teacher emotional engagement, teacher cognitive engagement, student behavioural engagement, student emotional engagement, and student cognitive engagement. The data displayed in Table 4 shows the spread of studies that have focused on either teachers or Indigenous Teacher Assistants reporting on their own behavioural, emotional or cognitive engagement with mathematics or their perceptions of student changes in engagement in mathematics. It is important to note that some of these papers emerged from large research projects with multi-faceted approaches and multiple participants hence they appear in more than one category.

Analysis of the papers reveal that majority of publications present data with a focus on changes in teachers' cognitive engagement, for example, improvements in mathematical content knowledge and pedagogical knowledge, or identifying students' cognitive engagement with mathematics, for example, how students learn particular concepts or changes in knowledge of mathematics content after an intervention has taken place.

It appears that there is a number of papers that report data from the teachers' perspective. A reason for this was that much of the government funding during this

Table 4. Papers data reported in relation to participants behavioural, emotional and cognitive engagement.

	Behavioural	Emotional	Cognitive
Teacher data (e.g., interviews, surveys, lesson observations)	Jorgensen et al. (2013), Papic et al. (2015), Sullivan et al. (2013), Warren and Miller (2016)	Hurst and Sparrow (2012), McDonald et al. (2011), Papic (2013), Warren and Miller (2016)	Edmonds-Wathen (2015), Hurst and Sparrow (2012), Jacob and McConney (2013), Jorgensen (2015), Jorgensen (2016), Jorgensen et al. (2013), McDonald et al. (2011), Owens (2015)*, Papic, 2013, Sullivan et al. (2013), Warren et al. (2010), Warren and Miller (2016).
Teachers perceptions of changes in students	Papic et al. (2015), Warren and Miller (2016)	Hurst and Sparrow (2012), Papic (2013), Papic et al. (2015), Warren and Miller (2016)	Hurst and Sparrow (2012), Papic (2013), Papic et al. (2015), Pegg and Graham (2013), Warren et al. (2010), Warren and Miller (2016)
ITAS data (e.g., interviews)	Armour et al. (2016), Baturo et al. (2008), Warren and Miller (2016)	Armour et al. (2016), Baturo et al. (2008), Kidman et al. (2012), Pegg and Graham (2013), Warren and Miller (2016)	Armour et al. (2016), Baturo et al. (2008), Kidman et al. (2012), Warren and Miller (2016)
ITAs perceptions of changes in students	Warren and Miller (2016)	Kidman et al. (2012), Warren and Miller (2016)	Kidman et al. (2012), Warren and Miller (2016)
Student data (e.g., task-based designed interviews, pre and post testing; attitude survey)		Leder and Forgasz (2012)	Edmonds-Wathen (2014), Grootenboer and Sullivan (2013), Miller (2015), Papic (2013), Papic (2015), Papic et al. (2015), Pegg and Graham (2013), Sarra and Ewing (2014), Treacy (2013), Treacy, Frid and Jacob (2015), Warren and DeVries (2009), Warren and Miller (2016), Warren and Miller (2013)

NB: indicates an evaluation study of other projects.

period of time focused on research projects that provided professional learning to teachers. Of concern is the lack of research reflected from the perspectives of Indigenous teachers and Indigenous teacher assistants. It is unclear how Indigenous teacher assistants engaged with professional learning and mathematics education programmes that have been implemented in their schools.

Finally, there is a paucity in the research with regards to student behavioural and emotional engagement from the perspective of the student. While student data has been drawn on to demonstrate the effect of professional learning/programme implementation, identify ways in which Indigenous student learn particular mathematical concepts, and use their home language to communicate their mathematical ideas, little is known about their emotional or behavioural changes. As such, at this stage, it is difficult to draw conclusions as to the perceived changes students experience as participate they in particular mathematical interventions. This only appears to be largely reported from a teachers' perspective.

