TEACHING SECONDARY MATHEMATICS WITH AN ONLINE LEARNING SYSTEM: THREE TEACHERS' EXPERIENCES

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We studied how three secondary mathematics teachers who had no prior experience teaching with technology used an online mathematics learning system. The teachers received minimal instruction on how to use the system before we observed them over four school terms as they taught with it. We used the Pedagogical Technology Knowledge framework (Thomas & Hong, 2005) to document changes in the teachers' practice. Results show teachers advanced toward using the technology in more sophisticated ways but the improvements were not uniform. We suggest some reasons to explain the variation.

Introduction

Teachers can learn to make more effective classroom use of technology through participation in professional development and training (Bennett & Lockyer, 1999; Bennison & Goos, 2010; Lawless & Pellegrino, 2007). To be effective, professional development should be intensive (Darling-Hammond, 1998), sustained over time (Guskey, 2003), and do more than enhance teachers' technical skills (Watson, 2001). However, creating sustainable, on-going professional development programs which operate effectively across a number of schools can be a challenge (Goos, Dole, & Makar, 2007). As a result, professional development activities are often short-term and sporadic, with an emphasis on learning to operate the technology at the expense of providing guidance on how technology can be used to improve learning and teaching (Fitzallen, 2005).

We report on an investigation into whether the inbuilt structure of an online mathematics learning system can assist teachers who are inexperienced users of ICT develop their ability to teach mathematics with technology in new and different ways that constructively engage students in their learning. Online systems typically incorporate several of the following student learning activities:

- Lesson notes (text material) linked to a particular curriculum;
- Worksheets (activities such as puzzles and games linked to each lesson);
- Lesson Questions (multiple choice and short answer questions, usually graded for different ability levels);
- Timed drill and practice questions (sometimes called a Basic Scorcher);

- Lesson Scorchers (like the Basic Scorcher, but with questions focused on specific lesson topics);
- Walkthroughs (similar to school textbook examples that students complete online while receiving step-by-step explanations and feedback); and
- Widgets (interactive animations linked to a particular topic).

Students can access these features for individual practice and exploration at the computer, or teachers can display them via a data projector for whole class demonstrations and investigations. We based our research on Cambridge HOTmaths (http://www.hotmaths.com.au), an online system incorporating all the activities listed above as well as a student messaging and reporting facility. Our research seeks answers to the following questions:

- What happens in a classroom situation where the online mathematics learning system is implemented with minimal professional development by teachers who have limited experience with technology?
- Do teachers become more confident users of the technology?
- Do teachers shift towards more student-centred teaching approaches?

The research is significant because it shows how teachers who lack technology experience and training begin to use technology in the classroom.

Theoretical framework

Goos, Galbraith, Renshaw and Geiger (2000) conducted a three-year longitudinal study in five secondary mathematics classrooms to investigate the role of graphics calculators in assisting students to conduct mathematical investigations and promote discussion. Goos et al. suggest four roles to describe interactions between the teacher and the graphics calculator: *technology as master*, where teachers' limited knowledge of how to operate the technology means they are subordinate to the technology; *technology as servant*, where technology supports the teacher's preferred pedagogy; *technology as partner*, where familiarity with the class and the technology allow teachers to use the technology more creatively in ways that encourage collaboration in the classroom; and *technology as extension of self*, which features the most powerful, creative and sophisticated uses of technology.

Thomas and Hong (2005) developed the construct of *Pedagogical Technology Knowledge* (PTK) or "knowing how to teach mathematics with the technology" (p. 258). PTK encompasses teachers' recognition of the role of technology in learning and teaching and includes how teachers decide to use technology to assist students learn mathematical concepts and processes. PTK also includes techniques and approaches used to teach mathematics in qualitatively different ways through technology. Teachers who have an advanced PTK will therefore be most likely build on the affordances provided by technology to transform learning and teaching in ways that are not possible without technology (Garofalo, Drier, Harper, Timmerman, & Shockey, 2000).

Method

Data described in this paper are drawn from a larger study of 14 secondary mathematics teachers at 3 schools as they used the online learning system with Years 7 and 8. We deliberately chose schools where the levels of technology use in mathematics lessons prior to the commencement of the study were low.

An experienced teacher from the company that developed the selected learning system presented a half-day professional development session for the teachers at the start of the project. The presenter showed some of the main features of the system and how to navigate around them. She also demonstrated three Widgets, but there was little discussion about how to use them in the classroom.

