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IMPROVING THE MATHEMATICAL CONTENT KNOWLEDGE OF PRE-SERVICE MIDDLE SCHOOL TEACHERS

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Improving the Mathematical Content Knowledge of Pre-Service Middle School Teachers

Synopsis:

The University of Notre Dame Australia's Fremantle campus offers aspiring middle school teachers a unit focused on improving mathematical content knowledge and proficiency. The students who completed the pre-unit surveys indicated a need to refresh and consolidate mathematical content knowledge. Post-unit surveys indicated overwhelmingly that the unit helped prepare students to become more confident, competent and knowledgeable in mathematical content.

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Abstract/Proposal

The tertiary training of pre-service teachers is pivotal in their professional preparation and formation as qualified educators. Multiple authors posit that teachers require a development of *pedagogical content knowledge*, or knowing a variety of ways to present mathematical content and to assist students to deepen their understanding (Chick, 2012; Shulman, 1987). Emerick, Hirsch and Berry (2003) argue that high quality teachers must possess appropriate *mathematical content knowledge*, and must also possess considerable background in communicating effectively to students. There are two aims of this educational research. The first is to investigate the self-perceptions of pre-service middle school teachers enrolled in a mathematics education unit as they engage with and consolidate their mathematics content. The second aim is to explore how these pre-service teachers understand and perceive their 'readiness' to undertake such a task, based on their recent tertiary training. Data were collected from participants through the exercise of pre-unit (Stage 1) and post-unit (Stage 2) surveys. This paper will present participant self-reflections from both stages of data collection. Students who completed the pre-unit surveys indicated a need to refresh and consolidate mathematical content knowledge. Post-unit surveys indicated overwhelmingly that the unit helped prepare students to become more confident, competent and knowledgeable users of mathematical content.

Introduction

Over the past two decades there has been a growing body of literature concerning the preparation of pre-service mathematics teachers. Research efforts have focused principally on approaches conducted by tertiary educators to adequately prepare pre-service teachers (PST) for the mathematics classroom. In particular, such efforts have emphasized the importance of *pedagogical content knowledge* (PCK) (Beswick & Goos, 2012; Shulman, 1986; 1987) and *mathematical content knowledge* (MCK) (Meany & Lange, 2012; Ponte & Chapman, 2008) in teacher preparation programs. Specifically, researchers have reported on ways to best support pre-service primary and secondary teachers' PCK (Aguirre, del Rosario Zavala & Katanyoutanant, 2012; Kennedy, Ball & McDiarmid, 1993) and MCK (Ma, 1999; Stohlmann, Moore, & Cramer, 2013), the effects of mathematical content units on PST (Matthews, Rech & Grandgenett, 2010), and the effects of mathematical pedagogy units on PST (Sowder, 2007). Other research has drawn attention to PST confidence levels and attitudes towards mathematics (Hamlett, 2009). Despite the extensive literature there is no consensus on how to adequately train PST of mathematics (Ball, Hill & Bass, 2003; Chapman, 2005). However, a growing number of scholars recommend teacher educators focus their efforts on *mathematical knowledge for teaching* (MKT), or teaching both for procedural understanding and mathematical fluency (Delaney Ball, Hill, Schilling & Zopf, 2008).

Research Aims and Significance

There are two specific aims of this research project. The first is to investigate the self-perceptions of pre-service primary and secondary teachers enrolled in a mathematics education unit as they engage with and consolidate their mathematics content. The second aim is to explore how these pre-service teachers understand and perceive their 'readiness' to undertake such a task, based on their recent tertiary training. Both aims will be investigated during the two stages of the research project. The significance of this research lies in the belief that the unit *ED2315: Mathematical Learning for Early Adolescents* adequately prepares students' mathematical content knowledge in conjunction with their pedagogical content knowledge, and that research into this area can strengthen future efforts in preparing pre-service teachers. Specifically, the unit has the potential to influence the way pre-service mathematics teachers are professionally prepared to teach mathematical content in the classroom. This study seeks to build upon the extant literature by describing the self-perceptions of pre-service teachers preparing to teach mathematics to Middle School students.

