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PREPARING SECONDARY MATHEMATICS TEACHERS: A REVIEW OF RESEARCH

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The international literature base concerning the preparation of pre-service secondary mathematics teachers has grown steadily over the past two decades, yet there appears to be no consensus on a best practice approach. A review of three research projects (2 American; 1 Australian) that focus on different aspects of secondary mathematics teacher preparation provides consideration for universities wishing to strengthen existing programs.

Introduction

The tertiary training of pre-service secondary mathematics teachers is pivotal in their professional preparation and formation as qualified educators. With large numbers of Australian secondary mathematics teachers set to retire in the next decade (Weldon, 2015), schools are already experiencing difficulties replacing those leaving with suitably qualified staff. In a recent review of research, Hine (2015) noted that over the past two decades there has been a growing body of literature concerning the preparation of pre-service mathematics teachers (PSMTs). Specifically, research into teacher education programs have examined how pre-service teachers (PST) are prepared with respect to their pedagogical content knowledge (PCK) (Beswick & Goos, 2012) and mathematical content knowledge (MCK) (Meany & Lange, 2012). Other efforts have scrutinised how to best support pre-service primary and secondary teachers' PCK (Aguirre, del Rosario Zavala, & Katanyoutanant, 2012) and MCK (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). Moreover, various commentators herald the importance of reinforcing theory and practice within teacher-education programs (Emerick, Hirsch, & Berry, 2003; Miller & Davidson, 2006; TEMAG, 2014). For instance, the Teacher Education Ministerial Advisory Group (TEMAG) (2014, p. x) asserted that pre-service teachers must develop a "solid understanding of teaching practices that are proven to make a difference to student learning". Despite the extensive literature no consensus exists on how to adequately train pre-service mathematics teachers (Chapman, 2005). This paper will present key findings of three research projects which each examine a different aspect of mathematics teacher preparation. First, the work of Cox et al. (2013) examines how capstone courses in the United States have been recommended as a way for pre-service secondary mathematics teachers to connect the mathematics they learn at university to the mathematics they will teach to high school students. Second, Cavanagh and Garvey's (2012) investigation of an Australian collaborative learning community that influenced the professional development experiences of PSMTs. Third, Bonner, Ruiz, and Travis (2013) compared the results of alternatively and traditionally trained PSMTs completing a mathematics content licensure examination within a large American university. The purpose of this paper is to present key findings from each project for the consideration of mathematics teacher-educators. Such consideration may inform and strengthen overall current approaches used in the preparation of PSMTs for the profession.

Capstone Courses

Commencing with the recommendation from the Conference Board of the Mathematical Sciences (CBMS) for PSMTs to complete "a 6-hour capstone course connecting their college mathematics courses with high school mathematics" (2001, p. 8), Cox et al. (2013) sought to adjudge the current status of capstone courses in secondary mathematics teacher education programs. Specifically, these researchers surveyed departments of mathematics and education within the United States to determine (i) the extent to which capstone courses were offered to PSMTs, and (ii) how such courses were designed. Within the study, the term *capstone course* was used according to the definition provided by Loe and Rezak (2006). Such a course must have been studied at the conclusion of a program of study for PSMTs, fulfilling at least one the following four criteria: (1) bridges content between upper-level mathematics courses, (2) makes connections to high school mathematics, (3) gives additional exposure to mathematics content in which students may be deficient, and/or (4) provides experiences communicating with and about mathematics (Loe & Rezak, 2006).

From the 200 departments of mathematics and education surveyed, 73 responded to the online questionnaire developed by the researchers. Of the 73 responding departments, 42 indicated that they offered a course that satisfied at least one of the criteria for capstone courses. Moreover, the capstone courses offered in 26 of these 42 departments were classified as CBMS courses,

insomuch as they aligned with the CBMS purpose to explore connections between college mathematics and secondary school mathematics. According to Cox et al. (2013), the collected data provided insight into three major aspects of the capstone courses: (1) Course Goals, (2) Logistics, and (3) Participants. Although the researchers noted a distinction between the goals of CBMS aligned and non-CBMS aligned courses, the most commonly stated course goal overall was for students to develop a deeper understanding to mathematics. To illustrate, specific course goals included students clearly writing and communicating mathematics (CBMS), and investigating a substantial mathematical topic and learning advanced mathematics independently (non-CBMS). A logistical review of capstone courses uncovered information regarding the prerequisites, topics, and resources of such courses. To commence, it was found that calculus and linear algebra were the most commonly listed prerequisites. Again, distinctions between CMBS and non-CBMS capstone courses emerged; 65% of CBMS courses required two or fewer upper division prerequisites (e.g. probability, calculus-based statistics, non-Euclidian geometry, abstract algebra, and real analysis) while only 46% of non-CBMS courses required two or fewer. Topically, the CBMS courses examined more secondary mathematics content and pedagogical concerns than non-CBMS courses; all of the latter's courses addressed advanced mathematical topics. A variety of electronic (e.g. Dynamic Geometric Software, Microsoft Excel) and print (texts, Education Organisation Standards) resources helped to develop and support both CBMS and non-CBMS courses. However, the development of CBMS courses far exceeded that of non-CBMS courses through the guidance of national organisations (e.g. National Council of Teacher of Mathematics) and recommendations (e.g. National Advisory Board Recommendations), as well as by educational organisation standards (Common Core State Standards).