What professional learning support is most effective for teachers to help them develop the teaching and learning strategies including the necessary knowledge and skills for improving engagement for Aboriginal and Torres Strait Islander students?

The following section will present the analysed data under three emerging themes: (i) professional learning models; (ii) importance of language; and finally, (iii) structures and representations of mathematics. It is important to acknowledge that language, mathematical structures and representations are all closely related constructs and while presented separately in this discussion, there is overlap and consideration to have an equal focus on these aspects in the teaching and learning of mathematics.

Professional learning models: enhancing mathematical content knowledge and pedagogical knowledge for teachers and indigenous teacher assistants

There were a number of key projects mentioned across the papers in this systematic review; for example, Mathematics in the Kimberley's, RoleM (representations, oral language and engagement in mathematics), Make it Count, and Yumi Deadly Mathematics. Majority of these studies took a whole school approach where researchers were working alongside schools and communities to implement, design and trial professional learning on site. Central to each of these projects was the focus on providing professional learning to teachers as a means to improve student outcomes in mathematics. As such each of these projects drew on a range of pedagogical frameworks to promote effective teaching and learning in mathematics. In conjunction with other studies examined, the common features advocated for teacher professional learning were:

Improving teachers' and/or Indigenous teacher assistants mathematical content knowledge: developing a deeper understanding of mathematics concepts and how each of these concepts relates to other areas of mathematics (e.g., Baturo, Matthews, Underwood, Cooper, & Warren, 2008; Warren et al., 2010; Warren & Miller, 2016)

Improving teachers' pedagogical knowledge: culturally rich resources; contextualising mathematics; providing hands-on learning experiences, having high expectations for students, designing lessons with multi-entry points, connecting mathematics to the

community, using multiple representations, building mathematical language, encouraging group work; targeted feedback (e.g., Grootenboer & Sullivan, 2013; Hurst & Sparrow, 2012; Jacob & McConney, 2013; Jorgensen et al., 2013; Papic, 2013; Pegg & Graham, 2013; Sarra & Ewing, 2014; Sullivan et al., 2013; Warren & Miller, 2016).

While the majority of the professional learning models in the literature draw on Western/Eurocentric models of teaching mathematics a unique teaching model that diverts from this is the Goompi model[1] developed by Dr Chris Matthews (2009, 2012) (See Figure 1).

The Goompi model emphasises creativity and students own created expressions of mathematics, hence central to this model is the perspective of the learner (Matthews, 2009, 2012). For many students, they only experience mathematics in the image depicted by the cloud (abstract), having limited opportunity to connect mathematics to their lives. This model can be used to create new pedagogies in mathematics and to forefront culture and cultural expression (Matthews, 2012). Examples of pedagogical approaches developed from the Goompi model are *mathematics as story-telling* and *mathematics as dance* (see Matthews, Cooper, & Baturo, 2007; Matthews, 2012; also visit the ATSIMA website: https://atsimanational.ning.com/). The studies examined in this systematic review, have indicated that the Goompi model, promotes a positive sense of Aboriginal identity which in turn develops a positive sense of self (Ewing, Sarra, Cooper, Matthews, & Fairfoot, 2014; Sarra & Ewing, 2014). It also provided a framework to develop culturally rich resources and a learning environment that focuses on developing a deep understanding of mathematics.

Importance of language and mathematics learning

Studies highlighted the importance of language to improve student engagement with mathematics. Research suggests that teachers do not always consider that students first language is not Standard Australian English (Warren et al., 2010) and when schools ban the contribution of home language this contributes to the devaluation of Indigenous culture (Edmonds-Wathen, 2015). Evidently, it is apparent that ignoring language has the potential to impact on students learning of mathematics. Understanding and using mathematical language is a predictor for success in mathematics for young students (Warren & Miller, 2013). Building an understanding of how students use mathematical language and map these terms to their own language (home language) appears to be necessary for successful outcomes in mathematics.