Methodology

Context

At The University of Notre Dame Australia the unit *ED2315: Mathematical Learning for Early Adolescents* is offered to pre-service Primary and Secondary teachers completing a Bachelor of Education degree. Enrolled students can use the unit towards a specialization or major in mathematics education. The unit is run over thirteen weeks for a total of 39 hours of contact time, and it is worth 25 credit points. During contact hours, pre-service teachers engage with middle school mathematical content (suitable both for Upper Primary and Lower Secondary students), receive exposure to best pedagogical approaches in teaching that content, review key curriculum and policy documents, and investigate best-practice approaches regarding planning, assessment, technology, and resources. Within the unit, students complete three assessments: An Analytical Paper (AP), Mid-Semester Examination (MSE) and a Final Summative Examination (FSE). The AP consists of two parts, where students must (i) complete 10 algebraic problems showing full working out and a final solution, and (ii) after choosing one of the problems completed in (i), write a 1 500-word analytical paper articulating best pedagogical approaches in teaching this problem to a middle school class. The MSE is a 75-minute assessment that requires students to demonstrate competency in the mathematical content covered in Weeks 1 - 7. The FSE is a 130-minute assessment consisting of two parts, where students must (i) write extended responses to two of five key topics in middle school mathematics, and (ii) demonstrate competency in the mathematical content covered in Weeks 7 - 13. The enrolment for this unit is approximately 40 students per semester.

Method

This study was interpretive in nature, and primarily used qualitative research methods to collect and analyze data about how pre-service teachers perceived their readiness to teach middle school mathematics. Participants recorded self-perceptions through three qualitative questions, and one seven-item, five-point, Likert scale question. The researcher used two online, qualitative surveys to collect data from research participants. In Stage 1 of the project, participants were asked to respond to four research questions prior to commencing a thirteen-week tertiary unit based on mathematical content. During Stage 2 (immediately following the completion of the unit), the participants were asked the same research questions written in the past tense. The research questions are included in Appendix 1.

Participants

Stage 1 & Stage 2

The entire student population enrolled in the tertiary unit *ED2315: Mathematical Learning for Early Adolescents* was invited to participate in the research. More than half of the students enrolled in this unit (20 of 37) comprised a self-selected sample for Stage 1, and 18 students participated in Stage 2. All students had the opportunity to review the ED2315 Unit Outline prior to giving informed consent to participate in the research.

Data Analysis

Qualitative data from the 20 pre-unit and 18 post-unit surveys were analyzed and explored for common themes. When analyzing these data, this project adhered to the framework and guidelines offered by Miles and Huberman (1994). This framework assisted the researcher in identifying relationships among social phenomena, based on the similarities and differences that connect these phenomena. The approach itself is comprised of three main components: data reduction, data display, and drawing and verifying conclusions. These components themselves involve three main operations: coding, memoing, and developing propositions. Codes, as Miles and Huberman (1994) explain, “are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study” (p. 56). These codes were attached to the data gathered through qualitative surveys, and were selected from those data based on their meaning. The researcher then used memoing to synthesize coded data together so that they formed a recognizable cluster grounded within one general concept. The memoing process also captured the ongoing thoughts of the researcher as the process of coding took place. Lastly, as a study proceeds, there is a greater need to “formalize and systematize the researcher’s thinking into a coherent set of explanations” (Miles & Huberman, 1994, p. 75). For both stages of this project, the researcher generated propositions about connected sets of statements made by participants, reflected on the findings, and drew preliminary conclusions about pre-service mathematics teachers from the study.

Presentation of Findings

Stage 1

Self-Perceptions of Readiness to Teach Mathematical Content

All of the participants (20 of 20) indicated the extent to which they felt ready to teach mathematical content to Upper Primary and Lower Secondary students. For the seven content topics available (Fractions, Decimals & Percentages; Algebra; Equations & Formulas; Perimeter, Area, Volume & Capacity; Calculating Probability; Using Statistics; Venn Diagrams) participants provided a Likert-

scale rating from 1 - 5 (with 1 representing feeling least ready, and 5 representing feeling completely ready). Overall, participants shared they felt most ready to teach the topic *Perimeter, Area, Volume and Capacity* (mean = 3.85) and least ready to teach the topic *Using Statistics* (mean = 3.15). The mean score for each topic indicated a feeling of readiness among participants ($3.15 \leq \text{mean} \leq 3.85$), although not overwhelmingly so. These data are tabulated in Table 2.