We studied classroom use of the system in five Year 7 classes. For four weeks at the end of Term 2, two weeks in the middle of Term 3, and four weeks at the start of Term 4. In the following year, we followed three of the Year 7 classes into Year 8 and observed lessons for four weeks at the start of Term 2. Throughout the project, a research assistant [RA] visited each classroom to observe between one and three mathematics lessons per week. We developed a schedule to record teacher and student actions during lessons, and the RA made detailed field notes in an observation log. Following most observed lessons, the RA interviewed the teacher. The teacher interviews were designed to gather data about each teacher's thoughts on how they had used the system rather than mentor them or influence their practice. All interviews were audio-recorded and transcribed for analysis.

At the end of the observation period, the RA submitted her classroom observation notes and teacher interviews for all 14 teachers to the authors. We compiled a profile for each teacher to outline changes in their classroom practices and made an initial comparison between them. We then selected three teachers at Hope Springs who best illustrated the range of variation. We examined their profiles in more detail, re-visiting the original notes and recordings to ensure that our descriptions were accurate and selecting excerpts that best exemplified their behaviour at different times. These profiles allowed us to identify up to three broad stages in the development of teachers' PTK. We also noted some similarities to the technology roles theorised by Goos et al. (2000). Finally, we sought possible explanations for the changes we had documented and formulated some implications for professional development.

Results

Teacher HA

Teacher HA had taught mathematics for over 25 years, including the last seven years at Hope Springs. HA's teaching emphasised student note-taking from the textbook and he was insistent that students kept a neat exercise book. Prior to the study, HA had briefly used the system at home with his own children, but he had not previously used computers for teaching.

HA initially used the system in the computer laboratory where he permitted students to work on anything related to the mathematics topic they were learning. This pattern continued well into the fourth term. Observations of HA demonstrated his lack of awareness about how to support student learning with technology. For example, he did not show students the different levels available in the Lesson Questions or demonstrate how to navigate the system. He continued to use the system exclusively in the computer laboratory, with students working on their own at activities of their own choosing, even when this approach was unproductive.

In an interview near the end of Term 4, HA mentioned using the system in the normal classroom by projecting activities onto the whiteboard so students could work together on a task he chose for them. At the start of Year 8, HA began to teach with the

system in the classroom by having students answer Scorcher questions. He displayed the questions one at a time on the whiteboard but sat with his back to the class while operating his laptop. He allowed students to shout out their answers without providing their reasoning. There was much noise as students competed for scores which made it difficult to hear their responses.

HA later commented that the wide range of ability levels in his classes made it difficult for him to keep all students working together when using the system for whole-class discussion, especially because students who could not keep pace with the lesson were prone to become disruptive. He concluded that he would revert to computer laboratory lessons "where they can work on their own at their own pace and those who are off task do not disrupt others or interfere with their learning."

Teacher HB

Teacher HB had a postgraduate research qualification and was the most proficient and confident user of technology. She had been teaching for 12 years, including seven years at Hope Springs. She had explored the system at home and had prepared a lesson with it, although technical problems with the school computers prevented her from giving the lesson as planned.

Observations of her initial use of the system showed a more varied approach than the other teachers in the study. HB used many of the system features in her lessons, although she continued to adopt a very teacher-centred approach. When teaching Year 7 in the computer laboratory, she soon realised that students needed her support to maximise their learning with the system. She spoke in an interview at the end of Term 2 about how students would often go straight to the Lesson Questions without first reading through the accompanying lesson notes and this meant that they could not answer the questions. So HB spent time teaching the concepts before the students were allowed to attempt the related system topic on the computers.

HB was the first to teach with the system away from the computer laboratory. In Term 3, she gave a lesson to Year 7 about surface area using the interactive whiteboard. Her lesson was based on a Widget called "Observing surface areas", which she used in quite a sophisticated manner by combining it with her own explanations to highlight various aspects of the solids she displayed. But she explained everything to the students and her explanations were given too quickly so it was clear that students found them difficult to follow. The RA noted that most students were not paying attention and the activity was not very successful in helping them learn about surface areas.

HB took up a teaching position at another school at the end of the first year of the study and so did not take part in the second phase of the project.

Teacher HC

Teacher HC had first trained as a primary school teacher and had taught for 30 years before moving to Hope Springs and had been at the school for eight years. HC had a good rapport with students and was an excellent classroom manager. She had previously used computers to prepare worksheets and tests for her classes, but had not used technology in the classroom. Based on lesson observations, the RA characterised HC's style as teacher-centred and traditional.

