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Considering pedagogical content knowledge in the context of research on teaching: An example from technology

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Abstract

When thinking about teaching, the pedagogical content knowledge of teachers cannot be ignored. We argue that pedagogical content knowledge is a major determiner of teaching practice and is central to teachers' curriculum decision-making at the classroom level. This paper takes a sociocultural perspective on the importance of developing teachers' pedagogical content knowledge. From our classroom-based research in technology education and the past research we propose a model of pedagogical content knowledge with seven characteristics that we believe are important for effective taching.

Introduction

Many studies about teacher effectiveness focus on the importance of teacher subject knowledge and pedagogical knowledge. More recently there has been increased attention to the distinction between abstract content knowledge and pedagogical content knowledge as well as an increasing recognition of the importance of formative interactions in the classroom to enhance student learning. Pedagogical content knowledge is a complex blending of pedagogy and subject content and includes aspects related to an understanding of what is to be taught, learned and assessed, an understanding of how learners learn, an understanding of ways to facilitate effective learning, and an understanding of how to blend content and pedagogy to organize particular topics for learners. However, as Appleton (2003) points out, most of the work on pedagogical content knowledge has been undertaken at the secondary school level in particular subject areas. In consequence previous research and models of pedagogical content knowledge have tended to overplay specific subject pedagogical content knowledge and underplay strategies to develop pedagogical content knowledge generally. From our classroom-based research and associated teacher development research we believe that definitions of pedagogical content knowledge do not provide an adequate description of it for primary school teachers. We therefore propose a model of pedagogical content knowledge with seven characteristics that we believe are important for effective teaching.

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Effective teaching and pedagogical content knowledge

A number of empirical studies have explored the characteristics of effective teachers (e.g., Gipps, 1999; Porter & Brophy, 1988; Wragg, Wragg, Hayes, & Chamberlain, 1998). The common characteristics are: having a broad understanding of curriculum aims and objectives; having a wide range of pedagogical strategies; having high expectations of all students; knowing students well; providing effective feedback; recognizing student success; having sound content knowledge of the subject and understanding what it means to make progress. Brophy and Good (1986) also indicate that students learn best when teachers spend most of their time focusing on content, with learning activities focused on the learners' levels of understanding. The student learns more effectively when the teacher structures new information in relation to prior knowledge of the learner. Where teachers' subject knowledge is weak, confidence levels to teach that subject are low, leading to restricted classroom practices (Harlen, 1999). All of these studies emphasize the importance of teacher subject knowledge as well as pedagogical knowledge.

Good teacher knowledge of subject content was found to have a positive effect on decision-making related to changing pedagogical strategies for creating better learning opportunities. In addition, sound content knowledge seems to have a positive effect on planning, assessment, implementation of curriculum and curriculum development. Harlen and James (1997) comment that teachers cannot provide experiences and activities that guide student progress toward understanding of ideas if they themselves do not know what the ideas are. If teachers have generally sound pedagogical skills they rely on them to carry them through difficult aspects of the subjects they teach, but this can limit student learning in the area. Corcoran and Goertz (1995) provide substantial evidence that content-relative knowledge had a positive impact on student performance. They also report other studies that have shown that teachers often lack the subject matter knowledge needed to incorporate appropriate pedagogical decisions. In reviewing past research Gess-Newsome (1999) notes that teachers with well-developed pedagogical skills still experience difficulty in responding appropriately to student ideas when they move outside their area of content expertise. With familiar content they are able to focus more on levels of student understanding than "mechanical success or failure" (p. 62). Compartmentalised subject knowledge of the discipline is often not enough though, as this knowledge can be rather fragmentary in nature, particularly in relation to teaching. Teachers with a strong overview and a structure of interrelated ideas are able to make more connections to draw on in teaching and learning situations. Similar findings from primary science education are also reported by Osborne and Simon (1996).

