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Authors(s)	Ní Shúilleabháin, Aoibhinn, Meehan, Maria
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Developing pedagogical content knowledge in initial teacher education: Lesson study and peer assisted tutoring

Aoibhinn Ni Shuilleabhain; Maria Meehan

¹ School of Mathematics & Statistics, University College Dublin

Learning to teach is a long-term and complex enterprise (Morris et al., 2009). In their commentary on initial teacher education (ITE), Hiebert, Morris, and Glass (2003) suggest that ITE programmes are more valuable when they support pre-service teachers to acquire the tools they will need to learn to teach, rather than focus on achieving complete and polished competencies of high-quality teaching. Peer-assisted tutoring and lesson study are two models which can build pre-service teachers' awareness of the knowledge and skills required to teach, while also providing them with tools to continue their path as life-long learners (Amador and Carter, 2018, Duah et al., 2014). In this paper, we will discuss the incorporation of these two models, conducted in tandem during one semester in the third year of a concurrent undergraduate ITE programme in Science and Mathematics. Seven pre-service teachers volunteered to participate in this research and qualitative data, generated through planning documents and weekly reflections, was analysed utilizing the Mathematical Knowledge for Teaching framework (Ball et al., 2008). Findings suggest that, due to their participation in peer-assisted tutoring and lesson study, these pre-service teachers developed important skills in noticing and reflecting as part of their repertoire of learning to learn to teach. Furthermore, findings suggest a development of their knowledge of content and teaching (KCT) and knowledge of content and students (KCS) over the course of the semester. This research may provide useful insight for ITE providers and teacher educators.

Keywords: Initial teacher education, Lesson study, Peer-assisted tutoring

INTRODUCTION

Initial teacher education (ITE) programmes strive to educate pre-service teachers to become high-quality, effective teachers. However, learning to learn to teach is a long and complex enterprise (Morris et al., 2009) and it may not be possible for ITE programmes to incorporate all of the learning required by pre-service teachers at the point of their graduation. Hiebert et al. (2003) suggest that rather than focusing on achieving complete and refined competencies of teaching at the end of ITE, programmes should instead focus on supporting pre-service teachers to acquire the skills and knowledge they will need to continue to learn to teach as life-long practitioners. Specifically focusing on the education of pre-service mathematics teachers, there have been calls to develop understandings of the knowledge and skills required to teach mathematics at post-primary level (Speer et al., 2015). Furthermore, research has suggested that ITE mathematics programmes should be developed to explicitly prepare pre-service teachers for the challenging and changing environment of teaching and learning (Hiebert et al., 2003).

This paper focuses on a recently established concurrent undergraduate to postgraduate post-primary Mathematics and Science ITE programme at University College Dublin. This programme, run through DN200 Science at undergraduate level and directed by the School of Mathematics and Statistics, has been designed to continuously develop both the content and pedagogical content knowledge of pre-service Mathematics and Science teachers over the course of their qualification. The programme incorporates four strands where students can

qualify as Mathematics and one of Biology, Chemistry, Physics or Applied Mathematics teachers and is fully recognised by the Teaching Council.

In this research, we investigate two modules which are undertaken by all students within the third year of this programme. These modules separately incorporate a focus on lesson study (Lewis et al., 2009), where students participate in a full cycle over the course of one semester, and peer-assisted tutoring (or peer-assisted learning) (Duah et al., 2014), where students act as tutors to first-year undergraduate mathematics students for a semester. In this research we ask four questions, focusing on the initial two in this paper:

1. How is mathematical pedagogical content knowledge developed through pre-service post-primary teachers' participation in lesson study?
2. How is mathematical pedagogical content knowledge developed through pre-service teachers' participation in undergraduate peer-assisted tutoring?
3. How does participation in lesson study and peer-assisted tutoring effect pre-service teachers' self-efficacy in teaching mathematics?
4. How does this new knowledge of pedagogy manifest in their initial teaching practice?

This paper reports on initial analysis and preliminary findings of this research.

LITERATURE REVIEW

In their investigation of the knowledge required to teach mathematics, Ball and colleagues proposed a framework of Mathematical Knowledge for Teaching (MKT) (Ball et al., 2008). While this framework emphasises the importance of teachers' knowledge of mathematical content (subject matter knowledge), it also builds upon Shulman's (1986) definition of pedagogical content knowledge and incorporates the type of knowledge that is required uniquely of mathematics teachers (see Figure 1).