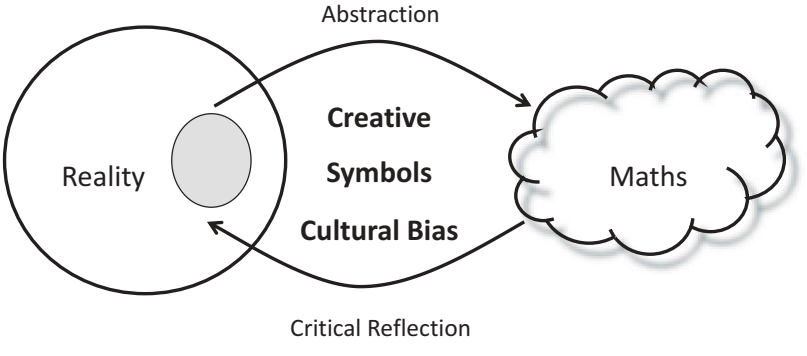

Figure 1. Goompi model (Matthews, 2009).

As examined by Edmonds-Wathen (2014) Aboriginal students have different terms for particular mathematical concepts (frames of reference for spatial concepts). She advocates for teachers becoming aware of the differences used in particular Aboriginal languages with regards to mathematical terms and how these terms relate English words used in mathematics classrooms (Edmonds-Wathen, 2014). Additional studies also advocate for the use of home language for Aboriginal students [and Torres Strait Islander] and then mapping these words on to mathematical terms in English (Jacob & McConney, 2013; Jorgensen, 2015; Jorgensen et al., 2013; Treacy, 2013; Treacy, Frid, & Jacob, 2015). As a means to address this, research findings support the relationship with the Indigenous Teacher Assistant to act as a conduit and assist with code-switching between languages for students (Jorgensen, 2015; Treacy, 2013) as well as the training of more Indigenous teachers, particularly Indigenous language speaking teachers (Edmonds-Wathen, 2015).

In addition to adopting home language, studies identify using an oral language approach as a pedagogy for teaching and learning mathematics (e.g., McDonald, Warren, & Devries, 2011; Warren & DeVries, 2009; Warren & Miller, 2016). These studies emphasis that this approach is more than using oral communication. Rather, an oral language approach entails speaking and listening, comprehending what is being said, understanding the vocabulary being used, and applying this to mathematical contexts. Teachers need to spend time mapping the language to mathematical representations and the hands-on materials to assist students to build their understanding (Warren & Miller, 2016). This includes ensuring students have a range of experiences with the language of mathematics, including mapping mathematical language onto Aboriginal and Torres Strait Islander languages within contexts that are meaningful for students (Warren & Miller, 2013). It is to be noted, that the studies that have been conducted using this pedagogical approach are predominately in the early years of primary school.

Structures and representations of mathematics

In addition to language, many of the studies highlighted the importance of teachers providing the opportunity for students to develop a deep understanding of mathematical structures in conjunction with the use of multiple representations. Research has indicated that, "the ability to see the structure of a mathematical concept brings about a relational understanding of the concept" (Warren & Miller, 2013, p. 154). Papic (2013, 2015) implemented a mathematics programme focusing on patterning and early algebra for preschool teachers and students. The research provides an evidence-base for an intervention focusing on mathematical structures (patterning and early algebra) to impact on successful academic outcomes for young Indigenous students. Warren and colleagues have also focused on developing students underlying mathematical understanding with an intervention that focuses on multiple representations of mathematical structures, using a hands-on approach to teaching mathematics (e.g., Warren & DeVries, 2009; Warren & Miller, 2016, 2013). Similar to Papic, Warren measured the effect of this changed pedagogical approach by not only interviewing teachers but also directly measuring students' academic outcomes in mathematics. Findings from this longitudinal study indicated that there were educationally significant changes in primary school students (Prep – Year 3) mathematical learning across the 12 months (Warren & Miller, 2016).

