THE ROLE OF VIDEO-BASED EXPERIENCES IN THE
TEACHER EDUCATION OF PRE-SERVICE MATHEMATICS
TEACHERS

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This paper will report on the role of video-based experiences and reflection among pre-service secondary school mathematics teachers as the drive towards a more constructivist approach to teaching and learning mathematics strengthens in Ireland through the introduction of a new initiative called ‘Project Maths’. This study uses the critical analysis and reflection of video recordings to examine pre-service mathematics teachers’ subject content knowledge. 29 pre-service teachers were video-taped teaching a mathematics class to mature students at the University of Limerick (UL) from January to May 2010. Rowland’s (2008) Knowledge Quartet was the framework used for reflection of this teaching. The findings are discussed and implications for mathematics teacher education are highlighted.

Key words: Mathematics Teacher Education, Pre-Service Mathematics Teachers, Video-Based Experiences, Subject Content Knowledge and Pedagogical Content Knowledge.

INTRODUCTION

The low uptake of Higher Level¹ mathematics (16% of total cohort in 2011) and the large failure rate of mathematics at Leaving Certificate² has highlighted the need for reform of mathematics education in Ireland. A move towards addressing the teaching and learning of mathematics is currently being implemented under a new initiative called ‘Project Maths’ which will see much greater emphasis placed on student understanding of mathematics concepts and applications.

However, there is also need for change to occur in the training of our mathematics teachers. Recent PhD work by the first author (ML) suggests that first year pre-service mathematics teachers (studying Physical Education and Mathematics at UL) have a fragmented, disjointed view of mathematics and the approaches that they adopt to learning mathematics are mainly of a procedural nature. There has been similar research internationally portraying the poor conceptual understanding that often exists among pre-service mathematics teachers (e.g. Nicol, 1999). This study was undertaken in order to link the research to a current teacher education programme by critically assessing, reflecting and most importantly, developing pre-service mathematics teachers’ awareness of their subject content knowledge, as well as their pedagogical content knowledge, through the use of video-based experiences. The study is predominantly exploratory in nature since it aims to identify and create awareness among pre-service mathematics teachers’ in relation to their subject and
pedagogical content knowledge. Although not analysed in this study, it is also hoped that in light of their KQ training, pre-service teachers will develop their knowledge in preparation for their video-based teaching experience and indeed after this experience. Shulman (1986) clarified subject matter knowledge as knowledge of the content of the discipline such as facts and concepts. He described pedagogical content knowledge as the manner in which a teacher can represent the subject in a way that others can comprehend and an understanding of what makes the learning of the subject easy or difficult.

There has been much research carried out on the use of video-based experiences in the training of prospective teachers as a tool to critically observe and reflect on their own teaching and the teaching of others. Alsawaie & Alghazo (2010) concluded from their study that video-based experiences increased pre-service teachers’ knowledge about problems in practice, developed their sensitivity toward student learning and lead to them to think in depth about efficient instructional strategies. In addition, Maher (2008) claims that it provides students with an opportunity to reflect and review theirs, and others, mathematics teaching, helping them to become aware of their practice as well as assisting them to grow in their pedagogical content knowledge.

For these reasons, one focus of the paper is on pre-service teachers’ reflection of their own teaching. The authors also believe that the use of video-based experiences in mathematics teacher education pedagogy classes are beneficial to teacher educators by enabling them to observe and evaluate their students’ subject and pedagogical content knowledge. Therefore, this study also focuses on the researchers’ critical observation and reflection of the pre-service teachers. Due to constraints to the length of this paper, as well as the need for further analysis of the data collected, pre-service teachers’ critical observation and reflection of their peers is not reported on here.

**THEORETICAL FRAMEWORK**

The theoretical framework employed in this study for investigating pre-service mathematics teachers’ subject content knowledge and to a lesser extent, their pedagogical content knowledge, is now discussed.

