Applying an alternative mathematics pedagogy for students with weak mathematics: meta-analysis of alternative pedagogies

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Applying an alternative mathematics pedagogy for students with weak mathematics: Meta-analysis of alternative pedagogies

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Applying an alternative mathematics pedagogy for students with weak mathematics: Meta-analysis of alternative pedagogies

Student mathematics performance and the need for work-ready graduates to be mathematics-competent is a core issue for many universities. While both student and teacher are responsible for learning outcomes, there is a need to explicitly acknowledge the weak mathematics foundation of many university students. A systematic literature review was undertaken of identified innovations and/or interventions that may lead to improvement in student outcomes for university mathematics-based units of study. The review revealed the importance of understanding the foundations of student performance in higher education mathematics learning, especially in first year. Pre-university mathematics skills were identified as significant in student retention and mathematics success at university, and a specific focus on student pre-university mathematics skill level was found to be more effective in providing help, rather than simply focusing on a particular at-risk group. Diagnostics tools were found to be important in identifying (1) student background and (2) appropriate intervention. The studies highlighted the importance of appropriate and validated interventions in mathematics teaching and learning, and the need to improve the learning model for mathematics-based subjects, communication and technology innovations.

Keywords: Mathematics Pedagogy; Interventions; Pre-University Mathematics; Diagnostics; Meta-analysis

1. Introduction

There is global discussion regarding the need to rethink and redesign university mathematics education [1, 2, 3]. Our university, for example, is instigating changes in the education degree programme, following federal Government mandates regarding numeracy. In
Australia, primary and early childhood education students are expected to have a level of numeracy broadly equivalent to the top 30% of the population [4]. There are parallel changes in other degree programmes, including engineering and nursing. Such changes can be informed by research on mathematics education, thus the need for a systematic literature review. Non-mathematics university students commonly find mathematics difficult, and success rates can be low [1, 5]. In our experience, continuing evaluation of student performance indicates that a core source of this low success lies in a fundamental weakness in the mathematical background of incoming students. In short, students enter education, nursing or engineering programmes with suitable entry qualifications, but with limited successful backgrounds in mathematics. Markopoulos and Chaseling [1] and Yeigh and Woolcott [6] both demonstrate that student attitudes and perception of their capacity to study mathematics contribute to student anxiety and a seemingly self-fulfilling failure [7].

The basis for a student’s poor past experience and background in mathematics learning is multi-faceted. Importantly, it often lies in the student’s social background. Demographic figures of, for example our student cohort, indicate the importance of social context and background as an influence on a student’s capacity for, and approach to, university learning [8, 9]. Students are frequently first-in-family (64%), and so do not inherit traditions of scholarship and academic support from their families. This requires them to learn new cultural behaviours, values and more associated with being a university student and working within the learning environment of a university [10]. Many are from low socio-economic backgrounds (31%), where school education may have focused on applied subjects, and the more traditional subjects (e.g. mathematics) were either absent or only taught at elementary levels. Many students also come from groups considered to be ‘mathematics-disadvantaged’, groups with weak backgrounds in mathematics
learning or who are long removed from their school mathematics education: female students (80%); students of Aboriginal and Torres Strait Islander descent (2%) or mature age students (33%).

There is an urgent need to move beyond refining, conceptualizing or redesigning current modes of mathematics teaching and delivery, to acknowledge the weak mathematics foundation of university students [11, 12, 13]. Externalizing higher education learning may exacerbate these issues, as building student capacity is a challenge within online learning [14]. It is timely to examine the literature on university mathematics education and teaching, especially in regard to identifying pedagogies suited to a new generation of university student.

This paper reports a literature review examining pedagogies best suited to the type of students our university typically engages in its programmes, and seeks to determine a sound scholarly basis for change of educational practice that directly addresses student limitations where students study mathematics in non-mathematical courses (e.g. in environmental science, education, engineering, nursing, psychology and business). The review focused on successful interventions in teaching undergraduate mathematics, and emphasized the first year experience within higher education, considering the types of pedagogical interventions that could leverage improved student interest and engagement.

