Australian Primary Mathematics Teacher Preparation: On-Campus or Online? Who? Why? So What?

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Australian universities providing mathematics teacher preparation are increasingly offering their courses online or in limited face-to-face mixed mode delivery. There are limited empirical data on why pre-service teachers make delivery mode choices and how these impact on academic standards and student satisfaction ratings. This paper reports on what motivated pre-service teachers to choose either online or mixed mode delivery that includes a face-to-face component; whether at the end of two mathematics curriculum courses their mathematical content knowledge and mathematical pedagogical content knowledge differed according to delivery mode; and whether their satisfaction ratings differed. Masters of Primary Education pre-service teachers undertook two mathematics curriculum courses (n = 189 and n = 153) with roughly half of the students enrolling online in each curriculum course. The course delivery was informed by cognitive load and transactional distance theory and aimed to develop pre-service teachers' relevant mathematics content and pedagogical content knowledge. Pre-service teachers were surveyed at the commencement of their study to determine what motivated them to choose a delivery format and to document prior mathematics courses completed. Their academic results at the end of each course indicated that online pre-service teachers made greater academic gains. It is suggested that this could be attributed to the academic capital they brought to the courses. Both cohorts rated the support highly, suggesting their learning needs were being met. The findings have implications for the design of mathematics pre-service teaching courses online and in mixed mode.

Keywords: Primary mathematics teacher preparation · online · mixed mode

Introduction

This paper documents the process of preparing Master of Education pre-service teachers (PSTs) to teach mathematics to children in primary school. The process involves two modes of delivery: entirely online and mixed mode. Online means that all communication between the teaching academic and the learner was undertaken via the digital medium, in the form of prepared written guidance, prepared video support, live and recorded lectures, and live and recorded workshops. Mixed mode involves all the same resource opportunities, and an additional 2-hour on-campus workshop each week for 7 weeks. There are three questions at the heart of the analysis presented in this paper:

1. What were the main motivating factors that inclined the PSTs to choose either online or mixed mode delivery?
2. Were the different modes of delivery associated with different academic scores at the end of each of the two mathematics curriculum courses?

3. Were the different modes of delivery associated with different satisfaction levels at the end of each of the two mathematics curriculum courses?

The use of multimedia, Internet, and video resources has been "particularly productive in providing pre-service teachers with authentic and realistic contexts within which to explore problems and issues that face teachers today, before they move to real classrooms" (Herrington, Herrington, & Omari, 2000, p. 62). These authors reviewed the literature and concluded that online learning "could be effective in enhancing cooperation, communication and human contact. Without the physical constraints…" (p. 73). With respect to physical constraints, Moore (1997, p. 22) used the term "transactional distance" and defined it as the psychological and communications space that is influenced by interacting factors including the structure of the programme, nature of the dialogue between teacher and learners, and the level of autonomy of individual learners.

This paper contributes empirical data to further the investigation into the relative effectiveness of online and mixed mode delivery of mathematics curriculum courses and takes into account transactional distance theory (TDT - Moore, 1997) with regard to the manner in which the content was presented, but the structure of the content and the detail and level of autonomy were informed by cognitive load theory (Kirschner, Sweller, & Clark, 2006). Cognitive load theory contends that memory can be divided into working memory which is limited and of short duration, and long-term memory where large amounts of information can be stored semi-permanently. In designing teaching material, it is important not to overload working memory, but rather to sequence the complexity of instruction such that schema can be developed, and facts, processes and understandings accessed from long-term memory automatically. Kirschner et al. (2006, p. 77) sum up the key features of effective instructional discourse: "The goal is to give learners specific guidance about how to cognitively manipulate information in ways that are consistent with a learning goal and store the result in long-term memory." The insights of multiple researchers were drawn upon in determining the focus of content (e.g., Howe, 2018; Kleickmann et al., 2013; Shulman, 1986; Zhang & Stephens, 2013).

The Importance of Mathematics Content and Pedagogical Knowledge

Howe (2018) conducted an extensive review of the literature on the importance of knowledge for teaching mathematics. He concluded that the knowledge for teaching mathematics was a special kind of applied mathematics, distinct from other fields such as engineering, statistics, and finance. Howe concluded, "Knowing mathematics for teaching demands a kind of depth and detail that goes well beyond what is needed to carry out the algorithm reliably" (p. 22) and used the term "mathematical knowledge for teaching" (p. 17). This involved multiple dimensions, including fluency and understanding of the facts, algorithms, and processes of mathematics – which was earlier called mathematical content knowledge (MCK; e.g., Dohrmann, Kaiser, & Blomeke, 2012). Regarding the level of mathematics that is needed, the National Mathematics Advisory Panel (NMAP; 2008, p. xxi) provides a useful description:

> The teachers must know in detail and from a more advanced perspective the mathematical content they are responsible for teaching and the connections of that content to other important mathematics, both prior and beyond the level they are assigned to teach.

In addition to knowing the content, teachers are expected to be able to analyse student errors, ask appropriate questions, and know and devise alternative models to represent that knowledge (e.g., Dohrmann et al., 2012; Qian & Youngs, 2016). Almost all educationalists agree that high levels of MCK and MPCK are interdependent and necessary for the effective teaching of mathematics. It has been argued that MCK and important aspects of MPCK can be measured using written tests

(Norton, 2018, 2019). While written tests do not capture the nuances of classroom practice, they can give insight into PSTs' capacity to identify and describe student errors, plan sequences of interventions using a variety of presentations of mathematics concepts and assess and grade children's work. This paper compared the grades, based on MCK and MPCK, of PSTs at the end of mathematics curriculum courses according to whether they undertook their study in mixed mode format that had an element of on-campus learning, or entirely online. It was not possible to get reliable data on PST's MCK at the commencement of the study, largely due to difficulties in assessing the mathematical content of the online learners. Enrolment data including high school mathematics, university mathematics courses passed and background data on working commitments were collected at the commencement of the courses.

The Emergence of Online Teacher Preparation

Dinham (2015) and Marginson (2006) contended that Australian universities have, over the past few decades, increasingly moved to an "enterprise" status. As enterprises, the universities enter a supplier/client relationship in competition with one another nationally and internationally for students. Important variables include; accessibility, convenience, and cost. The change in nature of a university from a highly funded institute with a focus on nation building to one with at least a semi-commercial focus has been accompanied by changing forms of governance, from interventionist to more market driven (Dinham, 2015; Elton, 2000; Keeling & Hersh, 2012; Marginson, 2002, 2006; Meyers, 2012).

In Australia, the changing role of universities has been paralleled by increasing autonomy to decide on the forms of assessment, content, teaching time, and delivery modes for courses. According to Masters (2016), autonomy in teacher preparation, including setting entry levels based on proxy measures, was a critical factor in determining the quality of primary school teacher preparation. Specifically related to teacher preparation, one change has been the increase in mixed mode and online delivery of courses and a decline in traditional on-campus lectures and workshops (Herrington et al., 2000). Offering online courses has become essential for remaining competitive (Elliot, 2012). Further, online delivery increases client flexibility and allows participation by students who otherwise might be excluded from the possibility of teacher preparation; potentially, it also increases market share and possibly student satisfaction.