However, Askew, Brown, Rhodes, Johnson and Wiliam (1997) found no relationship between teachers' level of subject qualification and student progress in mathematics. Instead, there was a strong correlation with their pedagogical content knowledge. Black, Harrison, Lee and Wiliam (2001) assert the need to analyse the interplay between models of cognition and learning, views of the nature of the subject matter, and the selection and articulation of goals and subject matter that follow. They support the view that the specific nature of subject matter is an important determinant in how teachers carry out teaching in their classrooms. They further suggest the importance of the two-way relationships between teachers and the subject matter, students and the subject matter, and between teachers and students. While much teacher education and teacher development research in the past has focused on the importance of teachers' subject knowledge, the research often did not distinguish between abstract content knowledge and pedagogical content knowledge (Shulman, 1987). More recently there has been increased attention given to this distinction in the research community as well as increasing recognition of the importance of formative interactions in the classroom to enhance student learning.

Ties between teachers' subject knowledge, how that is transformed for classrooms and assessment ability have been acknowledged (Bell & Cowie, 1997; Black & Wiliam, 1998; Sadler, 1998; Shulman, 1987). When teachers are unsure of their disciplines structure they are not well equipped to guide learning in it or assess that learning. Good knowledge of the subject matter enables teachers to construct learning hierarchies, which provide a blueprint for devising assessment procedures (Carr, McGee, Jones, McKinley, Bell, Barr & Simpson, 2000). Bell and Cowie's (1997) research on assessment in science education found that classroom interactions are dependent upon teachers' professional knowledge and experiences, while Black and Wiliam (1998) show a close link between teachers' formative interactions, the components of a teacher's personal pedagogy, and their conceptions of their role. Teachers' professional knowledge is central to the process of assessment, as knowledge of the subject, how students learn and the interaction of these two factors supports learning (Carr et al, 2000; Sizmar & Sainsbury, 1997). Sadler (1998) outlines resources that competent teachers bring to teaching, learning and assessment. These include knowledge about the content or substance of what is to be learned, attitudes towards learners and learning, skill in devising tasks, knowledge of criteria and appropriate standards, skill and expertise in previous similar tasks, and expertise in giving appropriate, targeted feedback. As Fleer (1999) comments:

> It can be expected that the way the learning context is structured is likely to be as a direct result of the teachers' pedagogical content knowledge and philosophy about how children think and learn. (p. 275)

Findings from Black et al.'s (2001) work on formative assessment examined in mathematics, science and English classrooms support Grossman and Stodolsky's (1994, cited Black et al., 2001) view that subject disciplines create strong differences between the identity of teachers and how learning is undertaken in classes. They indicate that the teacher, the subject and the student, and their various interactions, should be the focus in accounting adequately for what is going on. A focus on either the teacher or students or subject in isolation is inadequate.

Gipps and Brown (1999) argue that teachers require a range of pedagogical strategies to suit a range of situations. To choose the most appropriate strategy they need to know the understandings students have reached in order to engage in formative assessment. Underlying this is good content knowledge and good pedagogical content knowledge. They equate this blending of formative assessment, student understandings and pedagogic strategy to Shulman's (1987) act of pedagogic reasoning. Transformations of the subject matter as understood by teachers into aspects relevant and applicable to their students are required. Duschl and Gitomer (1997) also declare that successful facilitation of student-teacher conversations requires a reasonable grasp of the subject matter being explored. Teachers need to develop a clear sense of the conceptual terrain they are exploring and will also need to have a pedagogical sense of the likely understandings the students will bring to a domain. With sufficient content and pedagogical knowledge, teachers can respond to students productively.