HC's initial use of the system also involved classes in the computer laboratory. But, unlike HA and HB, she prescribed activities for students to complete: Widgets, then the

Walkthrough, the Lesson Questions, and finally the Scorcher. HC said she liked to start with the Widgets because students found them engaging, but it was observed that students often had difficulty identifying what the Widgets were about if they had not been given any prior instruction. Significantly, HC quickly realised the difficulties some students encountered. After just two weeks she started to split the lesson time between the classroom (where she introduced a mathematical concept) and the computer laboratory (where the students used the system to consolidate it).

Her split-lesson method was proving successful and HC saw "some definite advantages in integrating the system with the normal classroom lessons." But she commented in Term 4 that it was difficult to monitor student behaviour in the computer laboratory and students would visit other websites unless closely supervised. By the following year, HC no longer took her classes to the laboratory and used the system exclusively in the classroom. A Year 8 lesson on fractions demonstrated her more sophisticated approach. She began with an assortment of her own revision questions written on the board. While students attempted these, she set up the data projector. The system was then used to teach fractions, beginning with a Widget on "Representing fractions". The lesson notes were read aloud by a student but HC interrupted three times to give a further example or explanation on the whiteboard. She also circled or underlined parts of the text to emphasise key ideas. Students then copied HC's own definitions of the different types of fractions into their exercise books.

Discussion

Our research allowed us insight into how teachers' PTK develops. We identified three sequential stages to describe the changing roles we observed. We call these roles technology bystander, technology adopter, and technology adaptor. We also conjecture a fourth role of technology innovator. As teachers move from one stage to the next, their technology use becomes increasingly more varied and sophisticated. Our four stages resemble the metaphors of technology as master, servant, partner, and extension of self, proposed by Goos et al. (2000). But whereas Goos's terms refer to the roles of technology, we focus on teachers' roles as they use technology to support student learning.

Technology bystanders

All three teachers began teaching with the system in the computer laboratory where students worked individually at their own pace; HA and HB allowed students to work on any aspect of the system they wished, while HC mandated specific tasks for students to complete. Observations in the first weeks of the project showed that teacher-student interactions were minimal, focussing mainly on managing student behaviour or sorting out students' difficulties in operating the system. There was little actual teaching and the teachers' PTK did not advance beyond developing an initial familiarisation with the features of the system.

We describe the teachers' role in these early lessons as *technology bystanders*, because they essentially allowed students to work on their own. We see the initial computer laboratory lessons as an essential first step in developing the teachers' confidence in their ability to use the system. These lessons allowed teachers to become familiar with the system's features and to learn how to navigate around them. They also

provided opportunities for learning how to deal with relatively prosaic issues such as assisting students who had forgotten their passwords or could not login to the system.

Technology adopters

All three teachers eventually began to deploy the system in conjunction with their usual teaching practices, so that the technology was essentially used to support already established pedagogies. However, the success of the teachers' classroom use of the system was heavily dependent on their general pedagogical skills. HA was the last to begin employing the system away from the computer laboratory and the least successful in doing so. His PTK showed negligible development throughout the project and was characterised by an emphasis on trying to keep students busy regardless of how much they were learning. HB's PTK began to shift from an exclusive focus on helping students operate the system efficiently to a point where she began considering how the system could be used to help student learning. HC supplemented the system activities with her own examples and explanations, reasoning that this would be easier to achieve in the classroom where she could establish a stronger presence at the front of the room.

HB and HC changed their use of the online learning system much more than HA. Not only did they both modify their use of the system in the computer lab, but they also grafted the system onto their preferred classroom teaching method with the intention of making it more effective. Because these two teachers took the system fully into their repertoire of teaching actions, without making significant changes to those actions, we describe them at this stage of their PTK development as *technology adopters*. By contrast, HA essentially remained a technology bystander.

Technology adaptors

HC was the only one of the three teachers who progressed beyond the technology adopter stage. HC's lessons increased in variety and creativity as she became more practised in setting up and using the data projector. Her more sophisticated practice in the second year of the study reflects the early stages of what we call a *technology adaptor* role characterised by a more student-centred approach that teaches *through* rather than *with* technology to promote students' mathematical sense-making and reasoning. HC gradually learned how to integrate the system more successfully into her teaching, as evidenced by the increased number of transitions between the online system and other activities during her lessons. HC's interview comments about how well her students responded to visual images such as Widgets show that she had changed her focus from teaching with the system to consider how the system could assist student learning. Her PTK advanced from an emphasis on the technology to one where using the system to help students learn new mathematical concepts was more prominent in her thinking. The system was becoming an integral part of her teaching rather than an add-on to the lesson.

