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CHAPTER 8

Role of mobile digital technology in fostering the construction of pedagogical and content knowledge of mathematics

Mohan Chinnappan

Abstract:
The need for practicing teachers to reflect and build on their knowledge of mathematics for effective practice, and ongoing professional development is well recognised by the educational community. In this chapter I examine two dimensions of this knowledge (content and pedagogical content knowledge) as reported by two teachers who are new to the profession. The knowledge dimensions were examined by using a mobile technology tool (smartphone) to reflect on the design and teaching of fractions. Results indicate that the participants were competent users of smartphones and displayed a wide repertoire of the knowledge that was relevant for teaching of fractions in the primary curriculum. The smartphone appears to be a useful device for mediating teachers’ content and pedagogical content knowledge.

Context
The quality of teaching and the education of mathematics teachers are emerging as crucial elements vis-a-vis the global demand for numerate citizens and scientific talent. In this regard, the professional development of mathematics teachers has become a focal point of discussion for mathematical reforms in many countries including Australia (Council of Australian Governments, 2008). That teacher quality plays a key role in the mathematical learning outcomes of our students is a recurring theme in current debates. The multidimensional facet of teacher quality has spawned different models and characterisations. However, one dimension that continues to drive the deliberations on teacher quality is the state of knowledge that teachers bring to the teaching-learning interface, and how this knowledge influences students’ cognition and participation in mathematics (Sowder, 2007).

In light of the above developments, the need for practicing teachers to continue reflecting and updating their knowledge and skills has become a core issue for research on teacher expertise. One stream of such research has begun to examine the growth and trajectory of teachers’ knowledge within the framework of teachers as communities of learners and practice. This research focus underlines the need to examine teacher knowledge and the profound impact this knowledge could have on the quality of practice.

In his seminal work, Shulman (1986) argued that teachers needed to build a solid subject matter knowledge base or content knowledge (CK) and transform this knowledge into forms that would help them address learning needs of children. This latter knowledge was referred to as pedagogical content knowledge (PCK). The development and accessing of this knowledge, and its role in teachers’ actions in situ continues to interest researchers (Ball, 2000).
There are many contexts in which teachers could reflect on and construct new understandings of these two principal components of knowledge, and one would expect different learning environments will constrain the development of this knowledge differently (Shulman & Shulman, 2004). The advent of information technology provides a powerful learning environment for teachers to experiment with, reflect on and share their knowledge as practitioners. However, for this to happen, teachers must assess and revise their own knowledge and understand students’ cognition underlying the learning of mathematics. Thomas and Chinnappan (2008) developed the notion of *epistemic mediation* in order to recast the role of technology as effective tools of pedagogy. The implication is that researchers need to draw on technology to help teachers build, activate and expand their repertoire of knowledge for teaching.

The focus of the study reported here is the identification of pedagogical and content knowledge relevant to the teaching of mathematics in primary schools that could be activated by the use of a mobile technology specifically a smartphone. This device was assumed to facilitate co-learning among professionals by fostering teacher-to-teacher interaction better than other tools in that teachers could share their knowledge more spontaneously before, during and after practice (Olney & Lefoe, 2007).

**Theoretical framework**

The research was guided by a framework of teacher knowledge (Shulman, 1986; Ball, 2000; Chinnappan and Lawson, 2005) that consisted of the following dimensions: (1) the quality and the quantity of the mathematical content accessed and exploited by teachers both before and during teaching depends to a large extent on the organizational quality of the teachers’ repertoires of substantive mathematical knowledge and their reflective awareness of that knowledge, (2) the mathematical content accessed and exploited by teachers will be mediated by the teachers’ repertoires of pedagogical content knowledge and their dispositional orientation towards mathematics as indicated by the teachers’ perceptions and beliefs about mathematics, (3) the quantity and the quality of the knowledge about the learners is based on teachers’ observations of the learners before and during teaching and that these observations are mediated by teachers’ pedagogical content knowledge, perceptions about the learners and perceptions about their roles as teachers, (4) the quality and the quantity of the knowledge about how to teach the mathematical content accessed and exploited by teachers depends to a large extent on the organizational quality of the teachers’ repertoires of pedagogical content knowledge and their reflective awareness of that knowledge, and (5) the knowledge about how to teach the mathematical content accessed and exploited by teachers before and during teaching is also influenced by the following set of mediators: the teachers’ perceptions and beliefs about the role of a teacher and the teachers’ perceptions and beliefs about the learners.