Associated with the changed roles of universities are changes in measuring effectiveness or outcomes. Deneen, Brown, Bond, and Shroff (2013) described a shift to outcomes-based programme and course assessment and attention to student perceptions of the quality of higher education as a major objective of universities. Deneen et al. considered that students are "capable of accurately evaluating valuable educational experiences" (p. 442). According to these authors, PSTs' student evaluation of course (SEC) ought to yield valid data on these important outcomes and has high validity and reliability. Thus, this paper intends to:

1. Explore PSTs' reasons for choosing online or mixed mode delivery,
2. Determine if there is an academic achievement difference at the end of the course, and
3. Determine if the PSTs had different evaluations of their learning experience according to mode of delivery.

It is possible that the different cohorts entered with vastly different levels of MCK and MPCK, but proxy measures such as previous mathematical experience or course completed suggest this is unlikely. These will be described in more detail.

Method

The methodology is explanatory mixed methods (Gay, Mills, & Airasian, 2006), combining the collection of quantitative data on students' knowledge of MCK and MPCK with qualitative commentary by PSTs. Grounded theory methodology (Cresswell, 2005) underpins the analysis of themes that emerged from the qualitative data. The author started with questions and collected data, coded them, and collected more data in the anticipation that repeated ideas would become apparent. Descriptive statistics are used to describe summarised survey data collected at the commencement and end of the mathematics curriculum courses. Examples of PSTs' comments are presented to enhance the clarity of their voice.

Description of the Interventions (Mathematics curriculum course)

As in the intervention for online learning described by Larkin and Jamieson-Proctor (2015), transactional distance theory (Moore, 1997) informed the mechanics of content delivery. In particular, the design of online resources and the conduct of online lectures and workshops attempted to reduce the psychological space between the lecturer and the learners, using ECHO360 videoconferencing and prepared video and text material. In this study, perhaps more so than in the Larkin and Jamieson-Proctor study, there was a very high degree of structure as to what was studied in each week, what pedagogy represented evidenced-based pedagogy, and what level of MCK was anticipated. This included which aspects of MCK and MPCK were the focus of each week of work and direct links to the support video and text materials pertinent to those mathematical concepts.

In each course the teaching cycle was 7 weeks. All students had access to the online 2-hour lecture and its recording. The on-campus students had 2 hours of face-to-face workshops each week over the seven teaching weeks. On-campus attendance for the first 5 weeks was consistently between 80% and 90%, suggesting that this interaction was valued. In Weeks 6 and 7, attendance declined to as low as 50% and PSTs cited pressures with completing assignments in other courses as the major factor restricting their attendance. The online PSTs were offered an online workshop late one evening (Thursday) that was subsequently moved to a more PST friendly time of Saturday morning. These sessions were recorded and accessible to all. Attendance at collaborate online workshops varied, with between six and 20 students attending in real time out of 100-odd online students enrolled in the first curriculum course and six to 12 attending in real time in the for the second curriculum course out of 77 enrolled. In addition to the live time recorded lectures and workshops describe above, all students had access to extensive pre-recorded mathematics teaching support videos and written material. Table 1 summarises the digital resources offered to the PSTs; all were created by the author.

Table 1

Summary of Provided Resources

Resource	No of Videos/ Total duration in hrs	Text	Main function
Teaching and learning fundamental mathematics (Norton, 2011)	19/ 14 hrs	520 pages	Textbook of specific pedagogies for numeration, whole number computation, and problem solving; fraction computation and problem solving; proportional reasoning; early algebra; primary measuring; geometry and data
Diagnosis & remediation of whole number errors (Norton, 2018)	5/ 1.5 hrs	5 diagnostics tools relevant to whole number diagnosis	Templates of diagnostic tests including details on how to diagnose and remediate whole number computation and problem solving
Diagnosis & remediation of fractions errors (Norton, 2018)	4/ 2 hrs	4 diagnostic tools for fraction diagnosis	Details on how to diagnose and remediate fraction computation and problem-solving errors
Learning from NAPLAN Year 3	1/ 0.5 hr		How to analyse early years NAPLAN test and derived school-based data
Learning from NAPLAN Year 5	1/ 0.25 hr		How to analyse upper primary years NAPLAN test and school-based data
Factors influencing the learning and teaching of school mathematics (Norton, 2018)	12/ 3.5 hrs	63 pages	Critical summary of the main factors influencing the learning of mathematics including learning theories, intelligence, early childhood experiences, cognitive load theory, the nature of mathematics, assessment considerations, technology use, lesson recommendations

The focus of each course was to attempt to ensure that the PSTs graduated with three knowledge forms:

1. A deep and connected MCK to the level of a year or so beyond the minimum standards set out by Australian Curriculum, Assessment and Reporting Authority (ACARA) for primary years students. This included concepts with which primary children have consistently struggled, including problem solving using subtraction, multiplication, division, fraction operations, proportional reasoning, and early algebra.
2. A range of specific MPCK models for the above concepts; and

3. The capacity to diagnose common student errors and, using these data, plan and effect learning support.

The focus of the content, or forms of knowledge, was informed by multiple sources from over the past few decades (e.g., Howe, 2018; Kleickmann et al., 2013; Shulman, 1986; Zhang & Stephens, 2013). The intention to develop MCK simultaneously with MPCK and to do so within a learning theory framework is consistent with the advice of Yang, Porter, Massey, Merlino, and Desimone (2019). The level content focus was consistent with the advice of Wu (2018, p. 47): “It closely parallels what is taught in the classroom … it respects the integrity of mathematics”. In this regard, the content was organised in a manner consistent with Wu’s (2011) principles that the concepts were precisely defined and supported by reason, that the topic was coherent, and that the presentation of the mathematics was purposeful.

A further aspect of the course design is that, as much as possible, the tactile learning experiences (hands-on tutoring; Kersey, 2019) that the on-campus PSTs experienced was mimicked in the online learning environments. Online PSTs were asked to have the necessary concrete teaching tools at hand during online collaborative workshops and lectures. PSTs could and did ask questions and make commentary verbally and in written form in real time. This advice was consistent with that suggested by Hoogland and Gadanidis (2002) to incorporate authentic experiences, engage in practical inquiry, and discuss pedagogical implications. The presentation of a preferred pedagogy did not indicate that other pedagogical approaches are less valid, but the set of models, questions, and activities that were presented are widely accepted to enhance learning in a range of children. Numerous sources were used in constructing the supplied resources listed in Table 1 (e.g., Bobis, Mulligan, & Lowrie, 2004; Booker, Bond, Sparrow, & Swan, 2010; Van de Walle, Karp, Bay-Williams, & Wray, 2013).

There was a great deal of overlap between pre-recorded video and text support. In effect, PSTs could choose their preferred medium: written text, prepared video support, or recorded online real-time videoconferencing via collaborate. The video material described the underlying logic of MCK and the explicit teaching of this to children. Where appropriate, concrete materials such as place value charts, bundle sticks, base-ten materials, geometric shapes were also demonstrated. In addition, graphs, sketches, models, and paper-and-scissors manipulation were employed. In addition to the resources described above, the PSTs had access to videos and exemplars guiding their assignment conduct and write up as well as the examination structure, with model questions and some model solutions.