Technology innovators

A learning system can be used in more creative ways than any we observed in this study. For example, there are many opportunities for setting individual or group work. Students can follow ideas discussed in class to varying levels of complexity, depending on their interests and ability. They can even be set to explore concepts informally before they are discussed in class. We conjecture that some technology adaptors will

eventually recognise the affordances of the system and promote a greater focus on problem solving and student-centered learning. We call this role, in which teachers use technology to encourage and support students' mathematical development in novel ways to promote student-generated knowledge, inquiry and reflection, a *technology innovator*.

Implications and conclusions

Our results show that teachers can learn to use an online mathematics learning system to advantage, even after minimal professional development. We conjecture that this may be due to the structure of the system, which appeared to scaffold teachers' technology learning and support their PTK development. The changes we observed in teachers' roles—from bystanders who were subservient to the technology to taking ever greater control over how students used it—were more *evolutionary* than *revolutionary*. This allowed the teachers to gradually build up their confidence in using technology in their lessons.

Our research indicates the kinds of knowledge required by teachers who wish to use online learning systems (and other digital technologies) as tools for learning and teaching. Teachers require a basic familiarity with the structure of the learning system and its various features so they can find activities suitable for different stages in a lesson. Training in these aspects need only be minimal because once teachers become acquainted with the basic operation of the system, the most effective way for them to learn about it is to begin using it themselves.

A far more important role for professional development activities is to assist teachers develop their pedagogical skills in using the system—their PTK. Our results show that online learning systems have the potential to change the dynamics of the teacher-student relationship in the classroom and make learning more student-centred—but only if teachers learn how to use the system in ways that involve students more actively in lessons. But not even a discussion of the potential uses of an online learning system in the mathematics classroom is likely to cause teachers to use it in the most effective way possible. Professional development activities that attempt to demonstrate how technology can transform traditional classroom roles may not be successful unless teachers are already familiar with the particular tool and confident that they can operate it efficiently in the classroom. Instead, training is likely to be most effective after teachers have had time to progress from technology bystanders to technology adopters, since only then will they be in a position to become technology adaptors and innovators.

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References

Bennett, S., & Lockyer, L. (1999). *The impact of digital technologies on teaching and learning in K–12 education: A research and literature review.* Melbourne: Curriculum Corporation.

Bennison, A., & Goos, M. (2010). Learning to teach mathematics with technology: A survey of professional development needs, experiences and impacts. *Mathematics Education Research Journal, 22*(1), 31–56.

Darling-Hammond, L. (1998). Teacher learning that supports student learning. *Educational Leadership, 55*(5), 6–11.

Fitzallen, N. (2005). Integrating ICT into professional practice: A case study of four mathematics teachers. In P. Clarkson, D. Gronn, M. Horne, A. McDonough, R. Pierce, & A. Roche (Eds.) *Building connections: Research, theory and practice. Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australasia* (pp. 353–360). Sydney: MERGA.

Garofalo, J., Drier, H., Harper, S., Timmerman, M.A., & Shockey, T. (2000). Promoting appropriate uses of technology in mathematics teacher preparation. *Contemporary Issues in Technology and Teacher Education, 1*(1), 66–88.

Goos, M., Dole, S., & Makar, K. (2007). Designing professional development to support teachers' learning in complex environments. *Mathematics Teacher Education and Development, 8,* 23–47.

Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2000). Reshaping teacher and student roles in technology-enriched classrooms. *Mathematics Education Research Journal, 12,* 303–320.

Guskey, T. R. (2003). What makes professional development effective? *Phi Delta Kappan*, *84*, 748–750.

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research, 77,* 575–614.

Thomas, M. O. J., & Hong, Y. Y. (2005). Teacher factors in integration of graphics calculators into mathematics learning. In H. L. Chick & J. L. Vincent (Eds.), *Proceedings of the 29th annual conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 257–264). Melbourne: University of Melbourne.

Watson, G. (2001). Models of information technology teacher professional development that engage with teachers' hearts and minds. *Journal of Information Technology for Teacher Education, 10,* 179–190.