Limitations

As this study focuses only on empirical peer-reviewed publications there are many theoretical papers and reports that are not included in this systematic review. The methodology employed for this systematic review has eliminated important theoretical works from Aboriginal and Torres Strait Islander authors in the field of mathematics education and education more broadly (e.g., Stronger Smarter, 8-ways learning approach, Chris Matthews – Matthews et al., 2007). In addition, it is acknowledged that at times not all publications in the social sciences are accessible from databases. While a wide range of databases were utilised, it is recognised that some journals and conference papers were not captured. From the studies that were examined the main participants were teachers and students, therefore we did not capture the important role that parents can have as educators in teaching and learning of mathematics (e.g., Ewing, 2014). Finally, search terms may have impacted on the specificity of the search as mathematics education has a diverse set of concepts and terms for specific areas of mathematics which yields very large and unmanageable data sets. By controlling the search terms, it is acknowledged that different terms may have led to accessing additional studies.

Conclusions and future research

This systematic review has examined 28 empirical research papers (between 2008–2017) in relation to the teaching and learning strategies that promote positive engagement in mathematics for Aboriginal and Torres Strait Islander students. Majority of the research in this review were qualitative studies focusing on teachers' (from QLD and WA) cognitive engagement with mathematics (improving content knowledge or pedagogical practices). Key findings from this systematic review indicate whole school approaches of professional learning focusing on both building content knowledge and pedagogical content knowledge is important to support teachers and students to be successful in mathematics. In addition, it was evident that high expectations, changes in teachers' professional knowledge – emphasising the importance of language, and building a deep understanding of mathematics leads to positive engagement for both students and teachers. Importantly research indicates that Indigenous Teacher Assistants are central in supporting students to learn mathematics, as well as providing contextual understanding and language support for non-indigenous teachers while teaching mathematics.

From undertaking this systematic review, we would like to emphasise some key considerations for future research. First, while authors indicated the importance of establishing strong relationships between schools and communities few captured data indicating how this is fostered. Similar to this, while studies advocated for culturally responsive pedagogies few studies encapsulated how they worked with the community to develop these pedagogies or tasks used in their studies. Second, there is a lack of voice from Aboriginal and Torres Strait Islander; (i) authors, (ii) teachers, (iii) leaders, (iii) parents and (iv) students. Future research needs to advocate for a balance of voice in relation to teaching and learning practices in mathematics. Third, many of these studies were conducted over one or two years with very little opportunity to determine if an effective change was ongoing or sustained. In addition, with few longitudinal studies, there is a limited understanding of the long-term outcomes for students who have participated in mathematics intervention

programmes. Thus, there is a need for sustained research (with funding) that can ensure long-term outcomes, sustainability and scalability. Fourth, while there were no studies mentioned in this systematic review that examined direct or explicit instruction, there is a need to validate these types of pedagogical approaches with respect to learning mathematics. In particular, how do students develop mathematics thinking practices when teachers use such approaches? Finally, the areas of behavioural and affective engagement are under-researched, as well as, the measured effect of professional learning interventions on student learning. Few studies that implemented professional learning actually measured the cognitive effects on students. Many studies only reported teachers' perceptions of students learning. Finally, more multi-participant longitudinal research, that encompasses all facets of engagement, is needed to capture both Indigenous and non-Indigenous voices with respect to developing culturally appropriate pedagogies for mathematics education and to measure the long-term effects on student learning.

Note

1. In previous publications, this model was named the RAMR model or cloud model. After personal correspondence with the Author to seek permission to include the model, Matthews requested the model is presented with the new title.

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References

Aikenhead, G. S. (2001). Students' ease in crossing cultural borders into school science. *Science Education*, *85*(2), 180–188.

Armour, D., Warren, E., & Miller, J. (2016). Working together: Strategies that support cross-cultural engagement of Indigenous teacher assistants working in Indigenous contexts. *Asia-Pacific Journal of Teacher Education*, *44*(5), 421–435.