2. Methods

This systematic literature review sought evidence for interventions that may enhance mathematics learning at university. The aim was to identify innovations, insights and potential interventions to aid improvement in student outcomes in two educational contexts: (1) non-terminating units, i.e. foundational or introductory units within courses, teaching both discrete
mathematics (e.g. computing) and continuous mathematics (algebra and calculus); and (2) terminating units within courses, geared towards professional mathematics applied to workplace performance, often attached to professional accreditation.

Three electronic databases were initially searched: Scopus; Education Research Complete (ERC) and Education Resources Information Center (ERIC). Scopus is one of the most comprehensive multidisciplinary databases currently available [15], and includes a broader range of high quality journals than other databases such as ProQuest and Google Scholar [16, 17]. ERC searches replicated the Scopus searches to ensure inclusion of Education-specific resources and to take advantage of the embedded subject thesaurus (Table 1). Results retrieved from the ERIC searches were duplicates of those already retrieved.

Table 1. Search strategy key words for Scopus, ERC, and ERIC

<table>
<thead>
<tr>
<th>Scopus</th>
<th>Education Research Complete (ERC)</th>
<th>ERC</th>
</tr>
</thead>
<tbody>
<tr>
<td>((math* OR calculus OR algebra) OR ((comput* OR programming ) AND math*)) AND</td>
<td>((math* OR calculus OR algebra) OR ((comput* OR programming ) AND math*))</td>
<td>((math* OR calculus OR algebra) OR ((comput* OR programming ) AND math*))</td>
</tr>
<tr>
<td>(intervention* OR innovat*) AND</td>
<td>SU (intervention* OR innovat*) OR (intervention* OR innovat*)</td>
<td>(intervention* OR innovat*)</td>
</tr>
<tr>
<td>(“higher education” OR universit* OR college* OR postsecondary OR post-</td>
<td>SU (“higher education” OR universit* OR college* OR postsecondary OR post-compulsory OR (“higher education” OR</td>
<td>(“higher education” OR universit* OR college* OR postsecondary OR post-</td>
</tr>
<tr>
<td>compulsory) AND</td>
<td>universit* OR college* OR postsecondary OR post-compulsory OR (“higher education” OR universit* OR college* OR</td>
<td>compulsory)</td>
</tr>
<tr>
<td>(primary OR elementary OR secondary OR high OR “early childhood” OR kindergarten</td>
<td>(primary OR elementary OR secondary OR high OR “early childhood” OR kindergarten OR preschool* OR k-12)</td>
<td>(primary OR elementary OR secondary OR high OR “early childhood” OR</td>
</tr>
<tr>
<td>OR preschool* OR k-12)</td>
<td></td>
<td>kindergarten OR preschool* OR k-12)</td>
</tr>
</tbody>
</table>
Following this initial search, articles pertaining to preschool and school-level mathematics were excluded. Further exclusion was based on the following criteria: did not deal with first year university students; studied teachers and not students; described a particular programme without details of the intervention and evaluation; or were not contextually relevant to the study aims and objectives. All exclusions were peer reviewed by the research team.

Subsequently, the full text of the remaining articles was reviewed, using 24 parameters to guide the analysis of the search results. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [18] model was used for the systematic review (Figure 1), and details the number of studies (74) identified and reviewed. The interventions and study details described in each article were compiled into a comprehensive resource used in the subsequent research. This resource allowed for common themes to be noted regarding pedagogical approaches, and aided in the determination of the articles most relevant to the aims of this study. The following parameters guided the selection of articles for the study: Was behavioural change expected and achieved? Was the evaluation of the innovation and/or intervention rigorous? Were there major limitations? Those studies that did not meet these criteria were still included in the overall synthesis of ideas. The selection process permitted a focus on a smaller set of highly relevant pedagogical approaches.

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1 For a full list of parameters please contact the Corresponding author (warren.lake@scu.edu.au).
Figure. 1 PRISMA systematic review flow diagram, showing numbers of article considered at each stage. The process of review of the 74 included articles is illustrated in Fig. 2.

3. Results

A set of 74 records were reviewed, including conference papers (23), journal articles (50) and one book chapter (1). Disciplinary context included: engineering science (36); interdisciplinary units (20); computer science (7); science (5); commerce (3); mathematics bridging course (1); agriculture (1); both engineering and computer science (1). Despite an apparent emphasis on engineering, these papers largely focused on units of study that were used as prerequisites for other disciplines. Analysis revealed that 17 countries were represented in the studies reviewed, with 40% of the studies based on American students, 15% Australian, 14% South African, 9% UK, 3% Argentinean, 3% Mexican, and the remainder, individual studies in various countries.