The Knowledge Quartet (KQ) devised by Rowland, Huckstep & Thwaites (2005) was the framework upon which this study was conducted. Rowland and his colleagues created this framework for the observation and review of mathematics teaching. It consists of four units: foundation; transformation; connection and contingency. Each unit is subdivided into smaller sub codes of which there are 17 in total. The framework used in this study is a slight adaptation to Rowland et al.’s (2005) KQ since one or two of the sub codes are not identical to the original version e.g. “depth of mathematical knowledge” was not a code in the original KQ. Rowland (2008) describes foundation as trainees’ knowledge, beliefs and understanding acquired in preparation for their role in the classroom. Transformation concerns “knowledge-in-
action as demonstrated both in the planning to teach and in the act of teaching itself” (Rowland, 2008, p.289). Connection, the third category, links together choices and decisions for the more discrete parts of mathematical content. It includes making connections between concepts and procedures as well as sequencing of subject matter. The final category, contingency, incorporates the pre-service teachers’ ability to respond to students’ ideas and think on one’s feet. Table 1 below summarises the Knowledge Quartet framework adapted from Rowland and his colleagues for use in this study.

<table>
<thead>
<tr>
<th>Foundation</th>
<th>Transformation</th>
<th>Connection</th>
<th>Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Depth of mathematical knowledge.</td>
<td>- How the mathematics is communicated to the learner (the difference between someone who knows mathematics and someone who knows how to teach mathematics)</td>
<td>- Making connections between mathematical concepts</td>
<td>- Ability to think one one’s feet</td>
</tr>
<tr>
<td>- Use of terminology</td>
<td>- Example Choice (real-life examples, other subject areas etc.)</td>
<td>- Making connections between mathematical procedures</td>
<td>- Response to unexpected</td>
</tr>
<tr>
<td>- Use of textbooks</td>
<td>- Analogy</td>
<td>- Sequencing of subject matter (order in which the mathematical concepts are taught)</td>
<td>- Deviate from lesson plan if advantageous</td>
</tr>
<tr>
<td>- Reliance on procedures</td>
<td>- Demonstration</td>
<td>- Anticipation of complexity (knowledge/awareness of areas which students will find difficult)</td>
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<tr>
<td></td>
<td>- Representation</td>
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<td></td>
<td>- Illustrations</td>
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Table 1: The Knowledge Quartet (adapted from Rowland, 2008 and Rowland et al., 2005)

METHODOLOGY

Research Design

The research was carried out in two main stages. In stage one both authors separately watched and compared three extracts from a TIMSS video study and analysed them according to the KQ identifying aspects of each of the four units that impacted on the lesson. Following this, pre-service teachers were provided with KQ training in the form of two workshops. The first workshop included a 20 minute lecture and discussion of the KQ. They then observed and analysed one extract from the TIMSS video study in the same manner as that previously done by the authors. This was done individually firstly, following by paired and whole class discussion on findings. Finally, the pre-service teachers were provided with a copy of the researchers’ analysis to compare and contrast their own analysis with. The pre-service teachers had one further workshop where they again observed and reflected on a 30 minute extract from another TIMSS video and in pairs/groups they discussed what they had observed and reported on based on the KQ units and sub codes.
In the second stage of this research, the pre-service mathematics teachers were split into pairs for teaching a 50 minute support tutorial (25 minutes each) to “Access” mature students. As the name suggests, these tutorials support the work done in lectures and in the students’ regular tutorials provided by the University. Each pre-service teacher was required to teach a support tutorial and reflect on it once provided with the DVD of the lesson. They were also required to attend two other lessons observing and reflecting on their peers’ teaching although this is not reported on in this paper as explained earlier. The KQ is the basis for all observation and reflection. Pre-service teachers were provided with a copy of the KQ table and a critical observation and reflection report form devised by the authors for this analysis (available from the first author). Prior to teaching, each pre-service teacher was provided with a tutorial sheet from the lecturer of the Access Mathematics or Access Statistics course with specific questions to follow. The first author also attended all support tutorials and observed and reflected on each pre-service teaching session.