Baturo, A., Matthews, C., Underwood, P., Cooper, T., & Warren, E. (2008). Research empowering the researched: Reflections on supporting Indigenous teacher aides to tutor mathematics. In O. Figueras, J. L. Cortina, S. Alatorre, T. Rojano, & A. Sepulveda (Eds.), *Proceedings of the 32nd Annual Conference of the International Group for the Psychology of Mathematics Education*, (Vol. 2, pp. 137–144). Mexico: PME.

Bearman, M., Smith, C. D., Carbone, A., Slade, S., Baik, C., Hughes-Warrington, M., & Neumann, D. L. (2012). Systematic review methodology in higher education. *Higher Education Research & Development*, *31*(5), 625–640.

Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relatedness: A motivational analysis of self-system processes. In M. R. Gunnar & L. A. Sroufe (Eds.), *Self processes and development* (Vol. 23, pp. 43–77). Hillsdale, NJ: L. Erlbaum Associates.

Cooper, T. J., Baturo, A. R., & Warren, E. (2005). Indigenous and non-Indigenous teaching relationships in three mathematics classrooms in remote Queensland. In H. Chick, L. Helen, & J. L. Vincent (Eds.) *Proceedings of the 29th annual conference of the international group for the psychology of mathematics education*, (Vol. 2, pp. 265–272). Melbourne, Australia: PME.

Council for the Australian Federation. (2007). The future of schooling in Australia. Retrieved from http://apo.org.au/system/files/3139/apo-nid3139-48716.pdf

Durksen, T. L., Way, J., Bobis, J., Anderson, J., Skilling, K., & Martin, A. J. (2017). Motivation and engagement in mathematics: A qualitative framework for teacher-student interactions. *Mathematics Education Research Journal*, *29*(2), 163–181.

Edmonds-Wathen, C. (2014). Influences of indigenous language on spatial frames of reference in Aboriginal English. *Mathematics Education Research Journal*, *26*(2), 169–192.

Edmonds-Wathen, C. (2015). Indigenous language speaking students learning mathematics in english: Expectations of and for teachers. *The Australian Journal of Indigenous Education*, *44*(1), 48–58.

Ewing, B. (2014). Rich and purposeful mathematical knowledge of mothers and children in a Torres Strait Islander community. *SpringerPlus*, *3*(1), 42.

Ewing, B., Sarra, G., Cooper, T., Matthews, C., & Fairfoot, G. (2014). Successful outcomes in vocational education and training courses and mathematics: How pedagogy and expectations influence achievement. In B. Käpplinger, N. Lichte, E. Haberzeth, & C. Kulmus (Eds.), *Changing configurations of adult education in transitional times. Proceedings of the 7th European research conference* (pp. 307–337). Berlin: Humboldt-Universität zu Berlin.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). State of the evidence. *Review of Educational Research*, *74*, 59–109.

Gonski, D., Boston, K., Greiner, K., Lawrence, C., Scales, B., & Tannock, P. (2011). Review of funding for schooling. Final report. Retrieved from https://docs.education.gov.au/system/files/doc/other/review-of-funding-for-schooling-final-report-dec-2011.pdf

Gough, D. (2007). Weight of evidence: A framework for the appraisal of the quality and relevance of evidence. *Applied and Practice-based Research*, *22*(2), 213–228.

Grootenboer, P., & Sullivan, P. (2013). Remote indigenous students' understanding of measurement. *International Journal of Science and Mathematics Education*, *11*(1), 169–189.

Howard, P. (1997, Nov). *Aboriginal voices in our schools*. Paper presented at the Australian Association for Researchers in Education Conference, Brisbane, Australia.

Howard, P., & Perry, B. (2005). Learning mathematics: Perspectives of Australian Aboriginal children and their teachers. In H. L. Chick & J. L. Vincent (Eds.). *Proceedings of the 29 th conference of the international group for the psychology of mathematics education* (vol. 3, pp. 153–160). Melbourne: PME.