The teacher's role in providing feedback is crucial to effective learning. Attention is focused on classroom interactions, the connections between assessment and learning, and the premise that classroom assessment enhances learning (Black & Wiliam, 1998; Brown, 1990; Gipps, 1994; Glaser, 1990; Resnick & Resnick, 1992; Wiggins, 1993). Strengthening the feedback that students receive about their learning assists them to make substantial progress when that feedback is *task-involving* with focus on what students need to do to improve rather than *ego-involving* with focus on learners and their self-esteem (Black & Wiliam, 1998; Butler, 1987; Hattie & Jaeger, 1998). Crooks (1988) reasoned that to assist learning, emphasis should be given to classroom formative assessments that place weight on giving feedback to students that is focused on the task, regular, undertaken while still relevant, and specific to the task. Most importantly, assessment must emphasise the skills, knowledge and attitudes thought to be the most important, even if this is technically difficult. Harlen (1998) also asserts the importance of commenting on the substance of the work, rather than its superficial aspects, in order to convey what is important for subsequent learning. What is required is an appropriate setting of challenging goals, a structuring of situations to attain those goals effectively and the provision of feedback relevant to attaining the goals. Students have been shown to benefit from descriptive feedback that identifies the strengths and weaknesses of their work as this enables them to take control of their own learning. This feedback should focus on the qualities of student work, and specific ways in which student work could be improved. As such, descriptive feedback has motivational and social effects (Butler, 1987; Harlen, 1998; Mavrommatis, 1997; Tunstall & Gipps, 1996). Therefore, to be effective, teachers need to be able to give descriptive feedback related to the skills, knowledge and attitudes thought to be the most important.

In thinking about effective teaching we also need to consider the classroom environment. A sociocultural approach focuses our attention on the environment created by the teacher, especially the affordances of the different activities, the nature of the learning commentary, and the qualities that teachers model (Claxton, 2002). Sociocultural theory would suggest that knowledge emerges through social and cultural activity during community participation (Dalton & Tharp, 2002). In teaching and learning situations, learning proceeds best when assistance is provided that permits a learner to perform at a level higher than would be possible alone. When teachers and students work together towards a common goal and have opportunities to converse about the activity, learning is a likely outcome. One critical feature is applying that knowledge in productive action with others (Boaler, 1999). Only if the teacher is present and engaged in activities sufficiently to share the experiences with students will there be sustained, intensive discourse that maximizes learners' development (Dalton & Tharp, 2002). Effective teaching is therefore characterized by the use of meaningful content presented in lifelike situations where learning is enhanced through informed conversation. Assistance from the teacher can take many forms, such as the provision of models to be imitated, the orchestration of tasks and opportunities, practical scaffolding, feedback and guidance, and explicit explanations of principles and procedures (Wells & Claxton, 2002).

Defining pedagogical content knowledge

Making sound decisions about what and how to teach, termed by Shulman (1987) as pedagogical reasoning, requires sound subject knowledge, an expansive teaching repertoire and extensive pedagogical knowledge. The comprehensive framework includes knowledge of content, general pedagogy, curriculum, learners, educational contexts and educational ends. Pedagogical content knowledge is important for this identifies the distinctive bodies of knowledge for teaching. Shulman (1987) examines how the various kinds of teacher knowledge are used. Pedagogical content knowledge is a complex blending of pedagogy and subject content and includes aspects related to an understanding of what is to be taught, learned and assessed, an understanding of how learners learn, an understanding of ways to facilitate effective learning, and an understanding of how to blend content and pedagogy to organize particular topics for learners. Shulman describes pedagogical content knowledge as "the most useful forms of content representation … the most powerful analogies, illustrations, examples, explanations, and demonstrations … the ways of representing and formulating the subject that makes it comprehensible for others" (1987, p. 9). Not only do teachers need to understand content and purpose; they must be able to transform the content knowledge so that it becomes pedagogically powerful.

In elaboration of Shulman's original notion of pedagogical content knowledge, Gess-Newsome (1999) suggests five overlapping categories: conceptual knowledge, subject matter structure, and nature of the discipline, content-specific teaching orientations and contextual influences. Magnusson, Krajcik and Borko (1999) emphasise that pedagogical content knowledge results from the transformation of other domain knowledge. Their model of pedagogical content knowledge includes the teacher's orientation to teaching the subject, knowledge of subject curricula, knowledge of assessment, knowledge of student subject area understanding and knowledge of instruction strategies. Grossman (1990) suggests there are four central components to pedagogical content knowledge: knowledge and beliefs about purpose, knowledge of student conceptions, curricula knowledge and knowledge of instructional strategies. Cochran, deRuiter and King (1993) describe four components: knowledge, environmental contexts, pedagogy and subject matter. The characteristics of pedagogical content knowledge common to all these definitions are knowledge of subject matter, students, curriculum and associated pedagogy.

