Data Praxis: Teacher educators using data to inform and enhance pre-service teacher mathematics.

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This paper explores how data can shape and enhance mathematics learning and teaching in an initial teacher education Learning and Teaching Mathematics Course for First Bachelor of Education pre-service teachers in a Regional University. The implementation of a '*data praxis*' approach to teaching, required the development of a custom-designed suite of data gathering tools and approaches to inform our mathematics teaching and enhance pre-service teacher mathematical learning, underpinned the conduct of the study. *Praxis* required the teacher educators to constantly and systematically interact with the data sets and refine the pedagogical approaches to mathematics teaching and learning. The results of this research highlight the gains that students made and the challenges for teacher educators who choose a data based approach.

Keywords: pre-service teachers, mathematics education, data praxis, teacher educators.

Introduction

> The lecturers are making a big focus … to change any negative perceptions and ideals we have about the subject of mathematics due to our previous education in mathematics … If we change our attitudes and mindsets about a subject not only will we enjoy teaching it, we will also have more students enjoy the subject (Course evaluation survey, 2014)

Pre-service teachers (PSTs) enter undergraduate teacher education courses with diverse expectations, knowledge and experience (Beswick, 2006; Henderson, 2012) and there is extant literature to suggest that unless PSTs' attitudes and assumptions are challenged, they will ultimately teach in the same ways that they were taught (Brandenburg, 2008; Schuck, 2009). In this article, we examine the ways that a multi-faceted data gathering approach was developed and used to enable the identification of prior knowledge, attitudes and confidence of our PSTs. This data was used to introduce data-driven changes to our practice that required us as teacher educators to reflect critically on our approaches and redevelop our courses to better meet the needs of our PSTs. Mathematical content knowledge (MCK) and pedagogical content knowledge (PCK) were considered to be crucial to the improvement of courses, as was the development of mathematical confidence in our PSTs. The term '*data praxis*' is used by us to describe the practice of developing a custom-designed suite of data gathering tools and approaches to inform our mathematics teaching and enhance the mathematical learning of our PSTs. A *praxis* approach to research and teaching requires that we interact with data in an ongoing way and use a combination of evidence to refine and reshape practice as mathematics teacher educators. Through the ongoing interrogation and interaction with data, including online surveys, diagnostic testing and PST interviews, we have developed approaches to teaching mathematics that have enhanced student learning and confidence. These approaches focus on MCK and PCK while building PSTs' confidence, thereby equipping our PSTs with essential skills that will assist them to teach students in a manner that is engaging, relevant and relates to the world around them. The '*data praxis*' approach has enabled us as educators to better understand the needs of our learners, assisted us to make stronger links between MCK, PCK and mathematical confidence, and highlighted the importance of the cycle of assessment, analysis, reflection and intervention. Our research question was "What mathematics interventions successfully and effectively contribute to PSTs' conceptual and pedagogical understandings of mathematics teaching?"

An overview of the literature

Using data in education

Educational institutions collect data about their learners' ability to demonstrate key content knowledge (Renshaw, Baroutsis, van Kraayenoord, Goos & Dole, 2013). However, more recently, rather than the focus being on the collection of data *per se*, a renewed focus is on the ways in which teachers are examining the impact of data and the various ways in which this information can be used as a means to inform and enhance learning and teaching (Renshaw et al., 2013). The use of data to drive instruction ensures that data is used more effectively, thus moving the focus to enhancement of student learning, rather than a traditional focus on teaching (Bambrick-Santoyo, 2007; Pon, 2013; Timperley, 2009). Pon (2013), for example, refers to five key research findings based on using data to inform decision making in school mathematics classrooms. These five findings include custom designing test items; in-depth conversational analysis of data to identify student misconceptions; teacher reflection; course modification due to data analysis; and a culture of distributed leadership throughout a school.

The first of Pon's (2013) key findings centers on the importance of designing test items that allow teachers to gain insight into students' conceptual understanding of particular ideas. If students only rely on rote procedures to complete a particular test item, the item does not provide an insight into whether or not the students know why the procedure was the one that needs to be followed. In the second key finding, Pon (2013) highlights the importance of in depth conversational analysis of data so that teachers can question each other about what the data actually mean. Common misconceptions are identified through this type of analysis allowing teachers to better determine the learning needs of all students in their class as well as the appropriate pedagogy to meet these learning needs. The third key finding underscores the need for teachers to reflect on classes to focus more on understanding student thinking rather than the more traditional approach of reflecting on how the teaching was delivered as part of a lesson. Pon (2013) also espouses that data analysis must be connected to what she terms "powerful instructional or programmatic modifications" (p. 32). Such modifications must be more than just tinkering and must ensure that strategies or interventions are implemented to allow students to improve their proficiency of particular sets of skills or knowledge. The final key finding states that leadership needs to be distributed with the need for teachers to make decisions not only about the data sets that they use, but also about the way that they analyse the data.