Hurst, C., & Sparrow, L. (2012). Professional learning for teaching assistants and its effect on classroom roles. In J. Dindyal, L. P. Cheng, & S. F. Ng (Eds.), *Mathematics education: Expanding horizons (Proceedings of the 35th annual conference of the mathematics education research group of Australasia)* (pp. 362–369). Singapore: MERGA.

Jacob, L., & McConney, A. (2013). The Fitzroy Valley numeracy project: Assessment of early changes in teachers' self-reported pedagogic content knowledge and classroom practice. *The Australia Journal of Teacher Education*, *38*(9), 362–369.

Jorgensen, R. (2015). Language, culture and access to mathematics: A case of one remote Aboriginal community. *Intercultural Education*, *26*(4), 313–325.

Jorgensen, R. (2016). Playing the game of school mathematics: Being explicit for indigenous learners and access to learning. *Intercultural Education*, *27*(4), 321–336.

Jorgensen, R., Grootenboer, P., & Niesche, R. (2013). Teachers' beliefs and practices in teaching mathematics in remote Aboriginal schools. In R. Jorgensen, P. Grootenboer, & P. Sullivan (Eds.), *Pedagogies to enhance learning for Indigenous students* (pp. 75–87). Singapore: Springer.

Kidman, G., Cooper, T., & Sandhu, S. (2012). The pedagogical contribution of the teacher aide in indigenous classrooms. In A. Lindmeier & A. Heinze (Eds.), *Proceedings of the 37th conference of the international group for the psychology of mathematics education*, (Vol. 3, pp. 161–168), Kiel, Germany: PME.

Leder, G., & Forgasz, H. (2012). K-2 Make it count: Students' views of mathematics. In J. Dindyal, L. P. Cheng, & S. F. Ng (Eds.), *Mathematics education: Expanding horizons (Proceedings of the 35th annual conference of the mathematics education research group of Australasia)* (pp. 425–432). Singapore: MERGA.

Lowe, K., Tennent, C., Guenther, J., Harrison, N., Burgess, C., Moodie, N., & Vass, G. (2019). 'Aboriginal Voices': An overview of the methodology applied in the systematic review of recent research across ten key areas of Australian Indigenous education. *The Australian Educational Researcher*, *46* (2), 213–229.

Matthews, C. (2009). Stories and symbols: Maths as storytelling. *Professional Voice*, *6*(3), 45–50.

Matthews, C. (2012). Maths as storytelling: Maths is beautiful. In K. Price (Ed.), *Aboriginal and Torres Strait Islander education* (pp. 94–112). Crawley: University of WA.

Matthews, C., Cooper, T. J., & Baturo, A. R. (2007). Creating your own symbols: Beginning algebraic thinking with indigenous students. In J. H. Woo, H. C. Lew, K. S. Park, & D. Y. Seo, (Eds), *Proceedings of the 31st conference of the international group for the psychology of mathematics education* (Vol. 3, pp. 249–256). Seoul, South Korea: PME.

McDonald, S., Warren, E., & Devries, E. (2011). Refocusing on oral language and rich representations to develop the early mathematical understandings of indigenous students. *The Australian Journal of Indigenous Education*, *40*, 9–17.

Miller, J. (2015). Young Indigenous students' engagement with growing pattern tasks: A semiotic perspective. In M. Marshman, V. Geiger, & A. Bennison (Eds.), *Proceedings of the 38th annual conference of the mathematics education research group of Australasia* (pp. 421–428). Sunshine Coast, QLD: MERGA.

Miller, J., Warren, E., & Armour, D. 2019. Examining changes in young Aboriginal and Torres Strait Island students and their beginning primary school teachers' engagement in the teaching and learning of mathematics. *ZDM Mathematics Education*. Retrieved from https://link.springer.com/article/10.1007/s11858-019-01077-1

NSW Department of Education and Training. (1996). *Aboriginal education policy*. Sydney: NSW DET.