**Research Sample, Data Collection and Data Analysis**

The sample included 29 pre-service secondary school mathematics teachers studying Physical Education and Mathematics at UL. Access to the sample was not a problem since their mathematics pedagogy module from January 2010 to May 2010 was taught by the second author (OL). Olivia Gill is also manager of the Mathematics Learning Centre in UL and assigns tutors for all support tutorials. This provided us with the sample to teach – mature students studying an access certificate course designed to refresh students’ skills in areas such as basic mathematics and statistics. Many of these mature students have not studied any form of mathematics in a number of years and are returning to education in the form of this Access course which provides a means of entry to third level undergraduate courses in the future.

Prior to data collection, consent was obtained from all mature students and pre-service teachers for recording the lessons. The participants were informed that all data was anonymous and that it would be stored securely for the authors’ use only. Four pre-service teachers taught per week, two at the mathematics support tutorial and two at the statistics support tutorial with exception of one pre-service teacher who taught a full lesson on his own due to odd numbers. All lessons were recorded and DVDs developed of each lesson. Each pre-service teacher was given the DVD of their teaching only. The authors also had a copy of the DVD of each lesson.

This paper reports firstly on the researchers’ analysis of the 29 pre-service teachers’ teaching. The first author attended each lesson and at a later date she again reflected on all video-recordings in more detail. Again, the KQ and the codes designed by Rowland et al. (2005) was the framework for this analysis. On completion of this stage of analysis, the authors determined the main themes or findings that emerged from the data under each of the four units. The findings coming from the data were compared by the two researchers for consistency.
The pre-service teachers’ own critical observation and reflection reports are also analysed and discussed in this paper. These reports were completed in the same manner as the authors in that each pre-service teacher watched the DVD of their own teaching and reflected on it by identifying aspects of each of the four units of the KQ that they believed impacted on their lesson. The reports were then submitted to the first author. One pre-service teacher failed to submit his report so analysis is based on 28 pre-service teachers. Again, the first author determined the main themes/findings emerging from the pre-service teachers’ reports in terms of pre-service teachers’ awareness, or otherwise, of aspects of the KQ that impacted in any way on their lesson.

**FINDINGS AND DISCUSSION**

The findings and discussion in terms of both the researchers’ critical observation and reflection of the pre-service teachers and in terms of the pre-service teachers’ critical observation and reflection on their own teaching are now presented and discussed under the four main categories of the KQ; foundation, transformation, connection and contingency. The KQ sub codes as in Table 1 are in italics for clarity.

**Researchers’ critical observation and reflection of the pre-service teachers**

**Foundation**

The *depth of mathematical knowledge* demonstrated by the pre-service teachers was poor with only six teachers displaying a good depth of knowledge. In general, the pre-service teachers *relied on procedural knowledge* (19 out of 29), described by Skemp (1978) as instrumental understanding or knowing the ‘how’ rather than knowing the ‘why’. For example, one pre-service teacher did not relate to students’ method for calculating the median as it differed from her method. She was confused stating that

“5.5 is the median because it is the right middle number. I don’t know why the formula isn’t working”.

Many explanations were also focussed at a procedural level. When explaining the basic laws of probability one teacher reinforced the idea that students should multiply when they see the word ‘and’ and add when the see the word ‘or’. Mason & Spence (1999) stress the failings of rehearsal and practice of techniques. While a mixture of both procedural and conceptual understanding is important, an overreliance on procedural understanding can be damaging. A concluding remark from one teacher was that “If you can learn off the formulas you’ll be fine”.

This may have been the manner in which this pre-service was taught himself in school. Developing subject matter knowledge is essential for these pre-service teachers since improvements in particular kinds of subject matter competence contribute to better analysis of practice thus improve teaching (Hiebert, Morris, Berk & Jansen, 2007).
In addition, 25 out of the 29 pre-service teachers frequently used poor mathematical language or failed to introduce terminologies in their teaching.