Like Pon (2013), Timperley (2009) highlights the importance of using data to improve teaching practice and identifies a number of conditions that are required to ensure that data analysis has an impact on student learning. Such conditions include teachers having sufficient understanding of particular types of data to firstly make sense of the data and to secondly implement changes to classroom pedagogy. The importance of meaningful conversations between teachers and school leaders to unpack the meaning of data, and the need for teachers to see data as something that informs teaching and learning, rather than just something that is used for reporting purposes (Timperley, 2009). Timperley (2009), also presents a reflective "inquiry and knowledge building cycle" (p. 22) that looks at the skills teachers need to engage students in new learning experiences and then examines the impact of these new learning experiences on student knowledge and skills. Like Pon (2013) and Timperley (2009), Darling-Hammond (2013) highlights that student learning can be improved by the use of multiple sets of data. Darling-Hammond (2013) reports, "Studies of high-achieving or steeply improving schools have found that student gains were associated with teachers' regular practice of consulting multiple sources of data on student performance and using those data to inform discussions about ways to improve instruction" (p. 21).

The research discussed in this article is underpinned by what we refer to as a 'hybrid approach' (Wieman, 2014) to gathering and interpreting multiple data sets. This approach encompasses a 'diagnostic-methods-plan' of action cycle. The 'diagnostic' element refers to educators identifying and examining information about student performance; the 'methods' include the ways in which the data is collected as a means of improving instructional techniques and the 'teacher' focus enabled us as teacher educators to collect data about our "beliefs and knowledge that … enable [d] us to teach effectively" (p. 551).

Mathematical Content Knowledge (MCK)

Mathematics researchers support the importance of building MCK in primary PSTs (Henderson & Rodrigues, 2014; Hine, 2015; Maher & Muir, 2013; Meaney & Lange, 2012; Ponte & Chapman, 2008; Young-Loveridge, Bicknell, & Mills, 2012). Without strong MCK in a range of mathematical domains, PSTs struggle to meet the challenging demands of teaching mathematics to primary and secondary students (Young-Loveridge, et al., 2012). This development of robust and effective PST MCK can often be a challenge for mathematics teacher educators as it is vital to ascertain the entry level of MCK and then develop competence in a wide range of mathematical domains. Determining the entry level and developing MCK throughout a university degree demands that attention be given to ongoing data collection and analysis.

Identifying mathematical misconceptions

One approach to developing MCK is through the identification of common misconceptions associated with learning and teaching mathematics (Livy, Muir & Maher, 2012; Livy & Vale, 2011; Young-Loveridge, et al., 2012). Livy, et al. (2012) reported that in the area of measurement, for example, almost half of the 17 PSTs surveyed incorrectly deduced that students would be correct if they stated that "if the perimeter of a rectangle increases, its area also increases" (p. 102). This demonstrates that these PSTs would be unable to assist the student overcome such a misconception. Livy, et al. (2012) concluded that teacher educators must identify the gaps and misconceptions in the MCK of their PSTs with topics such as measurement so that the misconceptions can be explored and overcome prior to the PSTs completing their university studies. Test data is an effective way to develop teaching strategies to overcome misconceptions, highlighting the need to categorise PSTs' responses to mathematics test questions so that correct responses and common misconceptions are identified, interpreted and then used to determine the best course of action to correct the misconception (Livy & Vale, 2011). The issue of developing mathematical competence knowledge in PSTs is a critical issue for teacher educators (Henderson, 2012; Meaney & Lange, 2012; Verschaffel, Janssens, & Janssen, 2005) and as Verschaffel, et al. (2005) highlight, the importance of testing PSTs in mathematics several times during their initial teacher education course is critical as it indicates the level of mathematical competence in the areas required as a university graduate and in the beginning phase of their teaching career. Verschaffel, et al. (2005) also highlight the importance of using the data collected through testing as a teaching tool, so that the feedback provided to PSTs provides them with opportunities to develop a greater understanding of how particular mathematical concepts can be taught. Testing not only assists in the determination of the level of PST knowledge but it also allows further diagnosis, through using additional diagnostic tools, to ascertain where particular misconceptions emerged (Verschaffel, et al., 2005).

Developing MCK in PSTs

A recent Australian report into teacher education *Action Now: Classroom Ready Teachers* (Craven et al., 2014) recommended that primary PSTs must be in the top 30% of population before they are permitted to teach, and the Australian Government has approved a national testing regime of all PSTs in both literacy and numeracy in response to this recommendation. It is therefore imperative that teacher education students are equipped with effective MCK if they are to teach in Australia. One key contention about the national mathematical testing of PSTs is that this regime will lead to an emphasis on mathematical performance, which could in turn encourage PSTs to rely on procedural understanding of mathematics rather than the more desirable conceptual understanding of mathematics (Meaney & Lange, 2012). They also suggest that many of the PSTs tested as part of their study had a poor level of knowledge of topics such as fractions, place value, decimals and order of operations. These topics are known to be problematic for primary school students and while some PSTs accepted the importance of having a high level of MCK so that they were adequately prepared to competently teach primary aged students, they also felt that being tested led to anxiety around mathematics.

The requirement to have a high level of MCK was acknowledged by participants in a study conducted by Hine (2015) with the majority of the participants suggesting that they needed to improve their MCK to have the knowledge required to teach mathematics. Improving MCK also led to PSTs gaining the confidence needed to teach mathematics to primary students (Gautreau, Kirtman & Guillaume, 2011; Henderson, 2012; Henderson & Rodrigues, 2008; Hurst & Cooke, 2012; Klein, 2012). Cooke and Hurst (2012) also discuss mathematical anxiety and highlight the ways in which anxiety hinders the PSTs building the MCK required to effectively teach students. Cooke and Hurst (2012) suggest that there are multiple strategies that can be used to assist PSTs to overcome mathematical anxiety and build confidence, including PSTs developing a personal mathematics plan and using a social constructivist teaching style in the teaching of mathematics. It is important to allow PSTs to examine the antecedents of their own mathematical anxiety so that they can consider how these antecedents are impacting their own attitudes to mathematics and mathematics teaching (Hurst & Cooke, 2012).