3.1 Demographics

Studies that focused on mathematics disadvantaged groups exclusively included females, Black Africans, those with known knowledge gaps, and under-represented groups. Many studies,
although not focused exclusively on any one disadvantaged group, often cited the type(s) of students generally represented, or the groups that have already been identified as at-risk. For example, Payne and Dusenbury [19] target their early intervention program for minority science students, but do not specify the demographic makeup of participating students. Similarly, within the engineering-related studies, seven studies from the Scopus search focused on interventions to help improve retention rates in programmes that have a high dropout rate, while within the ERC search, interventions designed to improve retention rates covered other disciplines (e.g. science and technology disciplines [19], and STEM based studies [20]).

Although nine studies from the ERC search focused, to some extent, on mathematics disadvantaged groups, for the remaining studies, demographic information was often used to cite the type of students generally represented. Some studies, for example Steyn and Carr [21], give details about mathematics disadvantaged groups, but fail to present adequate demographic data to verify the type of students. Instead they rely on an implied understanding that certain groups are highly represented. This is often based on the funding provided by government to address retention rates in particular [22]. Many of the articles concentrated on all students, as deficiencies were noted across the whole cohort of students [23]. In contrast, a number of studies provide excellent demographic data to identify potential at-risk groups [24]. However, the majority of the studies in this data set appear to be focused towards understanding where knowledge gaps occur, how to identify them and how to help students overcome them, rather than concentrating on so called “at-risk” groups of students.

3.2 Pedagogical approaches

Significant pedagogical approaches suggested in the reviewed articles included: the implementation of active learning (in 38 of 74 studies); hands-on projects (14 of 74); mentoring
programmes (11 of 74); peer oriented study groups [25, 26]; gender only study mentor groups [27]; use of technology [28]; one-to-one help [29]; diagnostic testing to identify problem areas or knowledge gaps. [30, 31, 32].

The Scopus search revealed a wide range of factors relating to pedagogy. The pedagogical approach addressed in each study focused mostly on how to address the identified issue(s) via changes to educational design. Of the issues identified, the following themes were common: declining participation [22], lack of relevant experience [29], lack of entry requirements or lack of math prior to university [23], students’ perceptions of the level of fundamental skills required [29], first language [33], and mathematics anxiety [34]. Additionally, some studies focused on diagnostics [30], which could then be used to inform pedagogical approaches.

Articles from the ERC database, with its educational focus, documented a range of factors influencing the pedagogical approach, including declining participation in STEM related studies where engineering disciplines were prominent [26]. Additional issues identified included: knowledge gaps [32, 35]; the use of traditional teaching formats [36]; lack of student engagement with mathematics [37]; lack of consideration for individual learning variations [38]; lack of student interest [39]; mathematics anxiety or self-efficacy issues [40]. As with the Scopus records, not all studies were focused on testing a pedagogical innovation, with diagnostic tests again featuring amongst the studies reviewed in detail [32, 41, 42]. Notably, some studies streamline curriculum using “integrated curriculum” or “integrated programmes” to cope with student knowledge deficiencies in later units [43, 44, 45, 46], whereas others introduce alternative paths or extra units to deal with student knowledge deficiencies [22, 47, 48]. In some cases, this effectively increases the workload of students either prior to the normal course units,
during normal course units or in some cases the addition of an extra year of study, for those without relevant mathematics experience [49].

Given the focus on identifying innovative pedagogical approaches, a comprehensive list of the relevant studies was produced\(^2\). This list included studies that investigated and used pedagogical approaches expected to promote behavioural change, and that also successfully achieved behavioural change in students, with minimal identified study limitations.