While teachers need a knowledge base with the above dimensions, equally important is the relationship among these knowledge fragments as revealed by the quality of their connections. These
relationships can be analysed against the framework of schemas. A schema can be defined as a cluster of knowledge that helps teachers and students understand and represent a problem, and provide cues for the activation of relevant strategies. Marshall (1995) identified four primary components of schemas: feature recognition knowledge, constraint knowledge, planning knowledge and implementation knowledge. The more tightly connected these components are the easier it is for the parts to be accessed. In a similar vein, Mayer (1992) has suggested that schemas are involved in any successful problem-solving effort including teaching.

The report here investigated the educational potential of a mobile digital technology involving a smartphone. We used the device (See Figure 1) with primary teachers to facilitate interactions and reflections about K-6 mathematics concepts and the teaching of these concepts in the classroom. The aims of the research were to evaluate a) the quality of understandings that teachers developed as they discussed and shared each other’s knowledge and experience and b) the type of teaching aids that were deemed to be relevant to the teaching of a chosen mathematics topic.

The development of understandings can be examined in terms of the content, links and the structure of the knowledge schema that evolve during the course of their interactions with their peers as elucidated by framework above. These interactions and the ensuing activation of CK and PCK can be facilitated if teachers are supported in ways that would empower and encourage them to think ‘on the run’. Our framework about teacher knowledge also suggests that providing teachers with varying contexts and tools of communication to externalize their knowledge can be an effective strategy in order to generate a more complete picture about teacher knowledge.

The above line of reasoning led us to consider the following research questions:

- How do teachers respond to the use of mobile devices when they are required to share and critique a mathematics concept and appropriate pedagogies?
- What are the representations and models that teachers could construct with the aid of a smartphone?

**Methodology**

An action-research methodology was utilised that provided professional development opportunities for the participating teachers. The study was conducted over a 13-week period within a mathematics elective subject. The teachers who participated in the study were practising teachers who wanted to enhance their knowledge and skills in teaching numeracy via a postgraduate program.

Each participant was invited to explore the use of smartphones (Palm Treo 680). Treo 680 came with a large colour touch screen and an easy-type keyboard. It had a number of easy-to-use features including mobile phone, email, web browsing, multimedia, personal organiser, text messaging and document development. Participants could utilise one or more of these features in the development of innovative pedagogies for mathematics learning and teaching. Teachers could use...
the smartphone to capture images, develop videos, share ideas around a particular theme, and revise their ideas in light of peer feedback from a partner.

Following the introduction to smartphones, teachers were asked to think about using the device as a cognitive tool that could be used to design a range of mathematics learning experiences for children with diverse learning abilities and needs. Such a design expected teachers to activate not only their prior content knowledge of mathematics (CK) but also the translation of that knowledge into forms that would better relate to and engage learners (PCK). The participants were divided into collaborative pairs to initiate discussion and create digital products that could be used to support the learning of a mathematics concept. In so doing the teachers were asked to consider lesson aims, learning activities, their children’s prior experiences and learning outcomes. This phase demanded that participants select and analyse a focus mathematics concept, and the teaching of that concept. It was further suggested that they identify learning difficulties associated with the focus concept and teaching aids that could be used to help children. The report here examines the data generated by one of the above teams.

The teachers could capture and create pictures and videos, develop documents as well as record and email audio narration of each other’s views. While they could have accessed the internet for ideas, each team had to create its own product that could be used in practice and justify its appropriateness. Team members were instructed to use the smartphone for all communications particularly while they were in the school. Our view was that the mobility of the smartphones should be exploited fully to share insights especially when teachers were unable to meet face-to-face and while on the move.