Pedagogical Content Knowledge (PCK)

Pedagogical Content Knowledge is the way in which a teacher presents material for instruction. As Depaepe, Verschaffel and Kelchtermans (2013) suggest, PCK is most commonly introduced by scholars through the work of Shulman (1986) and there is general agreement amongst scholars that PCK can broadly be considered to be a point at which teaching pedagogy intersects with the knowledge relevant to a particular discipline. Depaepe, et al. (2013) further assert that discipline content knowledge is an important and necessary pre-requisite for PCK and that each discipline area has its own specific PCK which teachers learn and use to teach their students. It is therefore vital that PSTs who will be teaching mathematics, not only improve their MCK and have the mathematical content skills required to teach mathematics, but also the PCK specific to the mathematics discipline area in order to successfully teach mathematics (Ward & Thomas, 2007).

In a study that spanned several discipline areas including mathematics, Ward and Thomas (2007) also suggest that PCK is a critical foundation for the planning and delivery of a mathematics program that caters for all classroom learners. They also found that PSTs who had lower MCK generally had lower PCK but PSTs with higher MCK did not necessarily have a higher PCK. This link between MCK and PCK is highlighted by Maher and Muir (2013), who suggest that PSTs need a strong background in both MCK and PCK so that they are able to successfully diagnose student misconceptions from work samples and develop a teaching strategy that will assist the student to overcome such misconceptions. Whilst Maher and Muir (2013) focused predominately on PSTs' understanding of long multiplication, other studies such as Livy and Vale (2011) (ratio) and Livy, et al. (2012) (measurement) also highlight this requirement for strong links between MCK and PCK. In summary, Livy and Vale (2011) highlight the importance of using data sets to develop PST understanding of both MCK and PCK.

Aims and Objectives of the Research

A key aim of this mathematics research was to employ and evaluate a data-informed approach to enhance learning within undergraduate mathematics education programs and positively impact student learning. To achieve this aim, custom-designed tests and a survey were developed to identify PST competence, attitudes and confidence in mathematics and interviews were conducted to further explore attitudes and confidence and to obtain feedback on learning and teaching. PST course evaluation data provided another key source of data. Both teacher educators systematically and collaboratively gathered and analysed the data sets – *data praxis* - and used this information as an evidence base through which to modify teaching practices, approaches and programs to meet PSTs' needs in a more focused way that developed MCK, PCK and mathematical confidence.

Methods – A data praxis approach

The research presented in this article draws on quantitative and qualitative data sets to explore the research question "What mathematics interventions successfully and effectively contribute to a PSTs' conceptual and pedagogical understanding of mathematics teaching?". The data sets were collected in two phases (Phase 1 and Phase 2) and included PST completion of a diagnostic test and an online survey (Group One, n=66, 2014; and Group Two, n= 69, 2015); student course evaluation survey data (2014, 2015); and student interviews (2014, 2015). An overview of the *'data praxis'* approach to this research is shown in Figure 1.

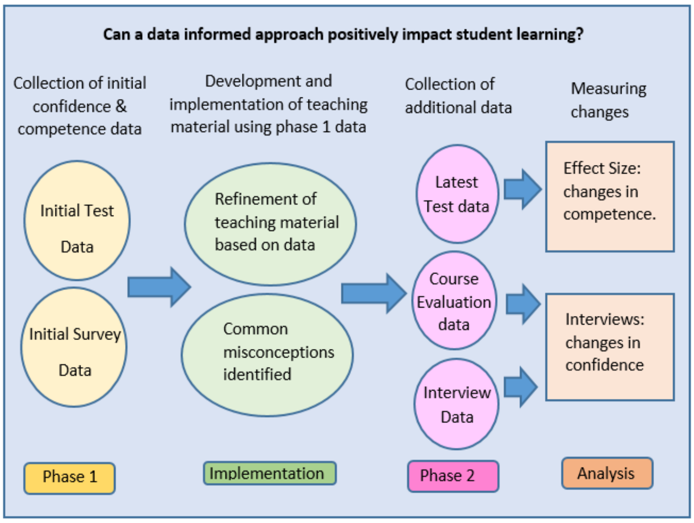

Figure 1. The data praxis approach used in this research.

Phase 1 data collection (as shown in Figure 1) included a multiple choice diagnostic mathematics test to determine competence and self-reporting of confidence by completion of an online survey. The multiple choice test was custom designed so that incorrect alternatives were often based on common misconceptions, such as those discussed in measurement by Gough (2008). An example of a measurement question the PSTs were required to answer was "The perimeter of a square is 32cm. What is the area of this square?" The online survey was completed during the mathematics tutorial immediately after the PSTs had completed the diagnostic test. This online survey contained questions on attitudes to mathematics, confidence in carrying out mathematical computations and motivation in mathematics and included questions such as "I am confident when working with fractions and decimals".