3.3 Synthesis of ideas for each database

The Scopus search revealed a heavy focus on engineering, where the most innovative approaches came from programs that focused on both engineering and computer science students. Its relevance in terms of pedagogical approaches is valid due to these studies focusing specifically on core units, and therefore their applicability across disciplines. For example, Engelbrecht and Harding [50,p.1] state that: “First year mathematics courses commonly provide the base knowledge necessary for progression in different degree programmes”. The majority of the studies were aimed at improving retention rates of students in disciplines that experience a high dropout rate, both of mainstream students and/or mathematics disadvantaged groups such as women. [27] The background literature in a majority of the studies (particularly engineering) also points to an understanding of the factors that influence retention rates. It clearly indicates that prior performance in mathematics is a significant factor that could be leveraged to identify students at risk of leaving university, regardless of background, and who, therefore, should be the focus of programmes to remedy skill deficits. [5]

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\(^2\) A detailed synthesis of this collection of papers can be obtained by contacting the Corresponding author (warren.lake@scu.edu.au).
In general, most innovations and/or interventions identified specify the importance of students having access to extra help directly related to the required math skills, or in aspects such as learning facilitation strategies. Interestingly, improving student performance and retention in disciplines that rely on mathematics does not necessarily need to be limited to a one-off single session intervention, as illustrated by Jacquez and Auzenne [51], who used an integrated learning community to help students with initially inadequate mathematics skills to improve their performance.

The results from the ERC search revealed an evenly distributed range of disciplinary areas. The background literature reveals the importance of prior mathematics performance, amongst other factors, as an indicator for identifying students at-risk. Specifically, Fonteyne and De Fruyt [42] argue that a simple diagnostic test can be effective at identifying students at risk, especially when administered prior to the start of the academic year. They also note that the more hours a student has been exposed to mathematics education, the more likely they are to obtain better results at university. Other notable studies such as Kremmer and Brimble’s [41], also make use of a simple diagnostics tool (a short ten question aptitude test) to identify students and invite students to a mathematics workshop intervention. Both these studies indicate that diagnostic tools are important for identification of at-risk students, regardless of background. Although many studies looked at supplementary instruction, such as peer assisted learning [31], this did not appear to be an effective innovation. However, in the Parkinson [31] study, tutored students improved their performance and were more engaged in university mathematics.

Other studies focused on delivering improved instruction in areas that students have previously seen as intimidating, such as MATLAB. [52] In addition, Barragués and Guisasola [53] attempted to solve mathematical learning difficulties by selecting activities that encourage
students to explain their ideas and to constructively confront other people’s ideas. Other studies focused on delivering instruction using a low stress multimodal approach grounded around multiple intelligence theory [54], and a study that focused on improving self-efficacy, but more specifically belief-perseverance. [40] As with the Scopus search, promoting active learning was a common theme. Tonkes and Isaac [52] make use of partially populated lecture notes, intended to facilitate active and reflective learning styles by enabling problem solving and illustrations in class, and for students to record their own annotations for later reflection.

### 3.4 Summary of key innovations, interventions and themes

The themes of the notable studies within Scopus (6 records) and ERC (10 records), uncovered a broad range of innovative approaches best described in two generic categories such as, diagnostics and early intervention programmes or activities. Based upon the established key groupings and key words associated with the references (Table 2), NVivo 10 was used to identify qualitative data that enhanced the discussion around the identified innovations and interventions and aided the construction of the study recommendations (Figure 2).

Table 2 Key themes associated with the 16 notable articles identified using the parameters specified in the methods.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Brief Description of innovations and/or intervention (Theme)</th>
<th>Diagnostics</th>
<th>Intervention programs / activities</th>
<th>Structure and organisation of learning community</th>
<th>Conceptual focus / principle</th>
<th>Communication / technology</th>
<th>Awareness and self-efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basitere &amp; Ivala (2014)</td>
<td>Extended curriculum program.</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>Cervesato (2011)</td>
<td>A 7-week mini course (comic text).</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cordero et al. (2010).</td>
<td>Belief-perseverance techniques</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
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</tr>
<tr>
<td>Reference</td>
<td>Brief Description of innovations and/or intervention (Theme)</td>
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<td>Conceptual focus / principle</td>
<td>Communication / technology</td>
<td>Awareness and self-efficacy</td>
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</tr>
<tr>
<td>Fonteyne et al. (2015)</td>
<td>Easy-to-administer diagnostics</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Jacquez et al. (2005)</td>
<td>Integrated learning community.</td>
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<td></td>
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<td>X</td>
<td></td>
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<tr>
<td>Marosi et al. (2013)</td>
<td>Residential pre-orientation</td>
<td>X</td>
<td>X</td>
<td></td>
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<td>X</td>
<td></td>
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<tr>
<td>Parkinson (2009)</td>
<td>Peer assisted learning support.</td>
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<td>X</td>
<td></td>
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<tr>
<td>Staniec et al. (2012)</td>
<td>Re-design of support program.</td>
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<td>X</td>
<td></td>
</tr>
<tr>
<td>Sullivan et al. (2015)</td>
<td>Alternative pathways (Bridge Programme)</td>
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</tr>
<tr>
<td>Tonkes et al. (2005)</td>
<td>Improving learning model (MATLAB).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tonkes et al. (2009)</td>
<td>Partially populated Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Windsor et al. (2015)</td>
<td>Mathematics Bridge Bootcamp</td>
<td></td>
<td></td>
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<td></td>
<td>X</td>
<td></td>
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</tbody>
</table>