The theorising of the organisation and presentation of the data was consistent with cognitive load theory. Consistent with the instructional advice associated with cognitive load theory, care was taken to limit the amount of new material introduced in any one learning sequence and ample opportunity afforded to clarify and apply this learning before new material was introduced. That is, the author attempted to logically develop schema and have this embedded into long-term memory through practice and repetition before advancing in abstraction. In the application of cognitive load theory, the expert (lecturer) gave very specific models of how to teach mathematical concepts (MPCK) and how to use the concrete materials, all of which have been recommended by the authors above. The PSTs were in the first year of their two-year Masters of Education degree and therefore it was assumed that the PSTs were novices. As noted by Kirschner et al., “The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide internal guidance” (p. 75). Thus, at this stage of their journey to become classroom teachers, specific guidance was abundant and was delivered via multiple modes. This is consistent with Benson and Samarawickrema’s (2009) advice that online learners commencing a new study area demonstrate low levels of autonomy and thus require high levels of structure to reduce transactional distance.

Data Collection Tools

Participants and their Background

The participants were all Master of Education students who had completed a degree and had enrolled in two courses (Mathematics Curriculum 1 and Mathematics Curriculum 2) as part of their accreditation to become primary teachers. There were two campuses delivering mixed mode courses (see Table 2). The author conducted all the teaching for both courses. Assessment items were randomly assigned to two experienced markers whose work was closely supervised and moderated by the author.

The participants were administered a survey which was voluntary and anonymous (Ethics protocol number EDN/34/14/HREC). The survey collected background data were collected towards the end of the first mathematics curriculum course. The intention was to collect data on the following variables:

- Level of high school mathematics completed;
- Any university mathematics courses completed;
- Factors that motivated them to choose the delivery mode;
- Factors that were hindering their success, or challenges that needed to be overcome to attain success in this subject;
- Hours spent on studying for this subject each week during the teaching period; and
- Hours of paid work undertaken or other non-paid work commitments during the teaching period.

It was hoped that from responses to these questions, baseline data for PSTs' motivations for delivery modes could be set in a context. Summaries of these data are presented in table, graphical and descriptive form. It was difficult to enlist the participation of on-line PSTs with 25 out of 103 (initial enrolment of online PSTs) or 24% completing the initial background survey. Participation rate for the mixed mode cohort on this survey was 63 out of 86 or 73% of initial mixed mode enrolment.

Table 2

Summary of Participants

	Mathematics Curriculum 1	Mathematics Curriculum 2
Online (*n*)	103	77
Mixed mode on-campus (*n*)	86 Campus 1 *n* = 51 Campus 2 *n* = 35	76 Campus 1 *n* = 45 Campus 2 *n* = 31

The first thing to note in Table 2 is that online delivery was the preferred option. However, there was a 17% - 25% attrition rate (depending on administrative processes) for online PSTs and a 12% - 15% attrition rate among the mixed mode PSTs. The reasons for this increased attrition rate for online students can be inferred from student comments reported later in the paper: mostly, online students found they could not juggle full-time study with their jobs and family responsibilities. Since the attrition rates from these courses were a mirror of withdrawal from the programme it is not possible to infer that the mathematics component of the programme was a deciding factor.

Who enrols and with what mathematics background?

The intake was dominated by women, and only 14 (9%) of 153 PSTs who completed the final exam were men. In terms of their high school level of mathematics completed, there were four categories, as illustrated in Table 3.

Table 3

Reported Level of Mathematics Undertaken at School (online n = 25; mixed mode n = 63)

Level of high school mathematics	Online	Mixed mode
No mathematics	1%	1%
Mathematics A (General mathematics) or its equivalent, a relatively low-level mathematics with limited demands upon abstract reasoning	50%	53%
Mathematics B (Mathematical methods), containing significant levels of calculus	42%	40%
Mathematics C (Specialist mathematics) containing high levels of calculus	7%	6%

Consistent with recent changes to enrolment prerequisites, almost all the respondents reported to have studied some mathematics in Year 12, with about half of these reporting to have studied Mathematics A or applied mathematics with limited algebra or calculus. Limitations in the sampling (size and issues related to representation) of the online students caution against the making of inferences. Table 4 illustrates the forms of mathematics studied during the PSTs' Bachelors study.

Table 4

University Level Mathematics Studied (online n = 25; mixed mode n = 63)

University mathematics	Online	Mixed Mode
No mathematics in prior tertiary study	28%	43%
Statistics associated with psychology, social work, criminal justice, or introduction to statistics	30%	32%
Mathematics related to business or accounting	40%	20%
Mathematics related to health studies, e.g., nursing	2%	5%

Table 4 illustrates that there was a prevalence of business-related mathematics studies among the online enrolments and a prevalence of no prior tertiary mathematics study among the mixed mode enrolments. It was rare for a PST to have taken studies likely to entail advanced university mathematics. This is confirmed by the findings presented in Table 5.

Table 5

Description of Earlier Tertiary Study (online n = 25; mixed mode n = 63)

Degree description	Online	Mixed Mode
Arts, including creative writing, drama, fine arts, history	14%	32%
Business related, including accounting, commerce	40%	17%
Social care oriented, including social work, human services, counselling	20%	14%
Legal studies, including law, legal studies, criminal justice	5%	11%
Health science, including exercise, nutrition, exercise and sport, nursing	5%	15%
Hospitality	5%	6%
Property and built environment	8%	2%
Music	0%	2%
Science	3%	1%

The background data presented in Tables 3, 4, and 5 illustrate that about half of PSTs had studied relatively low levels of mathematics at high school and did not study mathematics-rich courses at university, other than those associated with statistics, particularly that related to social care or health science. The mixed mode enrolment had a higher proportion of arts and health science students. Notably, about double the percentage of online students studied mathematics associated with business/finance. This overall variation in background mathematics preparation is typical of that found in most Western nations, according to several authors (Burghes, 2011; Ma, 1999; Qian & Youngs, 2016; Shulman, 1986).

Why choose online or mixed mode delivery?

To answer the first research question (What were the motivating factors that inclined PSTs to choose either online or mixed mode delivery?) the survey describe above was administered. The responses related to answering why PSTs chose a mode of delivery are summarised in Figures 3 and 4 and Table *6* located in the results section.

Does the mode of delivery make an academic difference?

To answer the question, does the mode of delivery make an academic difference; the scores of the students' assessment tasks were used. In each mathematics curriculum course, the PSTs were assessed by a 50% case study research assignment and a closed-book, 2-hour exam designed to assess MCK and MPCK. The 50% case study required the PSTs to locate a child in early years (Prep to Year 3 for Mathematics Curriculum 1) and upper primary (Years 4, 5, or 6 for Mathematics Curriculum 2), carry out a mathematics diagnosis on whole number and fraction understandings using the provided diagnostic tool, and with these data, plan and implement a remediation teaching cycle (usually four teaching sessions), implement a post-test, and write up the process, taking into consideration the child's affective and cognitive dispositions. Details of the marking schema for the 50% assignment are available by request from the author.

The PSTs' success on the final examination gives baseline data on the level of MCK and MPCK the PSTs took to graduation. These data are of interest to those academics concerned with the structure of PST programmes and courses. The details of the tests, along with success rates on each question, are available on request from the author. The sample questions below (see Figures 1 & 2) illustrate the assessment of diagnostic capacity MCK as assessed in the second mathematics curriculum course.

