

Towards a model of professional development for mathematics teachers integrating new technology into their teaching practice

Emma Rempe-Gillen
University of Leeds

This paper focuses on the professional development journeys of mathematics teachers when integrating new technology into their teaching practice. The research is part of a year-long innovative cooperative intervention in a cross-phase and cross-school setting with transcribed interviews, teacher meetings and on-line communication used for data collection. The Interconnected Model of Professional Growth was used to analyse these journeys and one teacher's journey is illustrated here. The analysis indicates that all four teachers' development journeys exhibited similar cycles of practical experimentation and reflection that led to long-term changes in teacher practice. A model for how mathematics teachers' integrate technology into their teaching is proposed.

Keywords: technology, professional development, mathematics teacher

Introduction

This paper focuses on the process of change experienced by mathematics teachers integrating technology into their teaching practice and is part of my PhD research, which investigated the professional development of mathematics teachers in a cross-phase and cross-school collaborative setting. The collaboration centred on teachers learning a new technology for teaching and learning mathematics and this paper focuses on the process of change experienced by the teachers in terms of their use of this new technology.

Historically, research has focused on how technology facilities and supports pupils' learning with little or no attention paid to the teacher (e.g. Pierce and Ball, 2009, and Williams et al., 2000). More recently, however, the complexities of integrating technology into teaching practice has been reflected in the literature and the focus is now not only the use of technology in learning mathematics, but also the *teacher use of technology* in teaching and learning mathematics (e.g. Lagrange and Erdogan, 2009). In addition, journals such as The International Journal for Technology in Mathematics Education (IJTME) and Educational Studies in Mathematics now regularly include the 'integration' aspect and reports from the teacher perspective. Of the 46 articles published in the eight IJTME issues during 1997 and 1998 only one incorporated a focus on the role of the teacher, compared to eleven of the 24 articles in the five issues from March 2008 to March 2009. This paper attempts to enrich the field of research into mathematics teacher use of technology by suggesting a model for teacher development when integrating technology into teaching practice.

Methodology

The wider research project was a longitudinal multiple case study of two pairs of teachers, where each teacher pair consisted of one primary school key stage 2 teacher and one secondary school key stage 3 teacher (see Rempe-Gillen, 2012). The teachers had ownership of their own professional development, with each teaching pair choosing the technology (Bowland Maths and Geogebra), the mathematics topic and the groups of pupils to focus on. Data was gathered in semi-structured interviews, teacher meetings and online communications, which were audio-recorded, transcribed and shared with the teachers. Data collection also included field notes and documents, and lessons were recorded for peer- and self-observation.

The area of research for the wider project, cross-phase and cross-school collaboration of mathematics teachers, is identified as an area for further research (NCETM, 2009) so a grounded approach was employed. This involved repeated readings of field notes, interview transcripts and meeting transcripts, with cycles of coding the data leading to emergent themes and teacher journeys of development. For each of the four teachers a journey of development was produced, which was a chronological list of activities and decisions that the teacher made during the project. The four journeys were then analysed using models of professional development. The next section summarises the teachers' journeys and these are then analysed using four models of development.

Results - the teachers' journeys of professional development

A summary of Kimberley's and Kirsten's journeys of development

The key stage 3 teacher, Kimberley, developed in relation to her learning Geogebra, from having only seen it some years previously, during her PGCE course, to confidently using it in her lessons.

Kimberley had been introduced to Geogebra during her PGCE course but she had never used it in her lessons. The training session on Geogebra, and discussions with the key stage 2 teacher, Kirsten, on topics that it could be used for, led her to decide to use it with her year 11 pupils. She did not feel the year 11 pupils were positive about Geogebra and they would have been more positive if they had been able to use Geogebra as well. This led her to consider that Geogebra was better used as a whole class pupil activity rather than a demonstration tool. However, she was unable to book an ICT room and, realising she would not be able to use Geogebra in an ICT room in future, she changed her goal, focusing on using it as a demonstration tool because she would have more opportunity to use it as a demonstration tool in the future. She used the internet to search for more information on Geogebra and how she might use it in her lessons. Kimberley then taught a lesson using Geogebra as a demonstration tool and after the lesson she reflected on her use of Geogebra. One example of her self-evaluation was that she considered Geogebra helpful in making certain tasks more efficient, e.g. drawing straight lines. She also considered how she could manipulate objects on the interactive whiteboard.