The online survey data (Likert scale/short answer responses) was collated, organised and quantified, while common misconceptions were identified from the multiple choice test responses. From these initial data, a teacher educator teaching and data gathering *plan of action* was developed and minor modifications to the learning and teaching mathematics courses were undertaken, based on the data outcomes and the changes were implemented and integrated within the Learning and Teaching Mathematics Course.

Phase two of this research (see Figure 1) involved the re-testing of any PST who had not achieved mastery (90%) on the initial test. The phase two test data was then used to calculate effect sizes. These quantitative data sets were complemented by the use of qualitative data as interviews were conducted with a voluntary group of PSTs (n = 15). The semi-structured interview questions highlighted a number of core areas and included: 'How confident were you when you started the Mathematics Course this year?' 'Do you feel more competent/confident now?', and, 'Has your attitude changed towards learning and teaching mathematics during the semester? Interview data sets were examined and are presented according to two "cases" which highlighted common changes to confidence and competence. Course Evaluation data was used as further evidence of whether or not our PST students viewed the courses as meeting their learning needs in mathematics. Course evaluation survey data sets were also examined as part of Phase 2 to examine the outcomes and success of the modified mathematics teaching and learning approach and implementation.

Participants

All PSTs completing Learning and Teaching Mathematics 1 (a core first year Bachelor of Education course) were invited to be part of this study. The focus of this Learning and Teaching Mathematics course was to develop PSTs as competent, capable and confident teachers of primary and secondary mathematics. These PSTs were in both the primary and the Foundation – Year 10 courses and approximately 40%of the students completing this Course in both 2014 and 2015 agreed to participate in the survey and interview phases of this study. A summary of the participants is shown in Table 1.

Table 1
Summary of participants (2014/2015)

Year	Participants	Female	Male
2014	N=66	49	17
2015	N=69	44	25

Table 1 shows that considerably more females than males agreed to participate in this research and the proportion of males who agreed to participate in 2014 was slightly lower than the proportion of males who agreed to participate in 2015.

The 'data praxis' approach – Results

The results of this study are presented for the two phases of data collection. Firstly, the data sets used in the *data praxis* approach will be presented, explaining how collaborative decisions were made and how data differed from year to year. Secondly, how the data sets were used to determine whether or not the *data praxis* approach improved student learning and how this change affected mathematics teacher educator practice will be discussed.

The initial data sets (Phase 1) collected were the overview data from both the competence testing and the survey results. These data sets were then used to determine any common areas of weakness. Each year, this overview data was analysed to provide a snapshot of the mathematical confidence and competence of the PST cohort. These overview data sets of the self-reported confidence from PSTs participating in the research in Group 1 (n=66, 2014) and Group 2 (n=69, 2015) were significantly different (as evidenced in the spread of scores in Figures 2 and Figure 3) suggesting that different approaches to the teaching and learning were needed to be implemented in each year. Figure 3 identifies the overview of competence testing in both 2014 and 2015, while Figure 3 provides the overview of self-reported confidence in both of these years.

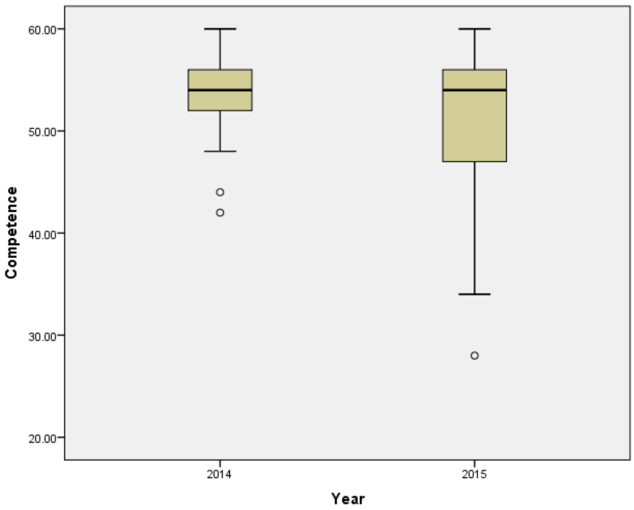

Figure 2. Tested competence of Pre-Service Teachers (PSTs) (2014/2015).

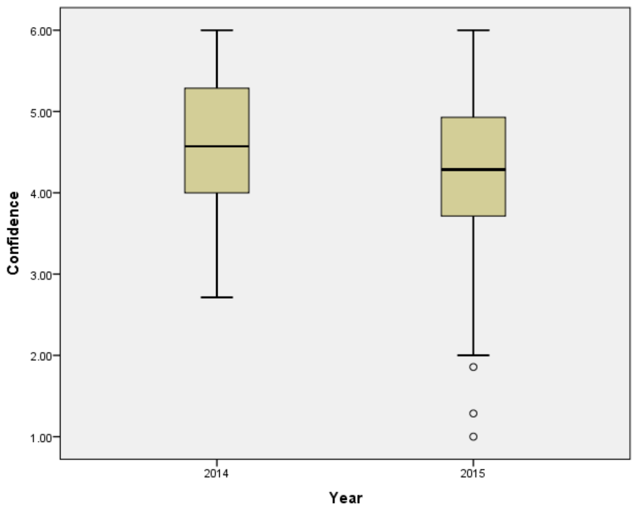

Figure 3. Self reported confidence of Pre-Service Teachers (PSTs).