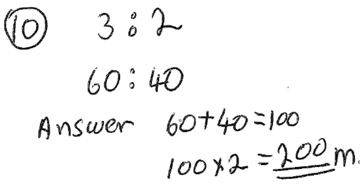
<table>
<tr><td colspan="2">Question 10: The ratio of side length to height on a painting is 3:2. If the length is 60 cm what is the area of the painting?</td></tr>
<tr><td rowspan="2">Child's working
</td><td>a) What can the child do and what is their error? (MPCK) (1 mark)
(Average score on item $\bar{x}$ = 0.53)</td></tr>
<tr><td>b) Set out the correct solution (MCK) (2 marks)
($\bar{x}$ = 1.23)</td></tr>
</table>

Figure 1. Sample of one of 12 questions assessing MCK and MPCK from Mathematics Curriculum 2.

The sample question below was one of three that assessed detailed MPCK.

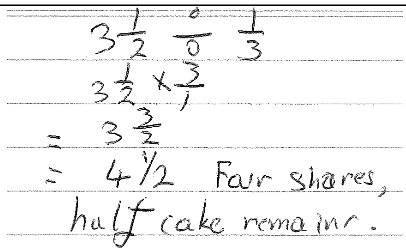
<table>
<tr><td colspan="2">Question 1: (The following question was given to a Year 6 Class.) Three and a half cakes were shared among children with each share being a third of a cake. How many full shares were there and did any remain?</td></tr>
<tr><td>The child responded
</td><td>(a) Describe the error in thinking (1 mark)
(Average score on item $\bar{x}$ = 0.5)</td></tr>
<tr><td colspan="2">(b) In the space below, set out how you would go about teaching the concept of fraction division. Be sure to use diagrams or models and use logical discussion to develop the algorithm for this process. (MPCK) (9 marks)
(Average score on item $\bar{x}$ = 6.0/9)</td></tr>
</table>

Figure 2. Sample of a detailed pedagogy test item from Mathematics Curriculum 2.

ANOVA tests were used to assess if there was statistical significance between the scores of PSTs according to delivery mode for both the assignment scores and closed book examinations. Cohen's d effect size calculations were used to describe the relative gains on assignment scores over the two curriculum courses.

How is delivery mode related to satisfaction ratings?

The third research question examines the level of satisfaction expressed by the online and mixed mode delivery students and what further support they desired. The data source for this was the standard SEC surveys that are carried out at the end of each teaching cycle. PSTs' responses to four, 5-point Likert items are reported:

1. Overall, I am satisfied with the quality of this course…
2. The focus on explicit teaching methods was important…
3. The focus on mathematical content knowledge was important…
4. The supplied video and math texts assisted my learning…

Two additional open-ended questions were added to the SEC survey. The PSTs responses add context and explanation to the quantitative Likert responses: "What did you find particularly good about this course?" and "How could this course be improved?" These prompts are standard SEC prompts at the study institution.

Analysis

PSTs' qualitative responses to the various questions asked in pre- and post-survey questionnaires were read for themes. Consistent with grounded theory methodology, open coding enabled initial categories or themes to emerge from the data (Cresswell, 2005). The frequency of these themes was counted and reported. The mechanism of this coding is articulated in the results sections. PSTs' mean achievements of each cohort on tests and assignments were reported. The average results and standard deviation on questions of interest were reported. ANOVA tests were used to determine the statistical significance of any differences. PSTs' Likert responses on SEC are reported as means. The implications of these data are discussed.

Results

The results are sequenced as follows: explanations for choice of delivery; academic outcomes; and responses to the course.

What were the Main Motivating Factors that Inclined PSTs to Choose either Online or Mixed mode Delivery?

In response to the prompt, "Please describe the factors that motivated you to choose the delivery mode you have chosen", those who had chosen on-campus with some face-to-face delivery expressed two key themes and a third less prevalent theme. The first was that they *believed they learned best in this form of delivery* (43% of total comments). This was typified by comments such as:

> I find it easier to ask questions to better consolidate my understanding when in class.
>
> Hands on required to learn efficiently for me. I learn from physical contact with objects.
>
> I learn best face to face learning. It helps me to understand information quickly and I have a better chance of committing it to long term memory.

A portion of these students linked the benefits of face to face delivery with mathematics anxiety.

> I have struggled with maths all my life and so need to be on-site for lectures. Also, I learn better by being shown something and then repeating.

> I was anxious at school in math and face to face gives me more support.

The second theme involved a need for social interactions with peers (30% of total comments) as exemplified by the following statement:

> I felt I would be more engaged on campus teaching is a very collegiate profession, therefor it is important to build a network.

The third dominant theme was related to PSTs' motivational status (27% of total comments). Comments such as those listed below illustrate the nuances of this sentiment:

> I will procrastinate until too late if I do not have accountability of face to face learning.

> I am not disciplined enough to study online, I need the structure of lectures and workshops and having peers around me working.

As evidenced above, some responses contained two themes; each was counted individually. The frequency of these themes is illustrated in Figure 3.

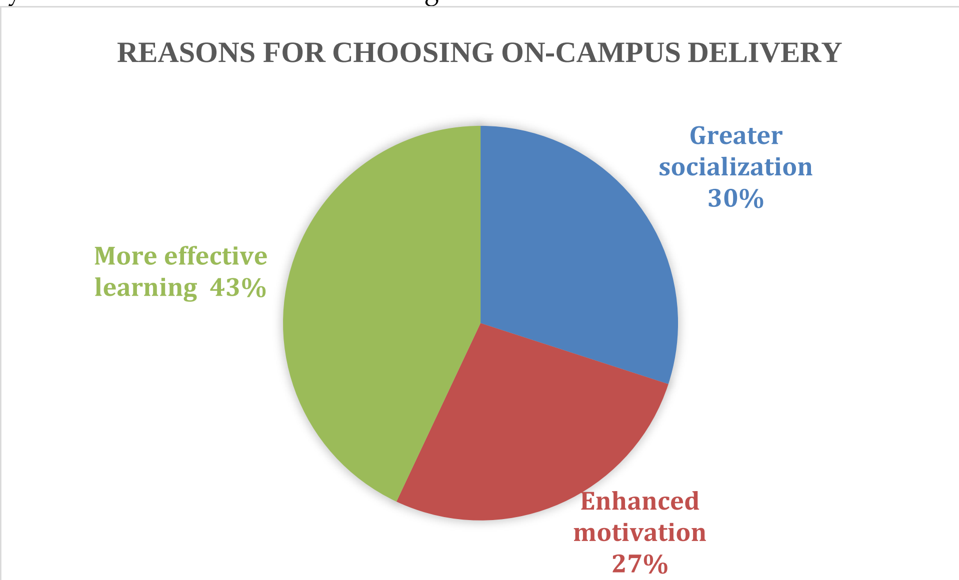


Figure 3. On-campus (mixed mode) PSTs' reasons for choosing this delivery mode (*n* =152 comments).

There are nuances in each theme, and we can see that the distribution is dominated by the belief that learning would be more effective (43%). The belief that motivation would be enhanced and the desire for face-to-face socialisation are roughly equally represented in the expressions for this choice.

The reasons PSTs articulated for choosing to study online were work commitments, family responsibility, travel challenges, and flexibility in general (see Figure 4). In almost all instances the PSTs reported several contributing factors, as exemplified by the response below:

> I have four children under the age of ten, I must run the household and run a small business. I cannot afford to lose 40 minutes each way to commute to university.