Kirsten's knowledge of Geogebra came from the training session, her discussions with Kimberley and her internet searches. These also informed how she would use Geogebra in her lessons. She then taught her lessons using Geogebra and then she considered how her pupils had used Geogebra, she considered their enjoyment in using it and their ability to complete the tasks she had designed. She compared Geogebra to other software that she used in lessons and her reflections on

these aspects of the use of Geogebra informed her decision of whether she would use it again. She also reflected on her own performance, how she manipulated the objects on screen and the ease of using Geogebra compared to other software that she knew about.

A summary of Wendy's and Winona's journeys of development

Each of the Bowland Maths Case Studies provides lesson plans and resources that teachers can use in their lessons. Winona, the key stage 3 teacher, chose the *Alien Invasion* case study and planned to rewrite the lesson plans herself but she did not have time to do so, and so used the provided plans with her year 8 pupils. After the lessons she considered the behaviour of her pupils and said she preferred lessons where pupils moved around the classroom more. Because she saw this as an important feature of her lessons she considered discontinuing the use of Bowland Maths. Winona considered pupil feedback also important, and at the end of the final lesson in the project she asked pupils for feedback on their learning and their enjoyment of the lessons. Pupil feedback was positive and she found that the resources motivated pupils. Speaking to me immediately after the lesson and then with Wendy, the key stage 2 teacher, Winona reflected on the lessons and considered how she might alter her own practice in future. Her consideration included what she had written on the board and if any resources could be removed from the series of lessons. From her reflections on the lessons, together with Wendy's comments on the lessons, Winona re-assessed her view of the important outcomes of the lesson and adapted parts of the lessons, removing some sections where she had used technology, for when she taught the same lessons again to a group of primary school pupils. At the end of the eight lessons Winona decided to share the resources with a colleague and she planned to use Bowland Maths with other primary schools.

For Wendy, participation in the project and her observation of Winona's year 8 lessons showed her how Bowland Maths could be a useful learning activity for her primary school pupils. Wendy chose not to teach the primary school pupils' lessons but she was involved in the planning of them with Winona. In the end, Wendy taught the final primary school pupil lesson because Winona was absent. Wendy's lesson preparation involved working through the resources herself, from her pupils' perspective, and she too garnered feedback from her pupils. The feedback focused on the pupils' enjoyment and learning and this informed her value of the resource and her confidence in using it. Although initially reluctant to teach with the Bowland Maths resources at the start of the project, after the project ended Wendy did use Bowland Maths again with primary school pupils.

Modelling the Process of Development

Understanding what constitutes professional development and what exactly is being developed can lead us to models of professional development. Day (1999), in giving his definition of professional development lists "knowledge, skills and emotional intelligence" (p. 4), Evans' (2011) model of professional development categorises attitudinal, behavioural and intellectual change and, in mathematics teacher use of technology. Monaghan (2004) highlights how research focuses on 'beliefs' and 'knowledge'. He notes the lack of focus on what he terms the 'whole experience', which suggests that for a mathematics teacher to develop from one who does not use technology in the teaching and learning of mathematics to one who does use technology we should consider both the internal - un-observable - changes (such as

beliefs, attitude and emotion) and external - observable - changes (e.g. behavioural and skills). In this research I used Evans' categories of intellectual, attitudinal and behavioural change.

A number of models for professional development exist in the literature and four models were applied to the teachers in the study, in conjunction with Evans' three categories to describe the changes that occurred in the process of development. Each model demonstrated a possible sequence of developmental change that may have been expected to occur but none of the models were able to model the process of all four teachers.

Model 1

One example of a possible sequence is intellectual change after learning how to use the new software, leading to attitudinal change motivating the teacher to use the technology in her classroom (behavioural change). This order of change is in line with an implicit model of teacher change following an in-service development activity, illustrated in figure 1:

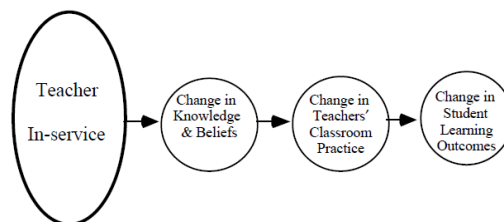


Figure 1: An implicit model of purpose of teacher professional development (Clarke and Hollingsworth, 2002: 949)

Here in-service CPD activities lead to change in teachers' knowledge and beliefs. This in turn leads to teachers changing their classroom practice that results in a change in student outcomes. An example of this model occurred in the case of Kirsten: she learned how to use Geogebra in the training session and then she designed a task for her pupils, evaluating the lesson by considering her pupils' learning and feedback. However, this model does not demonstrate the change process experienced by Winona, since her knowledge and beliefs changed after changes to her classroom practice.