As Appleton (2003) points out, most of the work on pedagogical content knowledge has been undertaken at the secondary school level in particular subject areas. In consequence previous research and models of pedagogical content knowledge have tended to overplay specific subject pedagogical content knowledge and underplay strategies to develop pedagogical content knowledge generally. From our classroom based research and associated teacher development research we believe that definitions of pedagogical content knowledge do not provide an adequate description of it for primary school teachers.

Towards a model of pedagogical content knowledge

Teachers' understanding of the nature and purpose of the discipline strongly influences their personal pedagogical content knowledge, that is, what they highlight as important for particular students, in particular contexts. Subjects taught in schools are a representation of that subject rather than the subject itself. The nature of the subject or discipline from a sociocultural perspective will also include ways of knowing and knowledge generation. Stetsenko and Arievitch (2002) describe the seminal work of Piotr Gal'perin, one of Vygotsky's students and colleagues, who argued in essence that teachers should organize their work around the most abstract and coherent principles that characterize a particular domain of knowledge. These principles are the core conceptual tools, the internalization of which enable students to think powerfully about a whole range of phenomena. This means that the teachers need to have a sense of the nature of the discipline, its organizing concepts and its tools. This includes also cultural notions of language concepts and the mediation of tools and frameworks. Stetsenko and Arievitch (2002) highlight that Gal'perin's theory emphasizes that to understand the development of the mind, one needs not only to observe how children participate in practices and make use of cultural tools, but also to construct instructional procedures that specially provide students with tool use, in which the evolving histories and functions of the tools are made explicit.

In considering the components of a more robust and comprehensive model for pedagogical content knowledge, we also need to consider what is meant by subject matter. We would see subject matter as being associated with the nature of the discipline, the structure of the big ideas (including notions of the progression), the conceptual and procedural knowledge of the subject and technical aspects. Notions of progression are combined with understanding conceptual and procedural ideas as well as how students might progress. Therefore progression or where to next' is a combination of the discipline structure and learning within that structure. Curriculum knowledge is fed by both content knowledge and knowledge of the curriculum goals, whereas pedagogical knowledge is fed by knowledge of learning and assessment.

A sociocultural perspective on learning and pedagogical content knowledge provides insights into the importance of teachers developing robust pedagogical content knowledge. A review of the literature on teaching, learning and assessment indicated the importance of pedagogical content knowledge alongside pedagogical knowledge. The emerging sociocultural notions of teaching, learning and assessment highlight the importance that the culture/discipline plays in teaching and student learning. Drawing from a sociocultural perspective (Stetsenko & Arievitch, 2002), what we know about effective teachers (Dalton & Tharp, 2002), research on pedagogical content knowledge (Gess-Newsome, 1999) and our own classroom research in the area (Jones & Moreland, 2001) we argue that pedagogical content knowledge has seven constructs:

- Nature of the subject and its characteristics;
- Conceptual, procedural and technical aspects of the subject;
- Knowledge of the curriculum, including goals and objectives as well as specific programmes;

- Knowledge of student learning in the subject, including existing knowledge, strengths and weaknesses and progression of student learning;
- Specific teaching and assessment practices of the subject, for example, authentic, holistic, construct reference;
- Understanding the role and place of context; and
- Classroom environment and management in relation to the subject, for example, managing resources, equipment and technical management.

We now discuss these components of pedagogical content knowledge with reference to classroom-based research conducted over a three-year period in the developing area of technology education. Although the work was carried out in the curriculum context of technology education, evidence to date suggests that this research has transferred to other curriculum areas such as science, environmental education and social studies (Jones & Moreland, 2003).

1. Nature of the subject and its characteristics

When teachers had an understanding of the characteristics of the discipline, they developed more secure guidelines for thinking about what was important in the learning activities and the intended learning. For example, teachers were able to choose more suitable tasks for developing student learning in technology and could more readily identify technological learning goals on which to base their teaching and assessment practices. By understanding the characteristics of the subject, the teachers were better able to identify general aspects of technology and differentiate between the technological areas. They were more able to audit existing classroom activities for their technological consistency: for example, 'Is this more a language activity, or a science activity, than a technology one?'