Figures 2 and 3 provide an insight into how the confidence and competence varied for both the 2014 and the 2015 cohorts suggesting the requirement to further examine data from each year to determine our pedagogical 'plan of action' (Wieman, 2014) for each distinct cohort. For example, the tested competence in 2014 was significantly higher in 2014 with three quarters of the PSTs scoring higher than 50 on the competence test. The lower quarter of the students in 2014 scored higher than 40 on the competence test with 2 "outliers" scoring less than 40. This was in contrast to the 2015 testing which had a lower top quarter as compared to 2014, a higher median score than 2014 and a larger "tail" with one "outlier" scoring significantly lower than outliers from 2014. The confidence data was again significantly different in 2014 to 2014, with PSTs in 2014 reporting higher levels of confidence than the 2015 cohort. This highlighted the need for us to examine data more closely and identify PSTs' needs when planning teaching and learning mathematics courses. These initial data sets were important as they provided a sense of whether each cohort had particular mathematical needs that needed to be considered when modifying coursework.

Further grouping of results enabled us to gain a deeper insight into the PSTs' actual needs. Figure 4 demonstrates the self-reported confidence of PSTs, divided into the four content areas of whole number, probability and statistics, fractions and decimals, and measurement.

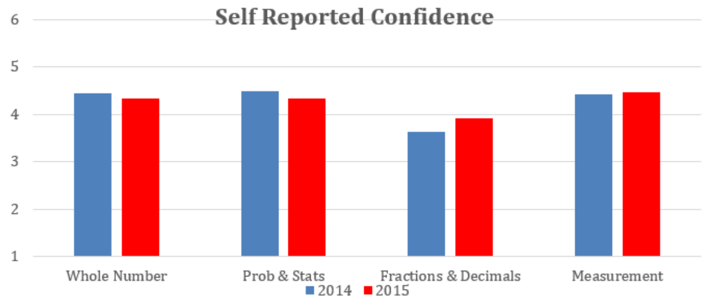

Figure 4. The self-reported confidence levels of PSTs.

Figure 4 highlights that the PSTs who were surveyed were generally more positive than negative in all areas of mathematics for both the 2014 and 2015 cohorts. It was also interesting to note that the topic areas of fractions and decimals revealed the lowest self-reported level in both the 2014 and 2015 cohorts. The topic area of fractions and decimals also revealed the most variation between the two cohorts of PSTs highlighting that this is an area where confidence varies greatly, and therefore indicating that it is a topic area that requires careful attention in order to build PSTs' confidence. Measurement and Probability & Statistics contained the least variation over the two cohorts, while the content area of whole number also produced an overall low variation between the two cohorts. There was a marked contrast between the self-reported confidence and the tested competence in these topic areas (Figure 5).

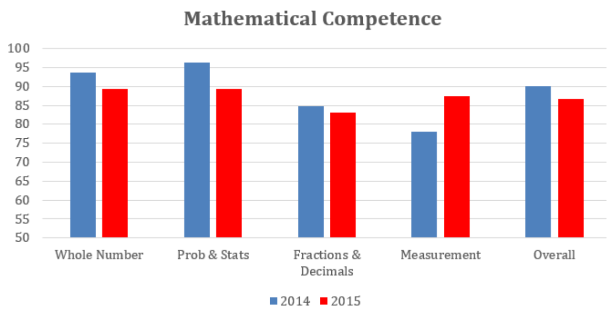

Figure 5. Mathematical competence in topic areas.

Figure 5 highlights the mathematical competence of PSTs, and it is evident that within the topic area of Fractions and Decimals there was minimal variation between the two cohorts with results for these topic areas only varying by a couple of percentage points. This is in stark contrast to the self-reported confidence in the topic area fractions and decimals that had the most variation. This suggests that the PSTs lack confidence in this area but have a level of competence that can be built on, further highlighting the need to cover this topic area in a way that builds MCK, fosters confidence and demonstrates some of the PCK that PSTs can use in their own classroom. Measurement was indeed the topic area with the most extensive variation in competence, with PSTs in the 2014 cohort scoring significantly lower on the competency test when compared to the 2015 cohort. This suggests that while measurement clearly needed to be a focus area in tutorials in 2014, the need was less imperative in 2015. The PST results in Fractions and Decimals in 2014 and 2015 highlighted the need for these areas to be a learning and teaching focus in both years.

Data sets to identify competence and misconceptions

The competence test results in the topic areas of measurement and fractions and decimals were then further analysed to examine common misconceptions that students were displaying. These misconceptions were then used to develop activities for tutorials to allow PSTs to explore the mathematical thinking required to address and overcome these misconceptions. One of the questions in the measurement section was written to determine the level at which the PSTs understood perimeter and area. This question stated: *The perimeter of a square is 32cm, what is the area of this square?* There were two specific groups of misconceptions identified from this question. Some PSTs stated that the area was 32cm^2, while other PSTs responded with 8cm^2, while others correctly identified the answer as 64 cm^2. The activity used to assist PSTs move past their misconceptions was a tutorial group task activity that required each group to define perimeter and area and discuss these definitions with all groups. The practice of 'in tutorial' responsiveness required teacher educators to have an increased awareness of PST feedback and constantly focus on and analyse PST discussions and, within instant timeframes, modify the teaching structure and approach according to PST needs and understandings.