Model 2

Another example of a possible sequence is an intellectual change after learning how to use the new software, leading to the teacher using the technology in their classroom (behavioural change) and an attitudinal change when the teacher evaluates the lesson. This order of change is in line with Guskey's model of teacher change, illustrated in figure 2:

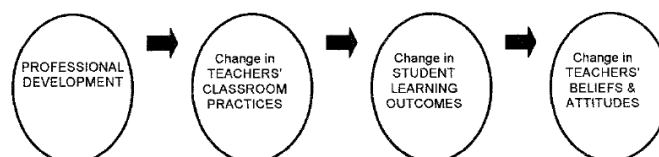


Figure 2: A model of teacher change (Guskey, 2002: 383)

Here CPD activities lead to change in teachers' classroom practices that in turn lead to changes in student outcomes, which influence teachers' beliefs and attitudes. Winona exemplified this model of change; she used the prepared Bowland Maths lesson plans

and evaluated the lessons by considering her pupils' learning and feedback, which influenced her continued use of Bowland Maths.

Despite these two models being evident in the case of two of the teachers, neither model incorporates consideration of a sequence of professional growth that does not include behavioural change. An example of this would be if the teacher considered the software inappropriate to use. In this case, there may still be intellectual and attitudinal change but no behavioural change. Kimberley exemplifies a teacher in this position because she wanted to design Geogebra activities where her pupils used Geogebra (intellectual and attitudinal change), but, since she was unable to access an ICT room, her behaviour did not change.

Model 3

A third potential model of teacher change is exemplified by the teacher having already identified a deficiency in her teaching, participating in the project as a means to improve her teaching. This would correlate with a deficit model of teacher development where the first stage involves identifying an aspect of the teacher's practice for improvement. This model of teacher change would be in line with Bell and Gilbert's (1996) model, where development occurs in three domains: social, professional and personal, with each of these having three stages. There is evidence that some of these stages occurred for some of the teachers, such as dealing with constraints (Kimberley encountered difficulty with access to ICT), empowerment (Wendy's use of Bowland Maths) and development of classroom practice (Winona's continued use of Bowland Maths). However, there is no evidence to suggest that the teachers participated in the research because they felt an aspect of their teaching was a problem (personal development 1), nor did they see working in isolation as a problem (social development 1).

Although elements of each of these models are evident in the development of the four teachers, none of the sequences reflects the development of all four teachers. If we consider only the elements of the models, without the constraint of a causal linear process, then we can begin to see a model that would allow for multiple pathways between elements, modelling the development of all four teachers. Moreover, it is evident that the teachers' development could involve change in some elements on more than one occasion. One example of this cyclic nature of development is Winona. Her initial use of Bowland Maths, based on her pupils' lack of movement around the classroom, led to her negative attitude towards Bowland Maths; however, feedback from her students led to a change in her knowledge. This then led to change in her classroom practice since she decided to use Bowland Maths again. Consideration for the cyclic nature of development is the basis of Clarke and Hollingsworth's (2002) Interconnected Model of Teacher Professional Growth, and this was the fourth model utilised to analyse the teachers' development.

Model 4

The Interconnected Model of Teacher Professional Growth (IMPG) (Clarke and Hollingsworth, 2002) is an analytic tool for the change process. Developed from empirical research, it is used in the development and design of courses (e.g. Coenders et al., 2010) and the analysis of professional development of science teachers (e.g. Justi and Van Driel, 2006) and mathematics teachers (e.g. Witterholt et al., 2012). The model situates professional change in one of four domains within a change environment: an external domain (sources of information or stimulus), a personal domain (teacher knowledge, beliefs and attitude), a domain of practice (professional

experimentation), and a domain of consequence (salient outcomes). Clarke and Hollingsworth acknowledge that these domains are “analogous (but not identical)” (p. 950) to those of Guskey’s model, however, where Guskey’s model is a linear path through the domains in a set order, Clarke and Hollingsworth’s model encompasses the complexity of the change process. Changes are mediated through en-action and reflection, where en-action is “the putting into action of a new idea or a new belief or a newly encountered practice” and they cite Dewey (1910) in their use of reflection as “active, persistent and careful consideration” (Clarke and Hollingsworth, 2002: 953-954).

Clarke and Hollingsworth consider salient outcomes as individual to the teacher and this was evident with these four teachers since they found different aspects of their lessons important. For example, Winona preferred her pupils to be out of their chairs and moving around the classroom during lessons so she considered not using the same lesson again with another group of pupils. However, her paired teacher, Wendy, after observing the same lessons, was very positive and eager to teach the same lesson to another group of pupils. The two teachers had different views of the lesson because they each had different views on the important aspects of a lesson.