Transformation

*Communicating the mathematics* to the learner is one of the sub codes under this category. 8 out of the 29 pre-service teachers were categorised as good transformers or communicators of knowledge, 14 categorised as poor transformers of knowledge and 7 as average. The pre-service teachers were categorised according to the way in which the teacher transformed his or her own meanings and descriptions of the content. An example of where knowledge was transformed effectively through representation and indeed by using a *real-life example* was where a pre-service teacher used a YouTube video of a car overtaking another car to introduce the concepts of velocity and acceleration. While the first author is not suggesting that real world contexts are the only effective way to transform the mathematics to the learner, she is in agreement with researchers such as De Lange (1996) that some real world connections develop students’ understanding of mathematical concepts.

While pre-service teachers were provided with specific questions to follow, they were given scope and encouraged to provide their own examples and vary their teaching strategies throughout the lesson. 5 out of the 29 pre-service teachers used *real-life examples* more than once in the lesson, while 7 out of the 29 made one attempt to put some concepts in context, and the remaining 17 used no real-life contexts. Boaler (1994) explains that teaching in context motivates students and builds their confidence and interest in mathematics so long as a realistic view of mathematics is given which makes sense both in the classroom and in the real world. There was some varied use of *demonstrations and analogies* but at times these were incorporated in the lesson to little effect e.g. one teacher used the interactive software package ‘GeoGebra’ to introduce the meaning of differentiation but she struggled to explain what was happening on the diagram. The importance of foundation knowledge is again to the fore here.

Connection

The main finding to emerge from this category in terms of *making connections between concepts or procedures* was that many of the pre-service teachers lacked the knowledge to do just that. In a number of lessons, in particular the statistics lessons, no link was made between the answer obtained and the actual concept involved. Ball, Lubienski & Mewborn (2001, p. 433) report on a lack of understanding of the mathematical knowledge necessary to teach well.

*Sequencing of subject matter* is another sub code within this category but as students were provided with tutorial sheets prior to the lesson the code was less relevant to this study. It was interesting to note however, that only four of the 29 pre-service teachers re-ordered the sequence of exercises or topics according to what they felt would most benefit the students’ learning. There were eight incidents observed where the pre-
service teachers *anticipated difficulties* their students may have with a particular concept.

**Contingency**

The final category in the KQ is contingency which is determined by the pre-service teachers’ *ability to think on his or her feet, respond to the students and deviate from the lesson* where he or she feels it would be beneficial for one or all learners. These three codes are discussed together since they are very much interlinked. The main findings emerging from this category were that most pre-service teachers (21 out of the 29) appeared to lack the content knowledge necessary to interpret students’ questions and misconceptions and to confidently deviate from the lesson plan to explain such misconceptions. For example, in a lesson on integration a number of students were confused when the pre-service teacher removed the integral sign when he had not in fact integrated yet. The pre-service teacher was unaware and struggled to correct his error. The importance of subject content knowledge has been reported many times throughout this paper.

There was however, some evidence of good *responses and ability to deviate from lesson plan* where appropriate and beneficial for students (6 out of the 29).

**Pre-service teachers’ critical observation and reflection on their own teaching**

**Foundation**

There was a mix of awareness among the pre-service teachers when reflecting on their foundation knowledge. 10 of the 28 pre-service teachers recognised their strengths or weaknesses in terms of *depth of mathematical knowledge*, use of *mathematical terminology* and *reliance on procedures*. One pre-service teacher who was categorised by the authors as having poor foundation knowledge recognises this to be the case and reflected that he

“Doubts own knowledge of the content while explaining (solve $64^{\frac{2}{3}}$) to the class, thus creating confusion for the pupils”.

A further 9 pre-service teachers displayed a poor ability to critically reflect on the aspects of foundation failing to recognise a *reliance on procedures* and unaware of their poor content knowledge. One pre-service teacher stated that she had a ‘comprehensive knowledge of the topic’ although she struggled to calculate the median. This would suggest that her beliefs about her knowledge do not match her actual content knowledge. Sullivan (2008) talks about the importance of teachers understanding the relevant mathematics needed to appreciate the work that their students are expected to do. The remaining four pre-service teachers submitted vague reflection reports suggesting that perhaps their interpretation and understanding of the KQ was not as the authors would have hoped.