**Key terms:** Bootcamp; Bridging course; Bridge program; Intervention program; Alternative pathways; pre-orientation; Integrated Learning community; Residential; Workshops; Peer-led; study groups; knowledge gaps; knowledge deficits; self-efficacy; belief-perseverance; future success; Basic diagnostics; diagnostics; easy to administer; Math aptitude; aptitude test; Peer assisted learning; Multiple intelligence; Action research; learning model; lecture notes; partially populated Lecture notes; Comics; Facebook; encouragement; working atmosphere.
Figure 2 Decision tree illustrating the use of supplementary material to support discussion of identified innovations emerging from the critical literature review (i.e. the output from Figure 1).

In addition, a scan of team-recommended studies (33) was also undertaken. These provided context to the study findings and captured qualitative data related to the already identified innovations, interventions and themes considered in this review. Although the team recommendations had the potential to highlight further innovative approaches, they were not identified within the rigorous systematic review process.

5. Discussion

While there is extensive literature on potential and applied interventions in mathematical education, there is relatively little literature that reports rigorous evaluation of such interventions. This review has identified interventions described and discussed in the literature which have been (1) rigorously evaluated, and (2) shown to be effective in supporting first year mathematics students. The major themes (Table 2) were determined using a constant comparative method iterative process [58], which ensured that each reviewed paper accurately represented the
theme(s) they were grouped in. Refinement of categories was conducted by re-reading each of the 16 notable studies, ensuring they were accurately categorised into each of the major themes.

Six interventions identified include the following: mathematics-based diagnostic tools; intervention programs or activities; unique approaches to structure and organisation of learning communities; successful new approaches to teaching based on conceptual principles; improved communication and Introduction of specific technology. The key findings relate to the importance of understanding the foundations of student performance in higher education mathematics learning, and linking this to university first-year mathematics learning.

5.1 Diagnostics tools

Pre-university mathematics skills were identified as a major factor in student retention and mathematics success, and therefore diagnostics tools were considered important in identifying (1) student background and skill level, and (2) appropriate intervention. The records reviewed considered what could be done to address mathematics skills of incoming university students, rather than concentrating on what has been missed in pre-university mathematics education. Basic maths diagnostics tools were identified as being suited to the identification of students who require remedial help. These mathematics diagnostics programs can be used to advise appropriate student learning options, e.g. alternative pathways (workshops), rather than relying on students to volunteer.

Another important aspect of addressing skill deficits is the identification of students with such difficulties. The studies suggest that the at-risk groups are not necessarily based on particular demographics, but rather on the presence or absence of particular mathematics content and skills sets. The decreasing performance of students prior to university is well documented [59, 60], with many attempts to remedy this undertaken throughout school education.
While a number of studies related to diagnostic tools were reviewed, only two were included in the final 16 studies. In both studies, basic mathematics-based tests were used to identify at-risk students regardless of demographic background. These provide valuable insight into successful approaches that may be adopted by universities, and could be used to identify alternative pathways or other customised options that allow students to achieve at a suitable level. The first study used an easy-to-administer diagnostic test [42] which identified very basic mathematics skill levels as a means to identify at-risk students both prior to and at the start of the academic year. The test, used to enact remedial interventions and support future students, was designed around two basic factors: first, the mathematical skills students should have acquired prior to university; and second, the mathematical prerequisites for the university unit of study. The second study focused on the use of a previously developed maths aptitude test by Ballard and Johnson [61], as a basis for offering a place in a maths workshop to assist students with basic mathematics skills [41]. Ballard and Johnson [61] found that the maths skills test is predictive of students’ performance in a first year statistics unit.