In contrast to the previous three models, the IMPG was employed to model all four teachers’ development. For conciseness I restate only Kimberley’s journey to illustrate the model (in figure 3) and I refer to Rempe-Gillen (2012) for further analysis of the other three teachers’ journeys utilising the IMPG.

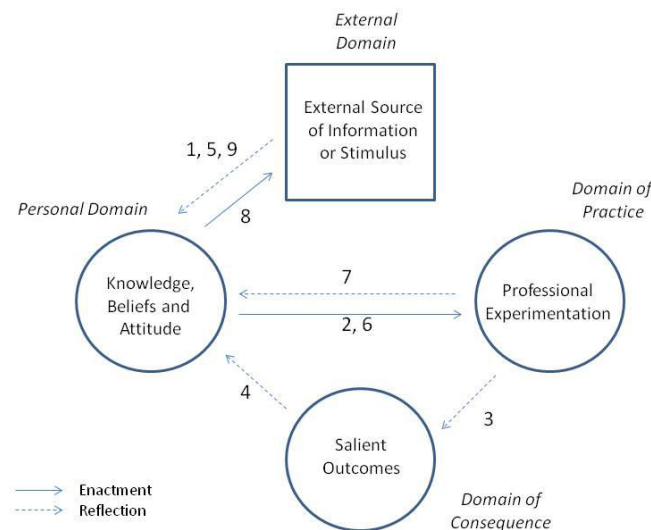


Figure 3: Kimberley’s professional growth

Kimberley had been introduced to Geogebra during her PGCE course but she had never used it in her lessons (Arrow 1). The training session on Geogebra, and discussions with Kirsten on topics that it could be used for, led her to decide to use it with her year 11 pupils (Arrow 2). She did not feel the year 11 pupils were positive about Geogebra and they would have been more positive if they had been able to use Geogebra as well (Arrow 3). This led her to consider that Geogebra was better used as a whole class pupil activity rather than a demonstration tool (Arrow 4). However, she was unable to book an ICT room and, realising she would not be able to use Geogebra in an ICT room in future, she changed her goal, focusing on using it as a

demonstration tool because she would have more opportunity to use it as a demonstration tool in the future (Arrow 5). She used the internet to search for more information on Geogebra and how she might use it in her lessons (Arrows 8 and 9). Kimberley then taught a lesson using Geogebra as a demonstration tool (Arrow 6) and after the lesson she reflected on her use of Geogebra. One example of her self-evaluation was that she considered Geogebra helpful in making certain tasks more efficient, e.g. drawing straight lines. She also considered how she could manipulate objects on the interactive whiteboard screen (Arrow 7).

Discussion

The first two models of professional development were able to model two, but not all four, teachers' journeys: the first model was suitable for Kirsten's journey, but not Winona's journey; and the second model was suitable for Winona's journey, but not Kimberley's journey. The third model was not suitable for any of the four teachers' journeys. Given that these three models were not able to model all four teachers' professional development, it would be reasonable to assume that the teachers' processes of development were very different. However, the IMPG was utilised to model all four teachers' journeys. Furthermore, there are clear similarities and common features between the four teachers' journeys when viewed through the IMPG.

The first common feature is that the external domain was the stimulus for development. Kimberley, Kirsten and Wendy reflected on the new technology in some way before putting it into practice (reflection from the external to personal domains). The fourth teacher, Winona, due to lack of time, used the provided lesson plans (enactment from the external to practice domains) but she viewed the lessons negatively. When she taught the lessons again, she made changes to the provided lesson plans, which resulted in her positive view of the lessons and her continued use of the software.

A second common feature for all teachers was the value they placed on pupil feedback (reflection from the domain of practice to salient outcomes). Their salient outcomes were pupil-orientated and impacted on the teachers' views of the new technology (reflection from the salient outcomes to personal domain).

A third commonality was the two-way connection between the teachers' lessons and their knowledge, beliefs and attitude (reflection and enactment between the personal and practice domains). Only Kirsten did not have a direct reflection from the domain of practice to personal domain, but she reflected on the salient outcomes of her experimentation.

Conclusion

Although there are only four teachers in this research their experiences were diverse enough to show that some models of professional development are not suitable to model the integration of technology into a teacher's practice. The IMPG was the only model suitable for all four teachers and, moreover, when using this model there were commonalities in the sequence of events for the four teachers. The research suggests that there are specific components of change and a specific order in which these occur when a teacher integrates technology into her/his teaching of mathematics. Further examination and analysis of the relationships between these elements are needed in order to advance our understanding of technology integration.

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