Owens, K. (2015). Changing the teaching of mathematics for improved Indigenous education in a rural Australian city. *Journal of Mathematics Teacher Education*, *18*(1), 53–78.

Papic, M. (2013). Improving numeracy outcomes for young Australian Indigenous children. In L. D. English & J. T. Mulligan (Eds.), *Reconceptualizing early mathematics learning* (pp. 253–281). Dordrecht, The Netherlands: Springer.

Papic, M. (2015). An early mathematical patterning assessment: Identifying young Australian indigenous children's patterning skills. *Mathematics Education Research Journal*, *27*(4), 519–534.

Papic, M. M., Mulligan, J. T., Highfield, K., McKay-Tempest, J., & Garrett, D. (2015). The impact of a patterns and early algebra program on children in transition to school in Australian Indigenous communities. In B. Perry, A. MacDonald, & A. Gervasoni (Eds.), *Mathematics and transition to school* (pp. 217–236). Singapore: Springer.

Pegg, J., & Graham, L. (2013). A three-level intervention pedagogy to enhance the academic achievement of indigenous students: Evidence from QuickSmart. In R. Jorgensen, P. Grootenboer, & P. Sullivan (Eds.), *Pedagogies to enhance learning for indigenous students: Evidence-based practice* (pp. 123–138). Singapore: Springer.

Peterson, P. L., Swing, S. R., Stark, K. D., & Waas, G. A. (1984). Students' cognitions and time on task during mathematics instruction. *American Educational Research Journal*, *21*(3), 487–515.

Reschly, A. L., & Christenson, S. L. (2012). Jingle, jangle, and conceptual haziness: Evolution and future directions of the engagement construct. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 3–20). New York, NY: Springer.

Sarra, G., & Ewing, B. (2014). Indigenous students transitioning to school: Responses to pre-foundational mathematics. *SpringerPlus*, *3*, 1.

Skilling, K., Bobis, J., Martin, A. J., Anderson, J., & Way, J. (2016). What secondary teachers think and do about student engagement in mathematics. *Mathematics Education Research Journal*, *28*(4), 545–566.

Stipek, D. J. (2002). *Motivation to learn: Integrating theory and practice*. Boston: Allyn and Bacon.

Sullivan, P., Jorgensen, R., Boaler, J., & Lerman, S. (2013). Transposing reform pedagogy into new contexts: Complex instruction in remote Australia. *Mathematics Education Research Journal*, *25*(1), 173–184.

Treacy, K. (2013). Students' understanding of everyday English and Kimberley Kriol in mathematics classrooms. In V. Steinle, L. Ball, & C. Bardini (Eds.), *Matheamtics education: Yesterday, today and tomorrow (Proceedings of the 36th annual conference of the mathematics education research group of Australasia)* (pp. 634–641). Melbourne: MERGA.

Treacy, K., Frid, S., & Jacob, L. (2015). Starting points and pathways in Aboriginal students' learning of number: Recognising different world views. *Mathematics Education Research Journal*, *27*(3), 263–281.

Warren, E., Cooper, T. J., & Baturo, A. R. (2010). Pedagogies to support Indigenous students' mathematics learning in rural and remote Queensland classrooms. In J. Zadja (Ed.), *Gobalisation, Education and social justice* (pp. 161–184). Dordrecht, Netherlands: Springer.

Warren, E., & DeVries, E. (2009). Young Australian indigenous students' engagement with numeracy: Actions that assist to bridge the gap. *Australian Journal of Education*, *53*(2), 159–175.

Warren, E., & Miller, J. (2013). Young Australian Indigenous students' effective engagement in mathematics: The role of language, patterns, and structure. *Mathematics Education Research Journal*, *25*(1), 151–171.

Warren, E., & Miller, J. (2016). *Mathematics at the margins*. Singapore: Springer.