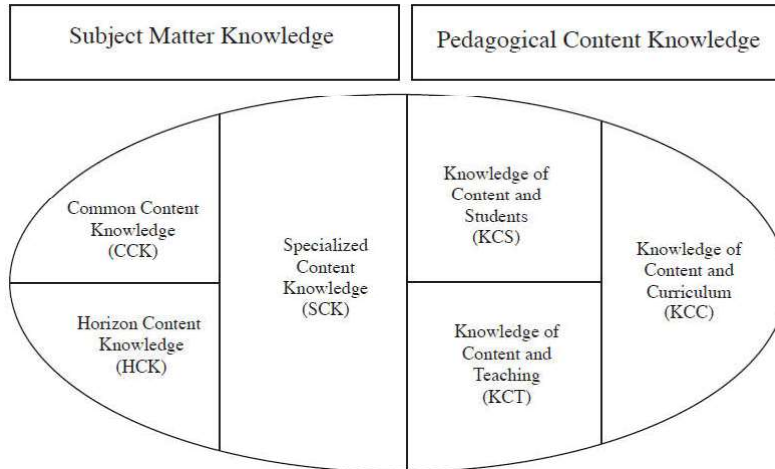


Figure 1: Mathematical Knowledge for Teaching Framework, Ball et al. (2008)

Ball et al.'s (2008) framework has become one of the most influential reconceptualization of teachers' knowledge (Depaepe et al., 2013). Research has demonstrated the importance of teachers' content knowledge and pedagogical content knowledge (PCK) in impacting their practice and impacting pupil learning (e.g., Baumert et al., 2010; Hill et al., 2008; Ma, 1999). Further studies have evidenced that high PCK cannot develop without strong content knowledge (Krauss et al., 2008). In reviewing models of professional development which support teacher learning, lesson study and peer assisted tutoring have emerged as ways of purposefully developing teachers' knowledge and skills.

Lesson Study

Lesson study, a model of teacher education originating in Japan, involves a collaborative group of teachers planning, conducting, reflecting on, and revising a research lesson in order to develop their understanding of mathematics teaching and learning (Fujii, 2018; Takahashi & McDougal, 2016). Much research has demonstrated teacher learning through lesson study (Ni Shuilleabhain, 2016) and also demonstrated positive impacts on student learning due to teachers' participation in the model (Lewis & Perry, 2017). More recently, lesson study has been incorporated in ITE and research has highlighted the skills and knowledge utilised and developed by pre-service teachers in their participation in lesson study (Amador & Carter, 2018; Corcoran, 2011; Leavy & Hourigan, 2016). However, few studies have yet focused on the development of pre-service teachers' PCK in post-primary ITE and none, as yet, in Ireland.

Peer Assisted Tutoring

Peer assisted tutoring (or peer assisted learning) is a model where students are assisted in their mathematics learning by peers that are close in age and educational level. Peer assisted tutoring has been shown to benefit undergraduate learning of mathematics (Duah et al., 2014) and research has demonstrated that undergraduate students can develop their pedagogical skills in noticing and communicating mathematical thinking by participating as tutors (Solomon et al., 2014).

ITE: Post-primary Mathematics

In this research, the directors of the ITE programme (authors of the paper) utilised the MKT framework to structure their design of content within the programme in an attempt to support the development of pre-service teachers' knowledge and skills. Considering the potential of lesson study and peer assisted tutoring to develop pre-service post-primary mathematics teachers' PCK, these models were incorporated into the programme. As part of their third year of undergraduate study, pre-service teachers complete a full cycle of lesson study, in groups of 3-5, as part of a core module. The research lesson is planned with the module lecturer (first author) acting as lesson study facilitator (Takahashi & McDougal, 2016). The research lesson is conducted in a nearby post-primary school and the pre-service teachers write a lesson reflection as part of their final report. In the same semester, these students act as peer-assisted tutors of a first-year undergraduate mathematics module within a core module of their ITE. As part of their learning, they reflect on their tutoring experiences through writing brief-but-vivid accounts (Mason, 2002) in order to develop their noticing skills of learners' mathematical thinking (Breen et al., 2014). In facilitation with the module lecturer (second author), pre-service teachers reflect on their learning from their weekly brief-but-vivid accounts.

METHODOLOGY AND PRELIMINARY FINDINGS

Seven pre-service teachers volunteered to participate in this research and data was generated through participants' weekly reflections, lesson study materials, and brief-but-vivid accounts. Analysis was undertaken according to a detailed framework of MKT sub-codes, as outlined by Ni Shuilleabhain and Clivaz (2017), and did not commence until all module grades had been assigned. Two samples of data from both modules are shared below and preliminary findings related to pre-service teachers' development of PCK are outlined.

Developing Knowledge for Content and Teaching

According to the MKT framework (Figure 1), Knowledge for Content and Teaching (KCT) combines knowing about teaching and knowing about mathematics (Ball et al. 2008, p. 401). This includes mathematical knowledge of the design of instruction such as: sequencing mathematical content, identifying or developing learning activities, and selecting models that support the development of mathematical understanding (Ball et al. 2008).

As part of their lesson study planning process, pre-service teachers developed tasks to match their articulated learning outcomes for the research lesson. One group of pre-service teachers designed a Geometry lesson and, at the beginning of the lesson, wished to revise pupils' knowledge of Trigonometry. The pre-service teachers designed a matching task which would encourage pupils, working in pairs, to articulate their understanding of right-angled triangles and Pythagoras' theorem, while also introducing pupils to the concept of inverse trigonometric functions (see Figure 2).