**Transformation**
The authors categorised 11 of the 28 pre-service teachers as demonstrating good critical reflection skills in terms of transformation of knowledge. These pre-service teachers were very much aware of the way in which the knowledge was communicated be it in an effective way or otherwise. One pre-service teacher recognises the effective transformation of Pythagoras’ Theorem through use of YouTube video while also noting that her explanation of angles of elevation was unclear. Similar findings were noted in the authors’ analysis. There was also some poor understanding of transformation (9 out of the 28 pre-service teachers). The pre-service teachers whose reports highlighted both good and poor critical awareness and reflection were categorised as mixed transformation reflections. One such pre-service teacher reflected on the many effective aspects to his lesson but also maintained that he used pair and group work to encourage peer learning. This was not evident to the authors and perhaps the pre-service teachers need more guidance in terms of how to implement group and pair work effectively.

Connection

This category was the most poorly reflected on by the pre-service teachers. 16 out of the 28 demonstrated very poor critical analysis and reflection here and it seemed they were unaware of what ‘connection’ means. Another possible reason for the poor reflection was the focus of some pre-service teachers on procedural knowledge. According to one student he had linked and made connections between the mathematical procedures because he had

“Reiterated to pupils the importance of showing all workings in case you make a mistake”.

The importance of teachers’ beliefs comes into play again here and the author is in agreement with Grootenboer’s (2008) suggestion that there is a strong case for considering the development of reform of prospective teacher’s beliefs.

Contingency

There were once again varied critical reflections for this category with 11 out of the 28 pre-service teachers demonstrating good critical awareness of where contingency was in action or where it could have been improved upon. 8 of these 11 pre-service teachers admitted that they lacked the content knowledge to deviate from their lesson plan or respond effectively to students’ questions. According to Shriki (2010), many teachers do not possess the abilities needed to foster their students’ creativity in mathematics, mostly due to lack of prior experience or proper college preparation. In the authors’ reflections, it was noted that foundation knowledge seemed to impact on the pre-service teachers’ contingency. Of the 9 pre-service teachers who reflected poorly on contingency, 6 were not aware that insufficient foundation or content knowledge hindered their ability to respond to the unexpected.
CONCLUSIONS

The above findings offer an insight into pre-service teachers’ subject and pedagogical content knowledge from the researchers’ perspective and from the pre-service teachers’ own perspective. Some findings suggest that pre-service mathematics teachers may not have sufficient subject matter knowledge to alter their teaching strategies and ultimately teach for understanding. There is an onus on mathematics teacher educators to develop pre-service teachers’ ability to move away from traditional approaches to teaching and create an awareness of the benefits of doing so. Video-based experiences are one way of doing that and this is one of the main reasons as to why the data was firstly analysed from the researchers’ perspective. It makes clear the challenge facing teacher educators to create awareness among pre-service teachers of the need to develop their subject and pedagogical content knowledge which was the focus of this study. From their own reflections and the findings reported above, it is clear that there is a mixed awareness among the pre-service teachers about the need for them to develop these essential tools for effective mathematics teaching. This offers a major challenge for teacher educators.

Video-based experiences also provide trainee teachers with the opportunity to develop critical reflection skills in terms of their own teaching which is why this study included analysis from the pre-service teachers’ perspective. Evidence from the paper highlights the further need to enhance pre-service teachers’ reflective skills and develop their awareness of how to do so effectively. The process of mathematics teachers’ reflecting on teaching situations is described by Garcia, Sanchez & Escudero (2006, p. 2) as “an important process providing information that contributes to our understanding of their professional knowledge”.

NOTES

1. There are three levels of mathematics in the Irish examination system with the highest level referred to as Higher.
2. The Leaving Certificate, commonly referred to as the Leaving Cert., is the final course in the Irish secondary school system and culminates with the Leaving Certificate Examination.

REFERENCES