5.2 Intervention programs

A key component of the studies reviewed was the basic idea of offering learning support in some form or other, whether as increased time for learning or offering one of the many common academic support programmes. Eight of the 16 studies focused on early intervention programmes or activities and highlighted the importance of appropriate and validated interventions in mathematics teaching and learning. A broad array of approaches designed to help remedy student skill and content deficits were identified, including: an extended curriculum program [32]; a 7-week mini course [55]; self-efficacy intervention in the form of a belief-perseverance technique [40]; a programme of developmental support in mathematics [49];
mathematics aptitude test and workshop [41]; residential pre-orientation [56]; alternative pathways for students (effectively decreasing the workload) [48]; a mathematics Bridge Bootcamp [26]. Tolley and Blat [62] reiterate the findings of Kajander and Lovric [63], indicating that many high school students develop a surface learning of mathematics considered insufficient at university level. Additionally, they note that a developmental course or expanded bridge programme may be effective in easing the transition into university courses. Given the success of the programmes covered in this review, this further supports the idea that universities should consider early interventions that directly address mathematical skill deficits for at-risk students.

A particularly interesting intervention was the use of a comic book textbook [55], designed to empower students to be active agents in their learning process. While active learning was a key theme that emerged in the initial overview, it only featured in one important example in the detailed study.

5.3 Structure and organisation of learning communities

Six of the 16 studies focused on the structure and organisation of learning communities, including: a developmental support program, offered as an extended degree program for those at risk of not coping in a traditional 4 year degree [49]; integrated learning community designed for first year students to develop a strong mathematics foundation [51]; residential pre-orientation recognising the need for a longer period of preparation, and to focus on skills and relationships that improve academic performance [56]; peer assisted learning support [31]; mentoring study groups for women [27]; and a support program consisting of a range of academic support programs including “learning communities, peer mentoring, summer bridge programs, tutorial services and supplemental instructional”. [25,p.2] These interventions reflect two core ideas:
first, the importance of providing support to students who have inadequate maths skills; and second, the institutional capacity to offer students support, either as time for learning or an academic support program identified in this study.

5.4 Focus on conceptual principles

The consideration of conceptual principles that could be implemented within study units or considered as part of an intervention program was identified in 4 of the 16 studies including: self-efficacy intervention in the form of a belief-perseverance technique in which students construct a rationale for their future success [40]; multiple intelligence theory applied to teaching mathematics [54]; improving learning models via a sequence of innovations designed to add value to computational and traditional learning process [57]; and the use of partially populated lecture notes to elicit active learning. [52]

5.5 Communication and technology

Communication and technology innovations were a significant focus for 4 of the 16 studies. Importantly many of the studies in Table 2 focus on more than one intervention, including: using computers to incorporate the problem-solving process as model [53]; a mini course using a comic book textbook; an unconventional tool using presentations and open discussions to empower students to be active learning agents [55]; implementation of an alternative learning model using a sequence of innovations and/or interventions specific to the technology that adds student-supported-value to the computational and traditional learning process [57]; use of partially populated lecture notes which accommodates various learning styles and abilities within a large class [52].

6. Conclusion and recommendations
This study focused on the core idea that universities should take responsibility for the curriculum, rather than expecting students to meet performance targets beyond their immediate capacity. The following recommendations are provided as a foundation to support student performance in mathematics learning. First, it should be recognised that students deemed at-risk in mathematics ability may not necessarily be associated with a particular disadvantaged demographic group, and focusing on pre-university mathematics skill level maybe more effective to assist learning. Second, basic diagnostics testing can be used to identify at-risk students, based on the notion that potential student ability in university mathematics is related to their pre-university mathematics skills set. Third, universities must consider interventions that directly address real mathematical skill deficits (at course or discipline level) for at-risk students. In this light, an important aspect to consider is that broad-based programs may not be specific enough to address either the skills deficits of incoming students, or the skill sets required in degrees with a heavy dependence on first year mathematics units. A more specific diagnostic tool for identifying at-risk students would allow for the ability to customise a mathematics pathway for students.

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