Table 2: Self-Perceptions on Teaching Content (Stage 1)

	1	2	3	4	5	Total	Mean	S.D.
Fractions, Decimals & Percentages	3	1	6	7	3	20	3.30	1.23
Algebra	1	2	8	7	2	20	3.35	0.96
Equations & Formulas	1	1	9	7	2	20	3.40	0.92
Perimeter, Area, Volume & Capacity	0	3	4	6	7	20	3.85	1.06
Calculating probability	3	2	5	5	5	20	3.35	1.35
Using Statistics	2	2	10	3	3	20	3.15	1.11
Venn Diagrams	2	4	4	4	6	20	3.40	1.36

Readiness to Teach Students

All participants (20 of 20) reported a variety of responses regarding their self-perceived readiness to teach mathematical content to Upper Primary and Lower Secondary students. Qualitative responses were classified by the researcher as: *Confident, Uncertain, Unconfident, or Undecided*. Eight of twenty participants communicated they felt ‘confident’ to teach mathematical content. Various participant comments included “I feel completely ready”, “My core knowledge is strong”, “As I excelled in mathematics in school I believe I believe I am ready to teach any level of maths”, and “I completed the highest level of maths in Year 12. I also currently tutor high school students in mathematics”. Nine of twenty participants shared that they felt ‘uncertain’ about teaching; for a majority of these responses participants articulated that they required further MCK, PCK and MKT, to varying degrees. To illustrate, one participant shared "I believe I have thorough content knowledge and skills, but would need to work on how I deliver [those] to the class." Another participant stated that "I would be able to confidently extend a fair amount of knowledge to students, but cautious to receive questions and queries." A comparatively smaller number of participants intimated that they felt either ‘unconfident’ (1 of 20) or ‘undecided’ (2 of 20) to teach mathematics. One of these participants offered that "My mathematical involvements during school were very poor and I feel myself being very unconfident in this subject. Therefore, I think my readiness to teach the subject is very low until I know the content strongly enough to teach it."

Mathematical Content Knowledge Support Needed

A majority of participants (18 of 20) asserted that they required further MCK in order to adequately teach Upper Primary and Lower Secondary students. In addition, these participants identified particular Australian Curriculum (AC) strands where they felt additional MCK was needed. Specifically, over half of these participants (12 of 18) reported they required support in the strand *Number & Algebra*. One participant commented that support in *Number & Algebra* could include “Recapping[sic] a lot of formulas as most have been forgotten leaving myself stuck in situations; long expanded word questions; I need to get familiar with algebra again as I have forgotten plenty which leaves me unsure if I’m doing it correctly”. A comparatively smaller proportion of participants reported that they needed further MCK from AC strands *Statistics & Probability* (4 of 18) and *Measurement & Geometry* (2 of 18). From the 2 of 20 who registered a feeling of ‘unsure’ one of them stated ‘None yet, but I’m sure we’ll find some’.

Getting the Most out of the Unit

All participants (20 of 20) predicted that completing the unit would positively contribute to their preparation as mathematics teachers. In particular, over half of the participants (14 of 20) mentioned that this unit would assist in both strengthening their MCK and PCK. One student was hopeful the unit would

Reinforce and clarify basic mathematics principles. Confirm that the way I do and think about them are correct and that I am not missing an easier or more certain method or understanding of them. I could probably do many of the examples at this level using a calculator, pen and paper but explaining the why of maths and the relationships between principles is something I hope to gain a clearer understanding of as well as the principles for teaching maths. The more times I work through it or have it explained the more ideas I hope to have for how to work through it clearly and logically with students.