Analysis of the data and discussion

Introduction

In the following section, the data collected from PSTs are analysed and discussed. The results are summarized with the change in PSTs' results highlighted. The impact on researchers implementing the '*data praxis*' approach is also presented, with an emphasis on the implications of such an approach for other mathematics teacher educators. The evidence and outcomes of this research suggest that a combined approach to data gathering (quantitative and qualitative), together with an ongoing, interactive and systematic review of PSTs and their entering PCK, MCK and Confidence levels is critical if learning is to be enhanced.

The success of the *data praxis* approach has been examined by evaluating the increase in mathematical competence as measured by PSTs who did not demonstrate mastery the first time they attempted the test and were subsequently retested. A number of PSTs who did not demonstrate mastery have not subsequently been retested at this stage due to illness, leave from studies and change of courses. Table two shows a summary of the performances of PSTs on their initial test.

Table 2
Performance of PSTs (n=135 – both groups 2014 & 2015) completing initial testing

Initial Test Performance	Number of PSTs
90% or higher	76 (56.3%)
80% to 89%	27 (20.0%)
Less than 80%	32 (23.7%)

Table 2 highlights that the majority of the PSTs demonstrated mastery on the test when they initially completed the test. The PSTs who scored less than 90% on the test were then supported in their classes through the use of data as discussed previously. After approximately three months, these PSTs were again tested with a summary of the retest results shown in Table 3. Forty-one of the PSTs who had not reached mastery (90%) in the first testing presented for the later testing.

Table 3
Performance of PSTs (n=135) after 2 rounds of testing

Test Performance	Number of PSTs
Achieved mastery test 1	76 (56.3%
90% or higher test 2	17 (12.6%)
80% to 89%	10 (7.4%)
Less than 80%	14 (10.4%)
Not tested test 2	18 (13.3%)
Total	41

Table 3 shows that another 17 PSTs achieved mastery in test 2. The other categories were lower than in initial testing indicating an improvement. There was a significant percentage of students who were not retested in test 2. There were various reasons why these PSTs were not tested a second time including absence, illness and leaving the university. To examine the performance of these 41 students that were retested further, averages on the initial test and on the retest were compared. This is shown in Table 4.

Table 4
Test averages for retested PSTs (n = 41)

Test	Average Test Score	Standard Deviation
Initial	22.54	2.52
Final	24.63	3.18

Table 4 indicates that the latest test score average for the 41 students who were retested was significantly higher than their original test score average. A paired t test was carried out on the data set and a p value of 0.0000002 was obtained. This means that the change in test scores is significant as $p < 0.05$. An effect size can then be calculated to see how significant the improvement in test results are. The effect size of the testing was 0.73, which is considered by Cohen (1992) to be at the higher end of a medium effect size. This effect size indicated to us, as mathematics teacher educators, that the '*data praxis*' approach, in these cases, appeared to assist us to improve our PSTs' understanding and application of mathematical concepts. It has to be noted however, that the approach is not the only possible explanation for student improvement as some students might have also sought assistance for their mathematics in other ways.

Identifying misconceptions through focused test results

Testing the PSTs, and evaluating the responses in an ongoing manner enabled the identification of specific misconceptions related to MCK. A key example of this insight, which subsequently led to focused teaching sessions, enabled the mathematics teacher educators to adapt the course and modify practices as a means of facilitating PSTs' learning and addressing misconceptions. For example, when PSTs were asked to explain "why the answer is 32cm^2", their responses centred on the idea that the length of one side was 8cm so you add up all the sides for the area. In the case of the 8cm^2 responses, the common response was that the square sign at the end also squared the 8. Both groups of PSTs with the incorrect responses struggled to explain the significance of the cm^2. Whilst these responses identified different misconceptions, the assistance provided for the PSTs to overcome the misconceptions meant the initial revisit of the definitions of perimeter and area as a small group activity in a tutorial. The definition of perimeter was explained well by all of the small groups, however it was clear that area was not as well understood. Several of the groups in each tutorial stated that area was "length multiplied by width". This notion of area was challenged by the tutor by drawing a non-regular shape and asking groups to find the area using their rule. This led to a discussion about what area really is and the significance of the cm^2 unit. This continued with discussions of the PCK required to effectively teach the concepts of perimeter and area to primary and secondary students. The PSTs involved in these tutorials performed better on the similar item on the next test. This question related to area and perimeter on the subsequent test required PSTs to think slightly differently. The question was "The perimeter of a square tile is 20cm. If 4 of these tiles were used to make a bigger square, what area would the 4 tiles cover?"

It was also interesting to note that overall PSTs in the 2014 cohort performed considerably better on the test than those in the 2015 cohort. This is in stark contrast to the measurement results in 2015, where PSTs performed considerably better than those in the 2014 cohort. This became an important consideration when developing the 2015 Learning and Teaching Mathematics 1 course as the needs, in the topic area of measurement for example, of the PSTs were quite different to those in the previous cohort. For example, PSTs in the 2014 cohort were not efficient at converting common units of measurement. To assist them to develop their understanding of common units of measurement, they were asked to physically show the units millimetre, centimetre and metre. They were then provided with conversion questions and asked to again show how they would convert the unit using this visual model. This visual model also saw PSTs discussing how to convert units and later how to teach the conversion of units.