A review of the capstone course participants revealed that all students in non-CBMS aligned courses were mathematics majors. For CBMS aligned courses, six capstone courses were described as being required specifically for PSMTs. Within most departments (both CBMS and non-CBMS), students intending to be mathematics teachers did not populate exclusively the capstone courses. As Cox et al. (2013, p. 7) asserted, "only six capstone courses (all CBMS) reported that they were exclusively for students seeking teaching licensure". These researchers found a variety of capstone university lecturer backgrounds, categorised as hailing from: mathematics, mathematics education, both mathematics and mathematics education, or neither. Lecturers of CBMS courses were more likely to have a mathematics education or both mathematics education and mathematics background, while non-CBMS lecturers had backgrounds in mathematics. Overall, Cox et al. (2013) concluded that ten years after the initial CBMS recommendation, course alignment with this recommendation appears not to be widespread. Consequently these researchers conceded that capstone courses for future teachers may be difficult to implement in institutions serving a small number of PSMTs. Nonetheless, a defining feature of the current state of capstone courses is the variety of forms – not least with reference to the goals, logistics and participants.

A Professional Learning Community

Cavanagh and Garvey (2012) examined how a group of nine Australian pre-service teachers (PSTs) and their supervisors participated in a professional experience learning community for secondary mathematics. Commencing with the notion of a learning community as a group of people "involved in some kind of activity that learn together and, more importantly, learn from each other" (Ponte et al., 2009, p. 197), the participating PSTs engaged in various activities to develop their professional practice. Prior to the commencement of the study, a secondary Head Teacher and the PSTs methods lecturer agreed to establish a learning community partnership between the school and the university. The researchers chiefly wished to investigate the participants' views about the learning community and to identify if it helped the PSTs to develop their professional practice. As Cavanagh and Garvey (2012, p. 61) noted, the teacher and lecturer " envisioned the learning community as an extended series of school visits (incorporating lesson observations, co-teaching, and sustained opportunities for discussion and critical reflection) combined with complementary activities during the university methods workshops". Over the course of one academic year the PSTs were all completing a Graduate Diploma of Secondary Education at an Australian university. The PSTs and methods lecturer visited the school in groups for Year 8 mathematics lessons. Following each observed or co-taught class the teacher, lecturer and PSTs discussed the lesson for approximately 15 minutes. The methods lecturer attended all visits, and undertook a role of observation and facilitation. Specifically, this lecturer observed all lessons, participated in the post-lesson discussions, and used field notes (from school visits) to frame subsequent workshop discussions at university. Within two days following each lesson, the PSTs also wrote and posted online a personal reflection for perusal and commentary by the other learning community members. Neither the teacher nor the lecturer contributed to the online forum.

Cavanagh and Garvey (2012) anticipated that the school visits would be opportunities for PSTs to learn from observing an experienced mathematics teacher present a series of problem-solving lessons. During the data collection stage of this research (i.e. through questionnaires, focus group interviews and reflections) PSTs reported that much fruitful learning took place when they co-taught, observed and discussed each other's lessons. The reflection-based activities also received significant mention from the PSTs. Specifically, Cavanagh and Garvey (2012, p. 69) highlighted how high quality reflection was achieved "through a combination of individual and group tasks, both oral and written, which encouraged pre-service teachers to think more deeply about their experiences". In addition, these authors asserted how the synchrony of reflective activities was achieved through interweaving school visits with follow-up activities in methods workshops; such synchrony helped to mirror the classroom experiences and reinforce the practice of reflection. Participants also commented on how their cohort developed a greater appreciation of the importance of problem solving as a practical way of teaching mathematics. Furthermore, partici-

pant testimony revealed that they felt encouraged to develop further their professional knowledge of mathematics teaching. Overall, the learning community activities assisted PSTs in establishing strong links between theory and practice, and opportunities for co-teaching and peer observation allowed participants to collaborate and support each other's learning.