Other expressions of work commitments (23% of total comments) included:

> I work near full time shift work and cannot commit to coming to campus.

A prominent reason for choosing online study was commitments to family, including household management and caring for children (32% of total comments):

> I have four children, two on the spectrum, and must work to help support the family finances. If I am not here, they two with disadvantage go off the rails.

> I am a single mum and must do this online.

Travel challenges (26% of total comments) were cited. For example:

> The cost of commuting both in time and in money is an issue.

A number of PSTs cited the general flexibility (18% of total comments) offered by online delivery without giving further details, with comments such as:

> Online gives me the flexibility to organise my life around other priorities.

A few PSTs simply preferred the flexibility of online learning without considering other commitments, for example:

> I like the flexibility of opening the laptop with my bed socks on and studying in my own time.

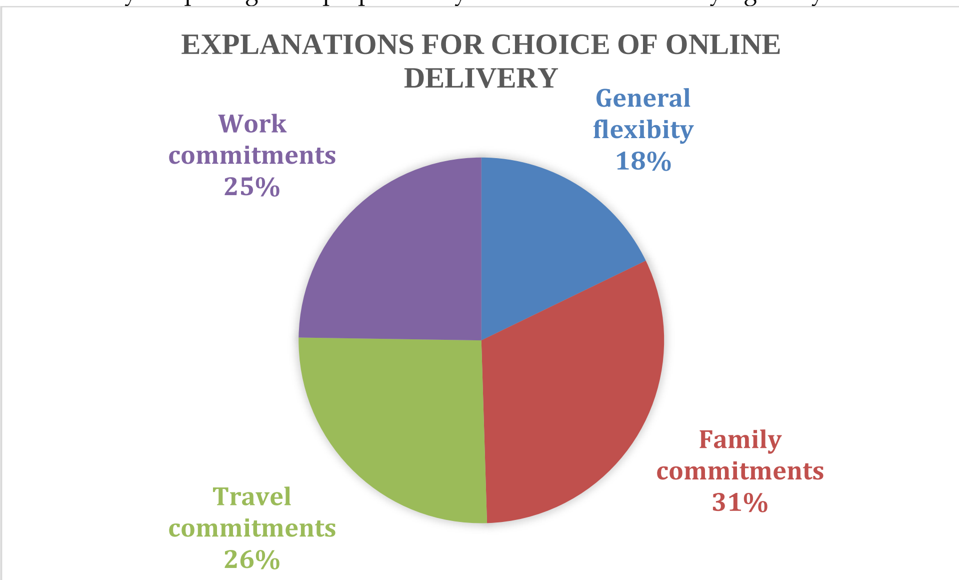


Figure 4. Online PSTs' explanations for choosing this delivery form (n = 45 comments).

Since work commitments were cited as a significant issue with respect to attendance, it is worth citing the PSTs' responses to the prompt "Please indicate if you had outside work commitments and roughly how many hours each week during the teaching weeks 1 to 7". These commitments are presented in Table 6.

Table 6

Reported Paid Work Each Week of Teaching Cycle

Reported work/week during teaching cycle	Online (n = 24)	On-campus (mixed mode) (n = 61)
zero		8
1 to 5 hours		8
6 to 10 hours	6	17
11 to 15 hours	3	9
16 to 20 hours		9
21 to 30 hours	6	4
Above 30 hours	3	5

While the limited numbers of respondents encourage caution, especially in the case of online PSTs, it is worth noting that no online PST reported working fewer than 6 hours, half reported working over 21 hours, and some worked above 30 hours per week. The data on the working commitments of on-campus PSTs were more extensive and indicate about 27% of on-campus students reported working fewer than 5 hours a week. Long working hours was an important factor in online students' choice of delivery. On the other hand, it is evident that a portion of on-campus PSTs had the luxury to commit to on-campus study without commitment to paid work.

In summary, the data suggest that on-campus PSTs chose this means of delivery because it was their preferred learning style, that is, they saw value in it for cognitive purposes (more effective learning), increased motivation, or social opportunities. Further, the data suggest that this option was feasible due to proximity and flexibility associated with their work and family commitments. In contrast, online PSTs tended to report that they elected this form of delivery because they had less choice. It was rare for online students to comment that it was their preferred mode of delivery from a learning perspective.

Were the Different Modes of Delivery Associated with Different Academic Scores?

The outcomes of the research described by Deneen et al. (2013) and Larkin and Jamieson-Proctor (2015) did not include academic scores. However, the development of MCK and MPCK are considered central to the goal of teacher preparation (Dohrmann et al., 2012; NMAP, 2008; Wu, 2018). In this study, MPCK was assessed by the written assignments and the closed-book examination, taken without calculators for a duration of 2 hours. The average and standard deviation scores for the assessment items of the PST cohorts are presented in Table 7.

Table 7

Summary of Academic Outcomes

	Online (Mean and standard deviation)	Mixed Mode (Mean and standard deviation)
Mathematics Curriculum 1 Assignment	68.95/100 (13.62)	68.85/100 (14.47)
Mathematics Curriculum 1 Examination	62.88/100 (13.89)	59.72/100 (13.55)
Mathematics Curriculum 2 Assignment	84.84/100 (11.46)	79.78/100 (10.48)
Mathematics Curriculum 2 Examination	59.38/100 (17.56)	53.52/100 (16.88)

ANOVA statistical analysis indicates that there were no significant differences between the groups for Assignment 1 (df = 178, F = .002, Sig = .962) or Examination 1 (df = 174, F = 2.334, Sig =.128). For Mathematics Curriculum 2, statistical differences were recorded for Assignment 2 (df = 147, F = 7.947, Sig = .005), favouring the online cohort. The assignment was intended to develop MCK and MPCK rather than to be an assessment of these knowledge forms. The process of performing an error analysis on student thinking (MPCK) was relatively novel for each PST and accounted for 10 out of 50 marks, a relatively small proportion of the assignment mark. Since the specific MCK and MPCK could be readily sourced from the provided learning materials, success on the assignment was more dependent upon PSTs' capacity to form a productive relationship with their subject, plan and implement a targeted teaching cycle and generic report writing and literacy skills. As noted above, the mean assignment scores increased from 68% to about 80% from Mathematics Curriculum 1 to Mathematics Curriculum 2. The Cohen's d effect size for the online students' improvement on the assignment tasks from Mathematics Curriculum 1 to Mathematics Curriculum 2 was 1.26 while the mixed mode students' Cohen's d calculation was 0.86 for assignment improvement. The assignment tasks for Mathematics Curriculum 1 and Mathematics Curriculum 2 were similar. Because extensive feedback was given to the students after the assignment in Mathematics Curriculum 1, it is not surprising that both groups improved their scores in the second unit. It is notable, however, that the online cohort had greater improvement. It needs to be noted that the assignment criteria for each course were almost identical, and the markers were the same and randomly allocated.

The online PSTs had marginally, but not statistically significant, higher grades on the first examination that were based on early years (Prep to Year 3) MCK and MPCK. There was a statistical difference in the means, favouring the online students in the final examination of Mathematics Curriculum 2 (df = 146, F = 4.542, Sig = .035). The MCK and MPCK for Examination 2 was associated with upper primary mathematics and included multiplication, division, fractions, ratio, rate, proportional reasoning, early algebra, and problem solving with these concepts.