Data and analyses
In order to generate data relevant to our research questions, we drew on two main sources of data: smartphone discussions and use of available digital tools. The digital tools included features such as in-built audio and video functionalities. Teachers were asked to engage in as many discussion sessions as was necessary. The average number of discussions was six with each recorded session lasting about five minutes. Students commented that they wished to conduct a number
of informal dialogues before using the device to record key events of their talk. This was allowed because it was decided that the informal talks would provide another way to help the teachers activate their CK and PCK. The recorded dialogues occurred at different locations depending on what members of each team wanted to teach. This included staff rooms in the schools, at home as well during our tutorial sessions.

The initial discussions were mainly concerned with decisions about selection of a suitable focus concept, types of learning resources and activities in which to immerse children. The teaching and learning resources formed the cognitive tools and the dialogue they engaged in about the tools provided windows into their quality of CK and PCK. The interactivity was an important element in the accessing and utilisation of schematised knowledge from long-term memory as well as evaluating the impact of smartphones.

Smartphones had inbuilt communication tools (email and mobile phone) that could be used to share audio messages and teachers showed a willingness and ease with which to utilise this technology from the day they were inducted into the project. However, we ran into problems with the use of the email and phone options as teachers had to register with the local email provider in the state of New South Wales.

As well, all participating teachers had their own mobile phones and this made the registration for a second SIM card rather difficult and teachers were reluctant to use their own SIM card with the smartphone. We circumvented this issue by allowing the teachers to use their own mobile phones for ‘on the run’ conversations but did record the main points of their discussions into Documents and Memos on the device. These documents were then emailed to each other via the university’s email system for reflection and critique. The smartphones were most effective in constructing video images of learning resources for the teaching of the focus concept.

In this report, I provide data from one team of two teachers (given the pseudonyms Sonia and Lisa).

Lisa1

Given that we will be concentrating on fractions and decimals within the number strand, I think we should concentrate on the Stage 2 and 3 outcomes. In doing so, I think we will be able to develop hands on activities, with concrete materials, such as different sorts of shapes and objects. These activities could then be followed up with written work and activities, and in working mathematically, will cement the concepts of fractions, decimals, percentages and how they are related. What do you think?

Sonia1

First of all I feel that looking at fractions and decimals within the number strand, will be something different for a change, as I feel that there is a lot of emphasis placed on the other subjects of the number strands including; whole numbers, addition and subtraction, multiplication and division, and although these are used in everyday life and students need to
know how to use these concepts, in my practical experiences not much time is spent on fractions and decimals, and I do believe that this number subject is just important.

I also think that concentrating on Stage 2 and 3 is a great idea, because I believe it is at this stage that they start to question and reason more deeply, and the basic skills test is also introduced in these stages, which unfortunately for Indigenous students they are well behind on scores.

In the above dialogue, the team identified fractions as an important area as teachers did not spend much time with this sub-strand of numbers. Sonia agreed with Lisa about the appropriate learning stage of potential students their teaching should be aimed at. In the state of New South Wales (Australia), children in Stage 2 and 3 are generally working at learning levels that can be expected in the last two years of primary school. Both teachers showed adequate knowledge of the mathematics curriculum and the importance of the topic within the Number strand. Sonia also showed another aspect of PCK that concerned the role of cultural roots of children, in this case Indigenous children of Australia.

Lisa

I am thinking this could be an early Stage 2 activity, so that by the end of Stage 2 the concept of a half and more complex percentages and fractions have been cemented, this can be done by using objects within the school, or in our case the uni, you can take pictures of basketball courts, football fields, artworks and so on. Have a look at the picture I took at uni, and tell me what you think!

Lisa captured an image of her school with the smartphone (Image 1).

Sonia

Your picture was a great example, and really would bring the students out into their environment, searching for halves, quarters etc… Because not only should we use basic shapes like a circle, but also shapes/objects used by students everyday, such as the food they eat or the toys they play with, this way they will better understand the reasoning behind
learning about fractions and decimals and be able to put it into an everyday context, which I think presents another learning difficulty in that when children are learning a new concept,

In this second interaction, Lisa reflected on the learning stage at which fractions could become a challenge to students. She identified the more complex features of these numbers and their links to other forms of fractions such as percentages. Here, one could detect the teacher’s knowledge of multiple representations of fractions and the need to teach for connectivity in mathematics. This constituted further evidence of a schema organised around solid content knowledge and PCK. Sonia was sharing pictures taken on the smartphone.