Traditional Versus Alternatively Prepared Content Knowledge

Bonner et al. (2013) investigated the extent to which Alternative Mathematics Teacher Education Programs (ATEPs) prepared teachers with the content knowledge needed to teach secondary mathematics. At one large, public university in the southern United States, the researchers reported on a quantitative analysis comparing scores between traditionally and alternatively prepared teachers on a secondary mathematics state licensure test. For this project, the ATEPs were defined as "teacher education programs that enrol non-certified individuals with at least a bachelor's degree offering shortcuts, special assistance, or unique curricula leading to eligibility for a standard teaching credential" (Adelman, 1986, p. 2). According to Bonner et al. (2013), ATEPs currently exist in all 50 states within the United States and have been a source of heated debate for some time. On one hand, supporters of ATEPs view such programs as viable means for universities and school districts alike to address teacher shortages and recruitment issues rapidly. Furthermore, Bonner et al. (2013, p. 1) contend that ATEPs may have the ability to recruit "highly skilled individuals (such as second career teachers or mathematics and science majors) who might not otherwise find their way into the field of education and can provide an expedited path to an advanced degree for in-service teachers". Conversely, opponents to these programs assert that by expediting the teacher preparation process, ATEPs provide a less rigorous teaching qualification which may undermine traditional programs and weaken overall the quality of the teaching profession. Moreover, some teachers who have completed ATEPs report feeling underprepared for the classroom and perceive a lack of support from programs (Foote et al., 2011).

At the researchers' site, aspirant secondary mathematics teachers can follow one of two options for certification. The traditional certification plan is where undergraduate students major in mathematics while taking courses in the College of Education (COE) during their undergraduate degree. Following this traditional plan, students complete at least 45 hours of mathematics content courses, including "Modern or Abstract Algebra, Real Analysis, and a Capstone Course that focuses on connections between college and high school level mathematics" (Bonner et al., 2013, p. 4). These students are also required to fulfil various teaching certification requirements and complete practicum teaching experiences. Non-traditional students can seek certification through a post-graduate program or via ATEP, operated from within the COE. All students who elect for the non-traditional plan are college graduates with STEM or human-service related degrees and second career professionals. Upon admission, students undertake 24-27 hours of teacher certification coursework, core graduate-level coursework in the COE, and 30 hours of field observations.

In summary, the researchers wished to discern any differences between the cohorts of traditionally and non-traditionally prepared mathematics teachers by comparing the performances of these individuals on the secondary mathematics certification examination. This examination is comprised of six mathematical domains: *Number Concepts*, *Patterns and Algebra*, *Geometry and Measurement*, *Probability and Statistics*, *Mathematical Processes and Perspectives*, and *Mathematical Learning, Instruction, and Assessment*. The data were gathered from the examination results of 89 pre-service teachers (20 ATEP, 69 traditional). While the researchers noted that neither cohort had a passing mean for the examination overall, they found significant differences in scores in the following domains: *Total Score*, *Patterns and Algebra*, *Probability and Statistics*, and *Mathematical Processes and Perspectives*. As such, it was concluded that students who participated in a traditional program of study are more prepared for the secondary mathematics licensure examination. The researchers acknowledged that this conclusion was expected, as traditionally prepared secondary mathematics teachers generally have majored in mathematics and therefore have received more mathematical content knowledge. Nevertheless, while neither group had a mean passing score for the examination, this cohorts' results were 9 points higher that the state average. The researchers felt that these results indicated three key findings. First, the teacher education programs currently offered are not preparing pre-service teachers adequately for the examination. Second, the content represented on the licensure examination is not aligned well with content taught in teacher education program. Third, the licensure examination is nor a valid nor reliable measure of achievement.

Conclusion

The review of three research projects indicates that there are various means by which universities prepare pre-service secondary mathematics teachers. Some factors that universities may consider in preparing the next generation of secondary mathematics teacher have been presented in the executive summaries of the three research projects presented. First, the introduction of a capstone course – as recommended by a national educational authority – could serve to standardise the preparation of mathematics teachers. Doing so might also assist in bridging the content of university mathematics courses closely with that content taught at secondary level, and in providing a final experience for student teachers to communicate with and about lingering mathematical deficiencies. Second, the implementation of a professional learning community within a teacher education program might provide mathematics teachers with an effective model of professional practice. Specifically, having students observe structured lessons taught by a master teacher and then engage meaningfully in a variety of collaborative learning activities promotes skills and practices essential to quality mathematics teaching. Notably these activities include co-teaching opportunities coupled with follow-up reflection and discussion, which have been found to drive a sense of professional develop-

ment. Third, and while Australia continues to prepare secondary mathematics teachers through 4-year (BEd), 2-year (MTeach) and 1-year (Grad Dip Ed) university programs, there is consideration for a competency-based exit examination focussed on demonstrating mastery of content knowledge. While literature suggests that higher scores on licensure tests lead to increased student achievement (Sawchuk, 2011) – and with all Australian graduate teachers set to undertake a mandatory competency test from 2016 (Literacy and Numeracy Test for Initial Teacher Education Students) – an additional examination might become a future certification requirement for secondary mathematics teachers. Following the findings of Bonner et al. (2013), for such an examination to be a useful measure of mathematics teacher competency the content would need to be aligned closely with mathematics taught both at university and secondary school level.

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