It is beyond the scope of this paper to do a detailed analysis on the level of MCK and MPCK attained upon graduation. Interested parties can examine the success rates on various questions on the Mathematics Curriculum 2 examination (available upon request from the author) and make their own judgements. What is relevant to this paper is student needs and perceptions, especially associated with satisfaction.

Were the Different Modes of Delivery Associated with Different Satisfaction Levels?

PSTs' reported levels of satisfaction are evidenced by the SEC mean scores and qualitative comments on SEC, mostly at the completion of the final Mathematics Curriculum 2 course and are shown in Table 8.

Table 8

Response to SEC (5 = Strongly Agree)

SEC prompt	Online	Mixed mode on-campus A and B	
Mathematics Curriculum 1 (Prep to Year 3)			
	Online *n* = 103	Campus A *n* = 51	Campus B *n* = 35
Overall, I am satisfied with the quality of this course (%) indicates participation rate.	4.2 (25%)*	4.9(24%)	4.4 (28%)
The focus on explicit mathematics teaching methods was important (MPCK)	4.6	5	4.5
The focus on mathematical content was important (MCK)	4.6	4.9	4.5
The supplied video and mathematics texts assisted my learning	4.7	4.9	4.7
Mathematics Curriculum 2 (Year 4 to Year 6)			
Overall, I am satisfied with the quality of this course	4.3 (56%)	4.5(59 %)	3.8(40%)
The focus on explicit mathematics teaching methods was important (MPCK)	4.7	4.7	4.3
The focus on mathematical content was important (MCK)	4.6	4.7	4.2
e supplied video and mathematics texts Assisted my learning	4.6	4.8	4.5

*** ( )** % participation rate on SEC survey at the end of the study period prior to the examination or allocation of any marks.

The response rates for the first mathematics curriculum course were relatively low (24% to 28%) suggesting caution in extrapolating the results. However, because over half the online cohort and Campus A responded to SEC for Mathematics Curriculum 2, we can be optimistic that the samples are representative. The data indicate that the delivery modes seemed not to result in different satisfaction ratings, overall, with respect to the focus on MCK and MPCK or assessment of the online video and text support. It needs to be remembered that all PSTs had access to the same online support: it is just that the mixed mode PSTs had the opportunity to engage with each other and peers face-to-face for 14 hours per course. The similarity in Likert ratings does not mean that their ratings could be attributed to the same factors. In order to unpack the nuances of what the online and mixed mode cohorts considered was "particularly good" and "how the course could be improved", it was necessary to analyse the qualitative response on SEC. These prompts are standard on the University SEC surveys.

In responding to "What did you find was particularly good about this course?" 68 online students submitted written comments, while 51 on-campus comments were submitted; some of these were extensive. Eight themes were identified and counted; the percentage occurrences are recorded in Table 9. In most instances it was near impossible to distinguish between comments that related to MCK and MPCK, such as exemplified in the comment below:

> The content was taught explicitly in great depth with lots of opportunities to practice skills, this gave me a lot of confidence.

In this instance it is not possible to determine if the "content" which gave the PST confidence refers to MCK or MPCK.

Table 9
Frequency of Comments Related to What was Good about the Course

Key themes with respect to "what was well done in the course", with exemplars (*n* = number of comments)	Online (*n* = 102)	On-campus (*n* = 100)
Video support: The delivery of the video (camera angle focusing directly from above the manipulated materials and written explanations) was excellent as was the specific nature of the content and I could watch on my own time.	26%	19%
Focus of course (MCK and MPCK): The content, the focus on the maths and the teaching methods was highly relevant to classroom practice.	19%	19%
Text support: The textbook was written in an easy to read format that was very practical to classroom practice.	11%	17%
Assessment: The practical assessment in which we applied taught strategies gave me more confidence.	12%	5%
General organisation: The clarity and structure, the way the multiple medium integrate is brilliant. All the necessary information was consolidated and accessible.	12%	14%
On-line collaboration: I liked to be able to ask questions on-line and get an immediate response.	7%	3%
On-campus workshops: In workshops we practiced with materials and that gave us a perspective on how the kids learn.	0%	14%
Timetable flexibility: I have two kids and work four days, so the flexibility is great.	6%	0%
Academic: He knows what he is doing and helped us learn to teach maths.	9%	9%

There is little to distinguish between online and on-campus qualitative responses except that, as expected, the online PSTs commented more about the video support and the on-campus mixed mode PSTs appreciated the on-campus workshops. This is as expected since the main motive for enrolling in on-campus mixed mode was to have face-to-face interaction. Unsurprisingly, the online PSTs made more mention of timetable flexibility. The video support tended to be more commented upon than the written textbook support material by both on-campus and online PSTs. The nuances of student evaluation are also evidenced by their comments on how the course could be improved (see Table 10).

Table 10

Qualitative Comments on how the Course could be Improved (n= number of comments)

Key themes with respect to "how could this course be improved", with exemplars	Online (n = 66)	On-campus (n = 30)
Assessment:	21%	28%
The assignment was very demanding and should be worth more than 50%…		
The assignment was too stressful to organise…		
Video quality:	15%	3%
The videos were hard for me to engage with…		
Content organisation:	5%	3%
The lectures, video and workshops were repetitive…		
The resources were not easy to navigate…		
Content focus:	12%	14%
Do not teach beyond Year 6.		
The more advanced maths stressed me…		
Amount of content:	14%	12%
There was too much material to get through each week…		
More time for face to face:	0%	24%
More lectures and workshops needed…		
More support:	11%	0%
More examples with solutions to practice with…		
Connection to curriculum:	5%	7%
More connections to ACARA curriculum…		
Timetable issues:	10%	7%
More outside hours lectures-		
Keep focused:	5%	2%
The lecturer got diverted from key content		

Lack of clarity around the assignment and anxiety associated with the assignment and exam dominated PSTs' suggestions for improvement. Both cohorts expressed discontent with the level of content and pedagogy taught; in particular, a significant portion considered that any content above Year 6 was redundant. This is an important finding as it illustrates a potential clash between the expectations of educational theories (e.g., NMAP, 2008) and student expectations, although in this instance the difference did not manifest in an overall negative judgment of the courses.

Discussion

Who Enrolled and with what Mathematical Background?

The different cohorts reported doing similar levels of high school mathematics with about half completing Mathematics A or General Mathematics. There is evidence to suggest that higher proportions of PSTs had backgrounds in commerce, business, and finance. Further, more of the mixed mode PSTs reported doing no mathematics study in their tertiary studies. The most common form of mathematics study among mixed mode PSTs was statistics associated with psychology, social work, or business-related degrees. More effective sampling would be needed to confirm these observations.

The overall variation in mathematics background is consistent with international and national findings over several decades (Norton, 2011, 2012, 2017, 2018; Burghes, 2011; Ma, 1999; Qian & Youngs, 2016; Shulman, 1986). The above authors have also noted that proxy measures such as number of courses completed are unreliable estimates of relevant MCK. Earlier studies by the author have reported that in the study institution (and likely across Australia) at intake, primary PSTs had varied and, in the main, low levels of relevant MCK. "Relevant" is an important term since a pass in a university calculus course might indicate a capacity to deal with abstract mathematics but does not necessarily indicate a deep and connected knowledge of multiplication and division of fractions and does not indicate depth of MPCK associated with primary school mathematics. As noted by Howe (2018), mathematics for teaching is a special form of applied mathematics.