In the areas of whole numbers and probability and statistics, PSTs scored around the 90% level in both years, a level that is described as mastery. PSTs at this mastery level possess sufficient MCK to teach the skill. Being at a level of mastery, does not however indicate that these PSTs have the level of PCK and the confidence to teach the particular skill. The development of PCK and confidence in mathematics is an ongoing process, but the development of PCK and confidence will not necessarily lead to the development of competent primary mathematics teachers unless mastery of MCK is evident. This is consistent with the findings of Ward and Thomas (2007) who suggested that higher MCK did not necessarily mean higher PCK in mathematics.

While teaching is provided through lectures and tutorials in the topic areas of whole numbers and probability and statistics, the data suggested that we were not required to allocate additional time to these specific areas as the PSTs were performing at an acceptable level. In these areas, less emphasis was spent on the MCK, with tutorial activities focusing on developing the PCK and confidence of PSTs. This development of the PCK and confidence included more 'hands on activities' than had previously been used, so that the PSTs not only see and understand the mathematics involved in the activity, but also understand the teaching strategies required to engage their students in learning mathematics. The key to the success of this approach to learning and teaching mathematics was dependent on the ways in which we gathered, interpreted and constantly engaged with the multiple forms of data we collated for each cohort. The needs of each cohort varied and the knowledge gained from data collection and analysis allowed us to determine more precisely the PSTs needs and teach each cohort, and at times, each tutorial group, accordingly.

Pre-service teacher (PST) feedback

The success of changes to the teaching approach was reflected in the feedback provided by the PSTs in both of the Learning and Teaching cohorts and through semi-structured interviews conducted with a number of PSTs at the conclusion of the 2014 and 2015 semesters.

The interviews revealed that

> The hands-on work, and seeing it, and visual, and like seeing it being done instead of just writing it on a board (Eric, interview, 2015);

> It was fairly confronting sitting there and trying to break those skills down to the point of teaching a grade prep – that was hard for me (Mary, interview, 2014);

> Doing the kinaesthetic approach has helped me to understand simple things that I should have understood on a different level when I was in school that I understand a lot better now. And if that kinaesthetic stuff was there in class I probably would have had a bit more of an enjoyable maths experience (Beau, interview 2015)

The interview responses again highlighted to us that the adaptations made to the course were effective with mostly positive feedback in both the interviews and course evaluation surveys. These examples of positive feedback lead us to believe that the use of data sets to guide our teaching has allowed the students to better connect with the mathematical content since it is more accessible to them. The use of a '*data praxis*' as a frame to shape our teaching and learning experiences has enabled us as researchers to explore the importance of using multiple sources of feedback to firstly develop a 'plan of action' and secondly to monitor how well modified plans meet the needs of PSTs. In the cases presented in this paper, we advocate the importance of accessing multiple sources of data for each cohort as the differences in mathematical background can vary considerably from year to year. This research has informed us as to the need for change in the way that we teach classes as mathematics teacher educators. While we still plan lessons in a similar way to what we always have, lessons often explore the 'point of need' that is discovered through data and subsequent conversations with our PSTs. This requires us as educators to think more 'in the moment', notice and address the 'teachable moment' and adapt the lesson while it is in progress to better develop our PSTs' skills in both the teaching and learning of mathematics.

Feedback from survey responses

The PSTs indicated through the survey responses that they appreciated the ongoing learning achievements that they experienced throughout the Course and the concept that they "were always thinking in a teacher's mind frame [and] also a child's" (Course evaluation survey, 2014). Others suggested there was a need for a mathematics refresher and specified a liking for the Course name "Teach and learn maths" as:

It's been a long time since I did some of this maths. It was nice to be refreshed and also corrected in some areas (course evaluation survey, 2014).

[The lecturer] has spent time with me to ensure I have a good understanding the work we have completed, as he knows I struggle with my mathematical thinking (course evaluation survey, 2015).

These comments are reflective of the feedback received, suggesting that the PSTs had not only enjoyed the course, but had refreshed and enhanced their mathematical understanding.

'Data Praxis': Changes made as a result of using data sets

Through interacting with the data sets discussed previously, we adapted courses in a number of ways. Firstly, we included more emphasis on MCK that was identified as problematic through competence testing. Secondly, we placed higher importance on mathematical confidence and explored ways of enhancing confidence in our PSTs. The third significant change made to our mathematics education courses was how we explicitly taught the three areas of MCK, PCK and confidence simultaneously. Figures 6 and 7 depict how the teaching in our mathematics education courses changed as a result of us using a '*data praxis*' approach.

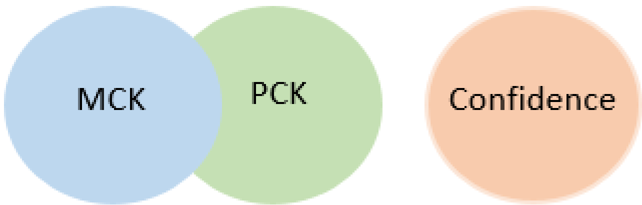

Figure 6. The teaching of MCK, PCK and confidence before the data praxis approach.

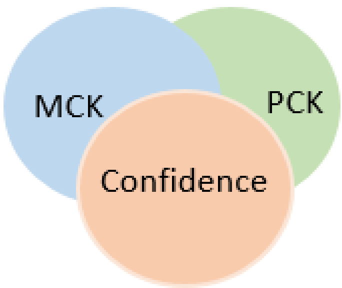

Figure 7. The teaching of MCK, PCK and confidence after the data praxis approach.