**Lisa3**

Building on the concept of a half, I think it would be beneficial to introduce the relatedness of a fraction to a decimal and to percentages. This could be done using a number line, with numbers 1 through to 100. The number line could then be folded in half, marking the 50 number. A discussion could be held then with students about the representation of 50 as \( \frac{1}{2} \), as .50 and as 50%. I think it would be beneficial if all students in a Stage 2 class had their own number line to manipulate as a concrete material. What do you think of the number line idea?

**Sonia3**

The number line is a great idea, because it gives the students a visual representation of the numbers and the concept of half, I think that we should not just stop at the number line, but also tap into concepts of multiple intelligences and use a variety of representations to suit all the students learning needs, especially our Indigenous students. Other examples we can use, are getting students to draw, cut out and paste the concept of a half, which can then be progressed to a \( \frac{1}{4} \), etc…

Lisa’s comment above suggests that she was able to identify not only interrelated mathematical concepts such as percentages and decimals, but also articulated the modelling of these concepts via a number line. While she was happy with this approach, she found it necessary to get a second opinion from her partner. Sonia was in agreement with this visual representation of fractions. Recognising the pedagogical value of number lines, Sonia suggested that they extend the number line approach to other representations and fractions.

**Lisa4**

I agree with you in that students need to have a variety of experiences to understand a concept, because no students learn the same way as other students. In continuation with manipulating concrete materials (NS2.4 and NS3.4), I think it would be good to develop activities where students had to order different materials according to size. For example, students could order shapes representing 1/2, 1/3 and 1/4. This could then be translated into percentages and decimals.

I think that this activity would be most appropriate for stage 2, with the concepts needing to be concrete before students’ progress to stage 3. I have taken a photo of this concept in
ordering different shapes, in representing a 1/2, 1/3 and 1/4, take a look at it and tell me what you think.

Sonia4

Yeh, I really liked the idea of ‘Fraction Families’, lots of shapes and lots of examples, and I definitely agree in that before students progress to stage three and the more complex fractions, percentages and decimals they need to have a concrete understanding, and I believe this would come from the constant reasoning that we should be implementing into lessons, so students are able to make that connection to everyday life, and how certain concepts should work.

I think that by using a variety of ways to show a ½ that we discussed earlier should be again implemented in using 1/3, and ¼. The only trouble and learning difficulty that presents it self is the time factor, and what I mean by this is that as a teacher we don’t always have enough time to spend on certain concepts, and so deep understanding is not always achieved.

In the above dialogue, both the teachers showed a deep appreciation of different models of fractions in the way they talked about Fraction Families. There was evidence of use of a blend of concrete and abstract approaches in the above exchange. It would seem that both teachers were aware of the need to design learning experiences to cater for children with varying learning styles. This is evidenced in their discussion about the different ways part-whole relations could manifest in fractions such as decimals and percentages. The notion of multiple intelligences from a psychology subject was weaved appropriately to buttress their case for the interpretation of different models of fractions.

Video

In addition to the discussions above, the teachers used the smartphone to shoot videos that would complement their teaching of fractions. Sonia’s video showed the concept of half in four different but related modes: half of a circle, half of a rectangle, paper folded onto to equal parts and slicing a banana into halves and quarters). Figure 2 shows a
screen shot from one of the videos. The paper folding actions and cutting of banana were shown in the full video display.

The video was used to generate further exchanges about the multidimensional nature of fractions including the value of using it to help other children conduct similar learning activities.

**Discussion**

The aim of the study was to examine how a group of practising teachers would use digital mobile technology to access, modify and share their content and pedagogical content knowledge that was deemed to be relevant to creating effective learning contexts for children. The expectation was that this tool would help teachers share their knowledge more readily and spontaneously. Data on the artefacts that were constructed and discussions held between two participating teachers suggest a number of interesting ways they had gone about using the tool resulting in the activation and further development of their CK and PCK.