Why Choose Online or Mixed Mode Delivery?

PSTs chose mixed mode course delivery for three key reasons: Firstly, they believed it was a more effective way for them to learn. In explaining this reason, the importance of interreacting with materials and the capacity to ask questions in person was reported. The second-cited reason was the importance of in-person social interaction. The importance of social interaction is central to learning (Vygotsky, 1987). The third prevalent factor cited by PSTs for opting for an element of face-to-face interaction was enhanced motivation. The comments reported in the results sections are an acknowledgement that having the structure of formal workshops on campus assisted the development of a more productive study routine for some students. PSTs who chose to study online did so primarily because commitments to work and family made on-campus attendance a very difficult option for most of them.

PST's choice of online delivery might have also been associated with a stronger background in mathematics and subsequent confidence to learn more autonomously. Several elements in the data suggest that this assertion is plausible; the lesser proportion of online students doing no mathematics in their earlier tertiary studies; the higher incidence of business and accounting mathematics undertaken; and the greater improvements over the two curriculum units on each form of assessment. The superior improvement in the assignment marks for online PSTs (Cohen's d 1.26 compared to mixed mode Cohen's d 0.86) potentially suggests stronger generic academic capacity that considers both application and aptitude.

The data on working hours suggested that at least some of the on-campus enrolments had no or limited work commitments. In contrast, the data indicated that more online PSTs tended to have more significant work commitments. About one quarter of the reasons cited for choosing online study were related to travel. In fact, over 90% of the cohort lived within the greater city limits. Still, excessive travel and parking costs were a stated reason not to attend campus. In some instances, at least, some of these PSTs would not have enrolled at all in the institution if the online option was not available. It was rare for online PSTs to cite this option as a matter of preferred learning environment: online engagement seemed to be chosen more from necessity than from desire.

Does the Mode of Delivery Make an Academic Difference?

Enrolment data suggest that it likely that online enrolment PSTs entered the courses with a higher proportions having undertaken mathematics associated with business-based mathematics. This was not reflected in statistically higher scores in the first examination. This is hardly surprising since the level of content and the associated pedagogy extended to Year 3. However, as noted above, the online PSTs made greater improvements with the assignment and had statistically significantly greater mean scores on the second examination ($p = .035$). The mathematical basis of this examination was upper primary and included concept areas that earlier cohorts had struggled with (Norton, 2011, 2012, 2017, 2018). Moore (1997) commented that separation of teachers from learners "profoundly affects both teaching and learning" (p. 22). The academic scores did not reflect a profound advantage being conferred by face-to-face learning as compared to online learning if transactional distance is accounted for.

There are two plausible explanations for the greater improvement and greater overall scores on the final examination for the online students. The first is that online PSTs enrolled with, on average, stronger mathematics backgrounds and this became important when the content they were preparing to teach entailed more difficult mathematics associated with fractions, rate, ratio, and early algebra. This may well have been correlated with general academic capacity as reflected in the greater improvements in the assignment scores. The second possibility is that the online students were more autonomous learners who work more effectively. The differences in PSTs' explanations for choosing online or mixed mode provide supporting evidence for this statement, with about 27% of mixed mode students citing enhanced motivation and a further 30% citing greater socialization as reasons for choosing this model of delivery. Online PSTs did not document socialisation, motivation, or preferred learning style: their responses were dominated by necessity (work, family, and travel). These findings suggest that the academic and potentially psychological needs of the different cohorts were different.

At the enrolment stage, mixed mode PSTs cited a need for face-to-face support and greater socialisation opportunities. The PSTs who attended the workshops had clearly stated that such activities met their preferred learning style for a variety of reasons, including that they could manipulate material, interact socially, and enjoy the positive motivational aspect of face-to-face learning. In this regard the findings mirror Kersey's (2019) conclusion that students believed that they learned best through tactile activities. If the intuitions of the respondents are correct, the absence of these in-person and intimate learning opportunities would likely have had a negative impact on the on-campus mixed mode cohort's academic outcomes and would almost certainly have had a negative impact on their ratings of the courses.

How is Delivery Mode Related to Satisfaction Ratings?

Deneen et al. (2013) argued that PSTs' SEC could yield valuable information about their learning experiences, particularly if we could assume the samples were representative. This assumption might be optimistic for the first curriculum subject where participation rates were about 25%. However, for the second curriculum course, with participation rates approaching 60%, such an assumption is probably realistic, particularly given the consistency of responses between delivery mode and campuses. There was very little difference in satisfaction ratings on any of the reported questions. The *Overall* SEC satisfactions ranged between 3.8/5 and 4.9/5. The additional questions (focus on explicit mathematics teaching methods; focus on mathematical content knowledge and supplied video and mathematical tests) tended to be rated more highly in each cohort than the *Overall* rating (4.2/5 to 4.8/5).

The high SEC scores on prompts related to MCK and MPCK suggest that the intervention format that attempted to develop MCK and MPCK simultaneously, at levels relevant to the immediate teaching (Herrington et al., 2000; Wu, 2011), was well received, although between 12% and 14% registered discontent at the level of MCK and MPCK expectation. The very explicit video and text support, consistent with the cognitive load theory advice for novice learners (Kirschner et al., 2006) and e-learning researchers (e.g., Benson & Samarawickrema, 2009), was almost universally valued. Written comments related to the hands-on manipulation of teaching materials and very specific pedagogy suggest that many PSTs appreciated the focus on authentic activity (Hoogland & Gadanidis, 2002) irrespective of the mode of delivery. In short, the transactional distance (Moore, 1997) seemed to be sufficiently accounted for despite the limited autonomy in developing novel pedagogical approaches. These conclusions were triangulated with quantitative SEC scores and the analysis of themes in PSTs' comments (n = 298).

In terms of what could be improved, most commented upon wanting greater guidance on assessment. Improved video quality was also a major consideration and a desire for more practice examples dominated online PSTs' written comments. On-campus PSTs wanted more face-to-face time. All cohorts considered that the amount of content was too much for the length of the teaching cycles and, as noted above, some did not think it was necessary to teach mathematics pedagogy targeted at beyond the minimum standard for Year 6 primary students.

Conclusions

From the perspective of the nature of universities as enterprises (Dinham, 2015; Marginson, 2006) the results that matter most are enrolments, completions, and student satisfaction. In this study, more than half the enrolments of the studied cohorts were online and entry survey data suggest that without the online option, a portion of these PSTs may not have enrolled in the programme. Since some of these PSTs were very significantly constrained by caring and work commitments, the offering of online courses has a social justice element.

The data presented here have illustrated that well-designed online delivery can meet the perceived learning needs of most PSTs who opt for online delivery. The enrolment data and academic scores suggest that many of the students who enrol for online delivery have different social and academic support preferences from those who enrol on-campus in mixed mode delivery. On-campus PSTs have expressed a preference for in-person interactions that is likely grounded in their social and cognitive needs. Teacher preparation providers are advised to consider the range of social and cognitive needs of potential PSTs when offering mathematics curriculum units.