Another student reinforced the link between PCK and MCK, stating that “I feel that it will provide me with pedagogy but also with the ability to calculate and solve mathematics problems effectively and accurately”. In addition to such comments, a number of participants (4 of 20) shared that the unit would be effective in refreshing mathematical content. One participant stated “this unit will refresh my own prior knowledge from middle school and also provide me with some new content knowledge, such as key terminology and strategies specific to the teaching of middle school mathematics”. Other participants (4 of 20) stressed that this unit would provide them with confidence to teach mathematics effectively. Here in one participant noted that “[the unit] will give me an understanding of the thinking processes during mathematics; it should give me an added confidence of delivering content to students”.

Self-Perceptions of Readiness to Teach Mathematical Content

In Stage 2 of data collection, 18 participants indicated the extent to which they felt ready to teach mathematical content to Upper Primary and Lower Secondary students. For the seven content topics available all participants provided a Likert-scale rating from 1 - 5 (with 1 representing feeling least ready, and 5 representing feeling completely ready). Overall, participants shared they felt most ready to teach the topic *Algebra* (mean = 4.56) and least ready to teach the topic *Fractions, Decimals and Percentages* (mean = 4.28). The mean score for each topic in Stage 2 indicated a significantly higher level of readiness than Stage 1 participants ($4.28 \leq \text{mean} \leq 4.56$). These data are tabulated in Table 3.

Table 3: Self-Perceptions on Teaching Content (Stage 2)

	1	2	3	4	5	Total	Mean	S.D.
Fractions, Decimals & Percentages	0	0	3	7	8	18	4.28	0.73
Algebra	0	0	2	4	12	18	4.56	0.68
Equations & Formulas	0	0	2	5	11	18	4.50	0.69
Perimeter, Area, Volume & Capacity	0	0	2	5	11	18	4.50	0.69
Calculating probability	0	0	2	7	9	18	4.39	0.68
Using Statistics	0	0	2	6	10	18	4.44	0.68
Venn Diagrams	0	0	2	6	10	18	4.44	0.68

An Increase in Confidence

After completing the unit, all Stage 2 participants (18 of 18) indicated they felt ready to teach Upper Primary and Lower Secondary students. Qualitative responses were classified by the researcher as: Ready/Confident, or More Ready/More Confident. A majority of participants (10 of 18) reported how they felt ‘more ready’ or ‘more confident’ to teach mathematical content following the completion of the unit, compared with pre-unit sentiments. For example, one participant expressed “feeling much more confident due to being in this unit which has helped me refresh content. I feel much better about teaching mathematics now I understand how to do it better”. Another participant echoed this claim, stating:

I feel I am more ready to teach mathematics to upper primary/lower secondary students after completing ED2315 as I have recapped on a lot of knowledge learnt in school. Based on my current skills I possess I feel I would have to become more confident in the subject before committing to teaching it completely; however, I feel I have improved.

A third participant noted feeling increasingly ready to teach mathematical content after observing various concepts taught by the unit lecturer before engaging in independent practice. A number of participants (8 of 18) also shared feeling 'ready' or 'confident' to teach middle school mathematics content after completing the unit, with many suggesting an area for self-improvement. One participant expressed feeling "rather ready [to teach]; however, I feel further personal study is required to make sure I understand it all in[side] and out". Other responses included "I feel that I possess [a] majority of the skills and knowledge necessary for me to teach upper primary/lower secondary maths" and "[I feel] very confident that with good preparation and lesson planning that I will be familiar enough with the content to teach and be capable of any left field questions as they arise". Despite having both a clearer understanding of the broad range of mathematical skills middle school students require to become mathematically literate, as well as attaining greater skills to teach the content, one participant reported a low level of confidence to teach. This self-perceived level of confidence was attributed directly to the lack of mathematics teaching experience.