Figure 6 represents the way that we were teaching MCK and PCK together in some instances and separately at times, while we worked on confidence separately and rarely integrated it with MCK and PCK. Figure 7 shows the change to our practice with a much more integrated approach and greater emphasis on working on all three areas simultaneously.

The approach to data collection, organization and re-visiting presented in this paper highlights the impact of the '*data praxis*' approach in the development of confidence, MCK and PCK. It can be argued that each of the three areas – MCK, PCK and confidence are equally important in PST mathematical development and that it is important for mathematics teacher educators to take each into account when designing interventions to ensure that courses identify PST learning and teaching mathematics needs and address PSTs' levels of initial understanding and subsequent growth in each of these areas.

Conclusions and Outcomes

The results suggest that learning about mathematics is a collective responsibility and demands that, as teacher educators, we challenge our own and others' assumptions about how best to prepare PSTs for teaching mathematics competently and confidently. We need to be fully informed using multiple data sources to ascertain each cohort's level of understanding and confidence. PSTs contribute to the agenda for teaching, discussion and maintain focus through a structured, reflective approach. The '*data praxis*' focus required a change in mindset. For us, it has meant changing our practices to privilege PST voice and experience. As mathematics teacher educators, we need to know the PSTs and their competence and confidence levels. We need to collect data and constantly engage with data to assess conceptual understanding and identify and examine mathematical misconceptions. This practice based research enabled PSTs to understand the ways in which mathematical expertise is developed; one that is not based on prescribed, discrete and de-contextualized knowledge.

There are some limitations to this research. It must be noted that learning is a complex activity and all individuals learn differently. So while there was significant MCK growth for the PSTs involved, it is by no means certain that this was due to the '*data praxis*' approach alone. We acknowledge that not all students obtained mastery and this is a challenge for us as teacher educators; we need to continually adapt material to meet student needs based on evidence.

The '*data praxis*' approach discussed in this paper suggests a number of implications for mathematics teacher educators. Firstly, it is important that teacher educators use data to guide the improvement of student learning. Understanding how to use data, collecting data from multiple sources and interacting with the data can assist the development of courses that meet PSTs' needs. The data presented also highlights how interacting with the data from multiple sources assists in the development of university level courses and improves the mathematical skills of PSTs, and ultimately students in schools. This research reinforces the importance of collecting data to understand each learner and their development as suggested by Pon (2013) and Timperley (2009). This research also highlights how mathematically different cohorts of students may be and why it can be beneficial to shape course material to assist in building mathematical, pedagogical and confidence skills in our PSTs.

Secondly, the article highlights the importance of teacher educators using data to identify misconceptions in similar ways to the research presented by Livy, et al. (2012) and Young-Loveridge, et al. (2012). These misconceptions can then be used to identify and shape learning opportunities and allow PSTs to move from the misconception to a deeper understanding of the concepts being studied. As part of this process it is important that teacher educators individually and collaboratively reflect on each class, focusing on data that is revealed in their reflections.

Finally, we suggest that mathematics teacher educators can work simultaneously in the areas of MCK, PCK and mathematical confidence to develop all areas rather than primarily focusing on individual areas. Employing a '*data praxis*' approach to the mathematics teaching and learning, whereby data is collected in all three of the areas, analysed and then used to inform and adapt course materials, is critical. This approach reflects Pon's (2013) framework, whereby data is collected, analysed and subsequently used to shape future learning activities. Combining data from multiple sources through a '*data praxis*' approach to concurrently focus on MCK, PCK and mathematical confidence is one that our research data suggests enhances outcomes for PSTs and teacher educators in the critical area of mathematics learning and teaching.

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Appendix One: Sample test questions.

Each test has 30 multiple choice questions. Below are 5 of the questions that are typical of the type of test questions used.

Measurement: Perimeter and Area
The perimeter of a square is 32cm. What is the area of this square?
A. $64cm^2$
B. $32cm^2$
C. $16cm^2$
D. $8cm^2$

Percentage: Percentage bigger than 100
A ticket costs $40. There is a 10% fee added to the price. The new price of the ticket is:
A. 40 x 1.1
B. 40 + 0.1
C. 40 + 10
D. 40 x 10

Decimals: Dividing Decimals
Mark cuts 4.5m of wood into 0.3m lengths. The number of lengths that he will have is:
A. 15
B. 1.5
C. 0.15
D. 0.015

Indices: Powers of 10.
The land area of Russia is approximately 17 000 000 km^2. Scientific notation is often used to write large numbers in terms of powers of 10. For Russia's land area this notation would be:
A. 1.7×10^5
B. 1.7×10^6
C. 1.7×10^7
D. 1.7×10^8

Number: Round to a given place value
What number do you get if you round 63.539 to the nearest tenth?
A. 63.5
B. 63.6
C. 63.53
D. 63.54

Appendix 2: Survey questions about confidence in Mathematics:

I am confident at manipulating whole numbers.
I am confident at calculating probability.
I am confident at interpreting data.
I am confident when working with fractions and decimals.
I am confident at measurement.
I am confident when completing mathematical problems.
I am confident when using mathematics in my everyday life.