Limitations

The most significant limitation is making inferences from the entrance data of the online PSTs where only 25% responded to the initial survey. This weakness is mitigated to some degree by the testing (100% response rate) and SEC (56% response rate) data where the reader can be more confident that the sample is representative.

References

Benson, R., & Samarawickrema, G. (2009). Addressing the context of e-learning: Using transactional distance theory to inform design. *Distance Education, 30*(1), 5-21.

Bobis, J., Mulligan, J., & Lowrie, T. (2004). *Mathematics for children: Challenging children to think mathematically.* Frenchs Forest, Sydney, Australia: Pearson/Prentice Hall.

Booker, G., Bond, D., Sparrow, L., & Swan, P. (2010). *Teaching primary mathematics*. Frenchs Forest, Sydney, Australia: Pearson.

Burghes, D. (2011). *International comparative study in Mathematics training: Recommendations for initial teacher training in England.* CfBT Education Trust. Retrieved from https://www.nationalstemcentre.org.uk/res/documents/page/International%20comparative%20study%20in%20mathematics%20teacher%20training.pdf/

Cresswell, J. (2005). *Educational research: Planning, conducting and evaluating quantitative and qualitative research*. NJ: Pearson.

Deneen, C., Brown, G., Bond, T., & Shroff, R. (2013). Understanding outcome-based education changes in teacher education: Evaluation of a new instrument with preliminary findings. *Asia-Pacific Journal of Teacher Education, 41*(4), 411-456.

Dinham, S. (2015). The worst of both worlds: How U.S. and U.K. models are influencing Australian education. *Education Policy Analysis, Archives, 23*(49). Retrieved from http://epaa.asu.edu/ojs/

Dohrmann, M., Kaiser, G., & Blomeke, S. (2012). The conceptualisation of mathematics competencies in the international teacher education study TEDS-M. ZDM. *Mathematics Education, 44*(3), 325-340.

Elliott, M. (2012). Mathematics online! Issues and solutions. In T. Bastiaens & G. Marks (Eds.), *Proceedings of E-Learn 2012--World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 1* (pp. 977-979). Montréal, Quebec, Canada: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/primary/p/41720/

Elton, L. (2000). The UK research assessment exercise: Unintended consequences. *Higher Education Quarterly, 54*(3), 274-283.

Gay, L., Mills, G., & Airasian, P. (2006). *Educational research: Competencies for analysis and application.* Upper Saddle River, NJ: Pearson, Merrill Prentice Hall.

Herrington, A., Herrington, J., & Omari, A. (2000). Online support for preservice mathematics teachers in schools. *Mathematics Teacher Education and Development, 2*, 62-74.

Hoogland, C., & Gadanidis, G. (2002). Mathematics teacher education online. In P. Barker & S. Rebelsky (Eds.), *Proceedings of ED-MEDIA 2002--World Conference on Educational Multimedia, Hypermedia & Telecommunications* (pp. 556-561). Denver, Colorado, USA: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/primary/p/10324/

Howe, R. (2018). Cultural knowledge for teaching mathematics. In L. Yeping, W. James, & J. Madden (Eds.), *Mathematics matters in education* (pp. 19-39). University College: Springer.

Keeling, R., & Hersh, R. (2012). *We're losing our minds. Rethinking American higher education*. New York: Palgrave Macmillan.

Kersey, S. (2019). Student perceptions on teaching and learning using open educational resources in college calculus. *Journal of Computers in Mathematics and Science Teaching, 38*(3), 249-265.

Kleickmann, T., Richter, D., Kunter, M., Elsner, M., Besser, M., Krauss, S., & Baumert, J. (2013). Teachers' content knowledge and pedagogical content knowledge: The role of structural differences in teacher education. *Journal of Teacher Education, 64*(1), 90-106.

Kirschner, P., Sweller, J., & Clark, R. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75-86.

Larkin, K., & Jamieson-Proctor, R. (2015). Using transactional distance theory to redesign an online mathematics education course for pre-service primary teachers. *Mathematics Teacher Education and Development, 17*(1), 44-61.

Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Marginson, S. (2002). Nation-building universities in a global environment: The case of Australia. *Higher Education, 43*, 409-428.

Marginson, S. (2006). Dynamics of national and global competition in higher education. *Higher Education, 52*, 1-39.

Masters, G. (2016). *Policy insights: Five challenges in Australian school education*. Retrieved from https://research.acer.edu.au/cgi/viewcontent.cgi?article=1004&context=policyinsights

Meyers, D. (2012). *Australian universities: A portrait of decline*. Retrieved from http://www.australian universities.id.au/

Moore, M. (1997). The theory of transactional distance. In D. Keegan (Ed.), *Theoretical principles of distance education* (pp. 22-38). London: Routledge.

National Mathematics Advisory Panel. (2008). *Foundations for success, final report*. Washington, DC: U.S. Department of Education.

Norton. S. (2011). How deeply and how well? How ready to teach mathematics after a one year program? *Mathematics Teacher Education and Development, 12*(1), 65-82.

Norton, S. (2012). Prior study of mathematics as a predictor of pre-service teachers' success on mathematics content and pedagogical content knowledge tests. *Mathematics Teacher Education and Development, 14*(1), 2-26.

Norton, S. (2017). Primary mathematics teacher confidence and its relationship to mathematical *knowledge. Australian Journal of Teacher Education.* 42(2), 47-61. Available from http://ro.ecu.edu.au/ajte/vol42/iss2/4/

Norton. S. (2018). The relationship between mathematical content knowledge and mathematical pedagogical content knowledge of prospective primary teachers. *Journal of Mathematics Teacher Education.* Available online: https://link.springer.com/article/10.1007/s10857-018-9401-y

Norton, S. (2019). Middle school mathematics pre-service teacher's responses to a mathematics content and specific mathematics pedagogy intervention. The Australian Journal of Teacher Education, 44(5). Available from: https://ro.ecu.edu.au/cgi/viewcontent.cgi?article=3948&context=ajte

Qian, H., & Youngs, P. (2016). The effect of teacher education programs on future elementary mathematics teachers' knowledge: A five country analysis using TEDS-M data. *Journal of Mathematics Teacher Education, 19*, 371-396.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Van de Walle, J., Karp, K., Bay-Williams, J., & Wray, J. (2013). *Elementary and middle school mathematics: Teaching developmentally*. Boston, MA: Pearson.

Vygotsky, L. S. (1987). *The collected works of L.S. Vygotsky Volume 1*. New York: Plenum Press.

Wu, H. (2011). The mis-education of mathematics teachers. *Notices of the American Mathematics Society, 58*, 372-384.

Wu, H. (2018). The content knowledge mathematics teachers need. In Y. Li, W. Lewis, & J. Madden (Eds.), *Mathematics matters in education: Essays in honor of Roger E Howe* (pp. 43-92). University College: Springer.

Yang, R., Porter, A., Massey, C., Merlino, J., & Desimone, L. (2019). Curriculum-based teacher professional development in middle school science: A comparison of training focused on cognitive science principles versus content knowledge. *Journal for Research in Science Teaching*, 1-31.

Zhang, Q., & Stephens, M. (2013). Utilising a construct of teacher capacity to examine national curriculum reform in mathematics. *Mathematics Education Research Journal, 25, 481-502*

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