Still More Work to be Done

Although indicating a self-perceived readiness to teach mathematics to middle school students, a majority of participants (13 of 18) identified one area of content knowledge on which to improve. Areas of mathematical content knowledge these participants identified included Australian Curriculum strands Number & Algebra (5), Measurement & Geometry (4), Statistics & Probability (1). Additionally, three participants expressed they wished to study higher level mathematics and two participants felt they required further help in all Australian Curriculum strands. One of the participants requiring further help stated "each of the major content areas were covered very quickly [in the unit], so I feel I need further development in each of the areas. Mathematical grammar is an area I also feel is of great importance when understanding content. This is an area I feel I lack in". Five participants expressed that they did not require any further mathematical content before teaching middle school students.

A Useful Unit

All Stage 2 participants (18 of 18) communicated that completing this unit was helpful in consolidating their middle school mathematical content. Qualitative responses were classified by the researcher as: *Refresher*, *Confidence*, *PCK* or *MCK*. Seven participants expressed that the unit was useful in refreshing mathematical content they had learnt previously. To amplify, responses included "Good revision of content for teaching middle school maths", "it's certainly rejuvenated my maths brain so to speak which makes me feel more confident if I were to teach this in the classroom", and "it has done well to remind me how to do maths without a calculator". Six participants indicated that the unit had given them confidence to teach mathematics content. For example, one participant noted how "[the unit] has contributed greatly to me being able to complete

middle school mathematics. I struggled with a lot of these concepts in middle school and I really enjoyed doing them in this class once I really got the hang of it”. Another response indicated “a big improvement; [I] really enjoyed the unit and feel much more confident in my mathematical knowledge and ability to teach mathematics to middle school students”.

A number of participants (6 of 18) highlighted that completing the unit had contributed to their understanding of how to teach mathematical content. With regards to pedagogical content knowledge, various comments included “[the unit] has given me a lot of ideas about how to teach the content”, and “[the unit] has been helpful in providing me with skills on how to explain how I solve problems better than [what] I could before”. In particular, one participant noted that further experience in teaching mathematics would be useful in consolidating the content knowledge acquired:

[the unit] has provided me with a great revision of middle school mathematical content. I believe further experience of actually teaching the content will provide me with a better grasp of how well I know the content. Further time is needed to gain full understanding.

Six participants underscored that their mathematical content knowledge had improved as a result of completing the unit. Of these six participants, three acknowledged how the acquisition of mathematical content had led to a feeling of confidence in teaching students. For instance, two responses indicated the unit was “Immensely helpful, [it] has refined my mathematical skills and allowed me to develop them into an effective way of teaching”, and “I feel this unit has provided me with the knowledge to teach mathematical concepts and principles effectively to a group of middle school students”. These responses suggest that the unit was beneficial in enhancing students’ MCK and PCK.

Conclusion

This paper explored the self-perceptions of pre-service primary and secondary teachers enrolled in a mathematics education unit as they prepared to engage with and consolidate their mathematics content. In addition, the self-reported understanding and perception of pre-service teachers’ ‘readiness’ to undertake such a task was interrogated, based on their recent tertiary training. In addition to the body of literature already suggesting that pre-service mathematics teachers require additional support in developing their MCK, the testimony of the research participants reinforces that claim. At the same time the collected data from Stages 1 and 2 indicated the extent to which pre-service teachers believed taking a mathematical content unit was valuable for their future professional roles. High value was ascribed to the acquisition of MCK, PCK, or any combination of these knowledge categories. In particular, all participants expressed a view that this unit was valuable for their confidence and overall readiness as they consolidated their MCK, especially with key topics in the Australian Curriculum.

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Appendices

Appendix 1: Pre-Unit Survey

1. How ready do you feel to teach the following topics? Complete each item by selecting a number (1 indicates the least ready, 5 indicates the most ready).

- (a) Fractions, Decimals, Percentages
- (b) Algebra
- (c) Equations and Formulas
- (d) Perimeter, Area, Volume, Capacity
- (e) Calculating Probability
- (f) Using Statistics
- (g) Venn Diagrams

2. Describe your readiness to teach mathematics to Upper Primary/Lower Secondary students in terms of the mathematical content knowledge and skills you currently possess.

3. In what area(s) of mathematical content knowledge do you feel you require further learning?

4. How do you feel this unit will contribute to your grasp of middle school mathematical content?