2. Conceptual, procedural and technical aspects of the subject

The teachers' developing conceptual and procedural knowledge enabled them to identify specific learning goals, and they began to move with more confidence between the characteristics of technology and the specific technological learning outcomes. The shift in focus from providing a technology experience to providing opportunities for students to develop particular technological learning outcomes was significant. They became focused on the technological learning of their students. Teachers demonstrated greater confidence with formative interactions, particularly in relation to providing appropriate and descriptive feedback to the learners. Direction was given where deemed appropriate, which led to more considered and purposeful interactions. Not only was there more emphasis on providing feedback and assistance to students to develop particular technical skills, there was also more emphasis on conceptual and procedural aspects than Social and managerial aspects.

The teachers put value on their increased capacity for: identifying specific and overall learning outcomes rather than just activities; identifying procedural, conceptual and technical learning outcomes; questioning using technological vocabulary and concepts; and allowing for multiple outcomes. There was encouragement for students to seek divergent solutions. Teachers also began developing understandings related to progression aspects, including linking and enhancing technological learning from one unit to the next. Teacher understanding of progression was also reflected in task selection and development. Tasks were identified to develop particular technological conceptual and procedural aspects rather than just providing a variety of experiences in different technological areas.

3. Knowledge of the curriculum

Teachers needed to be aware of what was highlighted in the curriculum as valuable for technology. Interaction between curriculum knowledge and subject knowledge assisted teachers to think about the goals and objectives as well as specific programmes for their students. There was a linking between the characteristics of the subject, the specific conceptual and procedural aspects and the curriculum objectives. This is a transformational process from subject to curriculum to classroom. When teachers just relied on curriculum objectives to define their teaching, they found it difficult to think of teaching in detailed conceptual and procedural terms. A curriculum objective focus for teaching resulted in teachers providing students with experiences in different technological areas rather than focussing on developing any degree of Sophistication or complexity in student learning.

4. Knowledge of student learning in the subject

Teachers needed to be aware of how they built on students' conceptual and procedural understandings and their strengths and weaknesses in technology. For example, the teachers were unaware of the difficulties students encountered when they tried to envisage their thinking in 2- or 3-dimensions and when making models. The teachers were not sure about how to approach the teaching of drawing and were unsure of the role of graphicacy in promoting technological learning. Teachers were uncertain whether students were capable of matching their imaginative abilities with representational skills. However, when teachers modelled drawing in front of students and when they used drawing as a tool to represent ideas, students used drawing to develop 'designerly thinking' and behaviours. When teacher support was provided students showed a strong correlation between what they intended to do and what they produced. Our research indicated that there is a need to give direct instruction in technical skills to assist student learning. Hidden dilemmas related to the status of practical work need to be addressed so there is acknowledgement that procedural knowledge is not simply acquired through doing, it needs to be planned for and taught. For example, young students need to be introduced to the different genres of drawing in order to develop useful designs. When teachers value student drawings and foster graphicacy through instruction, drawing becomes a powerful tool for students to make sense of the world.

Further to identifying what students bring to lessons is knowing how students progress in their technology learning. In technology education, where progression in learning may be thought to consist of dealing with a greater number and a more complex array of variables, the development of sophisticated feedback skills by teachers was critical to the enhancement of student learning. If learning is to be enhanced then teachers need to be knowledgeable about the next learning steps and how to guide students to get there.

5. Specific teaching and assessment practices of the subject

Knowing about the most appropriate ways to teach and assess particular subjects impacts on student learning in the subject. As Moreland, Jones and Northover (2001) found, teachers met difficulties when they applied more general teaching and assessment to technology, even when they had some technology curriculum knowledge. When the teachers had more detailed knowledge of the subject and the curriculum they were able to design appropriate teaching and assessment strategies, for example, transfer strategies, construct referenced assessment. They could use a variety of ways to explore, develop and focus students' technological thinking, for example, flow diagrams illustrating processes and stages to encourage student reflection, to encourage iteration between different phases and as a means to look forward.