Firstly, in the brief period the teachers were exposed to smartphones, a number of features were utilised including audio, video and text analyses. Both the participants saved their pictures and used them in subsequent discussions that in turn led them to develop other models for teaching fractions. There was clear evidence of the teachers’ developing competence in the use of the smartphone. It would seem that the ubiquity of mobile phones in general might have facilitated the uptake of smartphones that were used in the present study as both shared similar features in wireless communication.

Did the use of mobile technology reveal anything significant about the accessing, modification, state and development of teachers’ CK and PCK around fractions? The answer, it would seem, is yes. The
discussions held between the two teachers show that they have built up a reasonably robust body of knowledge about fractions. This was evidenced by the different concepts of fractions that surfaced both in their discussions and the variety of digital video artefacts.

One could also detect the availability of sophisticated schematised pedagogical content knowledge amongst the two teachers. This was indicated by their deliberations about which model (e.g., Number line) would be appropriate for children who have attained different conceptual maturity. The need to anchor core mathematical concepts in powerful models and use them in the rationale for effective classroom practice as displayed by the teachers here are consistent with arguments advanced by Sullivan (2005). Theories of multiple intelligences suggest that learners differ in the way they acquire, make sense of and develop new knowledge. The multi-model approach developed by Lisa and Sonia is consistent with such theories in that it has the potential to support learners with varying learning styles.

Our theoretical perspective suggests that, to be effective, mathematics teachers need to have a body of well-connected CK and PCK that they can access and modify before, during and after practice. This is an ongoing process that helps teachers to update their knowledge as they grow and interact with peers in the profession. Within the confines of one area of mathematics, there is evidence here to support the claim that the use of smartphones did help the teachers reflect critically on their own prior knowledge about fractions and the teaching of fractions. Further, the device afforded the modification and restructuring of that knowledge by supporting a high level of interactivity between the participants.

The use of mobile technology could involve teachers developing an additional body of knowledge that was described as Pedagogical Technology Knowledge (Hong and Thomas, 2006). Pedagogical Technology Knowledge (PTK) encompasses not only the pedagogical content knowledge but also teachers’ understanding of the mathematical content, the representation of that content via a technology medium and learning styles of individual students. Even though the present study did not directly examine PTK, the results do suggest that both teachers had a solid start in the development of this knowledge. The enactment of PTK during classroom practice on a long-term basis is an interesting area for future research.

In this study, both teachers have shown a high level of collegiality and openness in wanting to engage in a dialogue about using mobile technology in developing sound learning contexts. The willingness to take risks and be a co-learner in the use of technology was also found to be an important factor in teachers’ attitudes to and confidence with these tools (Goos, 2003).

With regard to use of mobile technology by teachers, it is important that teachers develop a good understanding of the tool that they will be using during the activity. Practitioners should allocate ample time for individual teachers to become familiar with the many features of the smartphone. The pedagogical value of the mobile technology is better emphasised by participants engaging in tasks that are reasonably demanding as in the case of the present study. Our experience with smartphones shows that in the initial stages of the
In the present study, analyses of CK and PCK were made based on dialogue between teachers. Future studies could improve on this strategy by examining concept maps. Participants could be asked to map their own schemas that they have developed. The trajectory of schemas (evidenced by the changes in the concept maps) as the teachers reflect on and engage peers via the mobile technology, would provide a valuable source of data that teachers could draw on in order to modify their numeracy-related content and pedagogical content schemas.

The above views are based on two teachers’ experiences with smartphones. Consequently, I am cautious about making generalisations regarding the impact of such tools on the larger cohort of teaching population. It is possible that the pattern of results reported here might be similar to one that emerges from a larger sample of participants but that has to be established in future studies. Although the teachers did not utilise all the email and phone options that were available, the participants did share a considerable amount of knowledge and understanding by drawing on other available technology. It would seem that future studies that help participants use all the options of smartphones could provide even more avenues through which teacher educators and researchers could examine the many attributes of their CK and PCK.

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