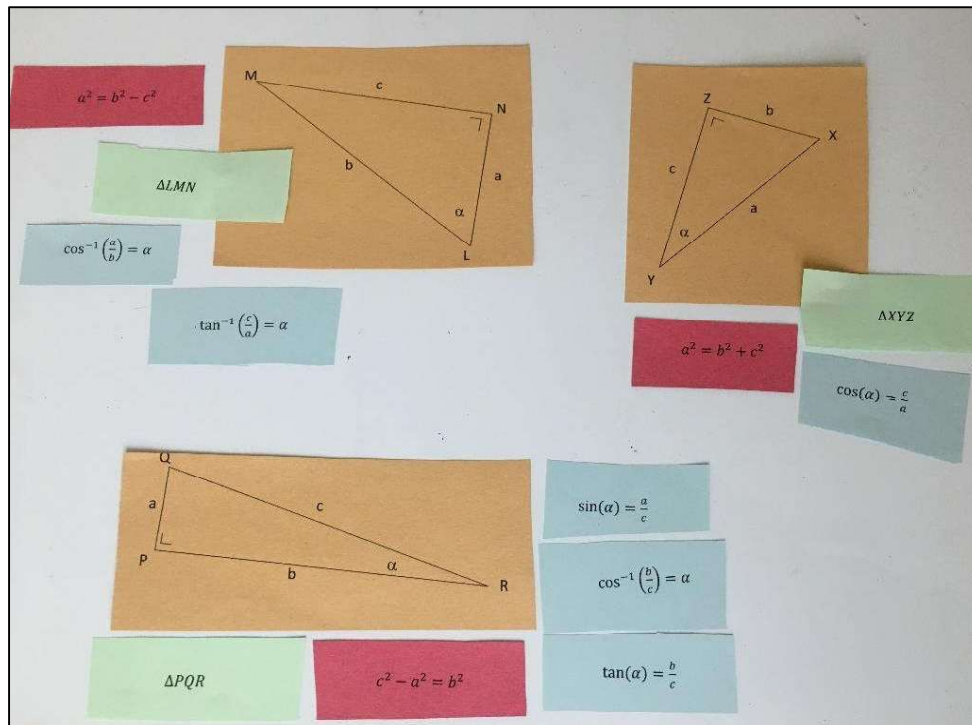


Figure 2: Mathematical task designed by pre-service teachers as part of their lesson study planning work

The creation of this task represents the development of these pre-service teachers' KCT, where they designed a learning activity and selected specific representations to support the development of pupils' understanding. Furthermore, in their lesson study reflection, these pre-service teachers recognised a need to further highlight the mathematical language they used during the lesson, distinguishing the angle 'alpha' from the side 'a'.

Developing Specialised Content Knowledge

Specialised Content Knowledge (SCK) represents a form of mathematical knowledge and skill that is unique to teaching. Types of SCK include: unpacking the mathematics of a pupil's work, looking for patterns in pupil errors, and explaining or justifying mathematical ideas (Ball et al., 2008). By participating in peer assisted tutoring, pre-service teachers were supported in developing their SCK by writing reflective, brief-but-vivid accounts of their interactions with learners. The following is a sample reflection from a pre-service teacher Emma (pseudonym) who had assisted an undergraduate student with a differentiation task.

Emma, Brief but Vivid Account "The Mysterious Three", Week 8

I asked a student who was sitting on their own if they were okay. They told me they didn't need any help. However, I glanced down at their page and saw that when they

differentiated $f(x) = 2\ln(3x) - e^{x/2}$ they got: $f'(x) = \frac{2}{3x} - \frac{e^{x/2}}{2}$.

I asked the student whether they had their notes on differentiating the natural log with them to which they replied “I know the rule - it is $1/x$.”

I questioned why they kept the 3 when differentiating $2\ln(3x)$ and they told me that they didn't keep the 3. I paused and stared at their page. I pointed to the 3 in their answer and asked “So where does this come from?” The student explained that they divided everything by 3 first and they then scribbled the following on the page:

$$2\ln(3x) = (2/3)\ln(x)$$

I asked them why they divided by 3 and the student let out a sigh: “To get rid of the 3 in brackets”. They paused before asking: “How else could I have differentiated it to get $1/x$?”

By being attuned to the student's thinking, Emma realised that the learner was not making an expected common error of differentiation, but rather was demonstrating a misunderstanding of 'log' as a function. This represented a new student misconception for Emma and, by looking for such patterns in student errors, she developed her SCK.

DISCUSSION AND CONCLUSION

Teaching mathematics is complex work and in order to prepare pre-service teachers for their future careers, it is important to support them in learning how to learn to teach (Hiebert et al., 2003). In this paper, we have focused on an ITE programme which incorporates models of lesson study and peer-assisted tutoring as part of a concurrent undergraduate to postgraduate course. These models of teacher education are included in this programme in order to begin developing pre-service teachers' knowledge and skills and build their Mathematical Knowledge for Teaching (Ball et al., 2008).

In this paper, we have shared preliminary findings of research into developing pre-service teachers' PCK through lesson study and peer-assisted tutoring. Further analysis is required in order to fully explicate how PCK is developed through these modules. Additional research is also required on how such learning may impact pre-service teachers' classroom practices following their participation in these modules.

There are several limitations in this research since it involves a small number of pre-service teachers. However, we hope such research will contribute to the literature on ITE in mathematics and will be of interest to other ITE programme designers.

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