Often in technology classes, the design process is treated as a series of steps (McCormick, 2000). This can be characterized as posing and thinking about the problem, clarification, thinking of alternatives, implementation and evaluation, and can become ritualized with lessons structured around it. It is a ritual that does not affect student thinking. Students undertake the process, often tidying up portfolios or work after the event, as they are required to show the development of ideas. A 'veneer of accomplishment' is apparent (Lave, 1988). Hence, how teachers structure lessons strongly affects how students undertake technological processes (Jones & Carr, 1993). Teacher knowledge of the technological problem-solving process students are engaged with is therefore important. For example, in our study, when teachers worked alongside students, cueing them to think about materials, material qualities and fixing and joining devices and mechanisms before they started design drawings, students worked iteratively between thinking, designing and making (Jones & Moreland, 2003). How to effectively teach and assess particular ideas in a subject "is not a solely pedagogical question; it impacts very considerably on the nature of the subject matter" (Barnett & Hodson, 2001, p. 433).

Technological learning is enhanced when students are engaged with authentic activities (Brown, Collins, & Duguid, 1989). However, in technology, many classroom activities have students beginning from scratch, rather than reflecting actual technological problem solving, which usually involves modification and adaptation of existing technologies (Hennessy, McCormick, & Murphy, 1993). Earlier research in New Zealand indicated that very few activities developed by teachers reflected principles of real technological practice (Jones & Carr, 1993). Knowing about culturally purposeful authenticity as a reflection of the technology world outside the classroom, and personal authenticity where the student is involved and the learning meaningful become important in teaching and assessing technology appropriately.

6. Understanding the role and place of context

The use of technological problems and contexts can be an important way to introduce subject-related ideas. Teachers needed to know the appropriate subject-related contexts for their students. For example, in our classroom research we have found that if problems are too openly defined, or there is limited teacher and student understanding of the context, learners may lose their way. Equally problematic were overly constrained tasks, as teacher over-specification led to lack of student ownership and control. Like Fleer (1999) we believe students should be involved in setting the technological agenda for this gives the tasks more personal meaning and buy-in from the students. This is not to say that anything goes. Developing technological capability should be organised so students learn in terms of procedures, concepts and skills in a structured, rather than haphazard, way (Anning, 1994). When students in our study were encouraged to see the issues surrounding any technological decision, they became involved in meaningful decision-making. Teachers therefore need to involve children in problem-solving tasks where the value positions are made clear to them and presented in a way to which they can relate. To teach in context is to bring relevance to an activity. In technology the context may also be a vehicle for bringing design ideas into the open. By considering the user considerations, for example, the task becomes richer and student decision-making more meaningful. Knowledge construction in technology must be learnt in context as in these circumstances students develop tacit 'doing' knowledge (Solomon & Hall, 1996).

7. Classroom environment and management in relation to the subject

The classroom culture and student expectations influence the way students carry out activities. In a practical subject like technology, the classroom environment and management practices impact on student learning. An environment that is supportive and challenging fosters positive attitudes of self-esteem and motivation and these help to create the conditions in which technological capability can thrive. A problem-solving approach to technology is an important approach for developing technological literacy. Problem-solving facilitates task ownership, can be cross-curricula and enhances communication (Parkinson, 2001). Students, therefore, need opportunities to work on tasks within their capability but which at the same time stretch them, where risk taking and failure are seen as positive and beneficial. It is vital for students to be engaged in technological learning that is within or just beyond their reach. This challenges students to extend into new understandings in order to achieve success (Kimbell, Stables, & Green, 1996; Stables, 1997). In our research we found that when students are given support to find out how things work, to make things work, and to create and express themselves they will have better chances to develop technological capability. Teachers as more knowledgeable and technically competent can assist student development through intervention and modelling of ideas and skills and thus accelerate students' acquisition of ways of representing meaning (Anning, 1997).

Concluding comments

The introduction of this model of pedagogical content knowledge in association with effective teacher development has been shown to have a positive impact on teaching and student performance in technology. Also it has become apparent that introducing teachers to these components of pedagogical content knowledge generally is beginning to lead to enhanced teaching, learning and assessment in other curriculum areas (Jones & Moreland, 2003).

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