The Knowledge of Teaching – Pedagogical Content Knowledge (PCK)

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ABSTRACT

Pedagogical content knowledge (PCK) was first introduced by Shulman in the 80's. It is defined as the integration or amalgamation of pedagogy and content which basically covers the 'what' and 'how' of teaching. PCK was considered as the missing paradigm in the study of teaching. This integration of knowledge was long searched by the scholars in the United States in their effort to elevate teaching to the professional status similar to that of doctor, lawyer and engineer. As PCK is the knowledge of teaching, this concept paper presents an overview on definitions of teaching, indicators and knowledge bases required in good teaching. This paper also presents the conceptions and models of PCK, the processes (PRA Model) involved in the growth and development of PCK of teachers and the importance of PCK.

Keywords: *Pedagogical Content Knowledge (PCK), Teaching, Subject Matter Knowledge, Pedagogy*

INTRODUCTION

Pedagogical content knowledge (PCK) is the blending or amalgamation of pedagogy and subject content knowledge and was introduced by Shulman in the 80's. According to him, PCK was not something new because even as early as in the 1950's, both content and pedagogy were regarded as one indistinguishable body of knowledge whereby content is about what is known and pedagogy is about how to teach it (1986b). The reason why Shulman introduced PCK was because teaching career is often perceived as a non-professional career when compared to careers like lawyer, doctor and engineer. In Malaysia, individuals with no teaching qualification were employed as temporary teachers to overcome the shortage of trained teachers in the schools. Such practice further proven the non-professional status of a teacher. As the saying goes 'those who can, do, those who can't, teach' (Shaw, 1903), it means people who are able to do something well can do that for a living, while people who are not able to do anything that well make a living by teaching (McGraw-Hill Dictionary, 2002). The proverb was used to disparage teachers. To exacerbate the status of teachers, it was reported that teachers in Malaysia lack of pedagogical preparation (Lee, 2014).

Two major recurring themes noted in the education reform reports in the United States during the 80's were the 'professionalization of teaching' and 'teaching deserved a professional status' (Shulman, 1987). Shulman further argued that it was necessary to raise and articulate clearly the education and performance standards of teachers in order to elevate teaching to "a more respected, more responsible, more rewarding and better rewarded occupation" (pp. 3). The urgency had brought about the searching of a missing paradigm in the research on teaching and teacher knowledge (Shulman, 1986a, 1986b, 1987).

Definitions of teaching

Teaching is a process greatly explored by academicians and yet what we knew about teaching was only a glimpse of it mainly because teaching is a complex activity (Barnett & Hodson, 2001; Calderhead, 1987, 1988; Calderhead & Shorrock, 1997; Dunkin & Biddle, 1974; Holly, 1989; Mulhall, Berry, & Loughran, 2003; Newton, 2000; Parkay & Standford, 1995; Shulman, 1986a, 1986b, 1987; Smith & Neale, 1989; Sockett, 1987; Tigchelaar & Korthagen, 2004). Others said 'teaching is a highly stressful activity for both novice and experienced teachers as it is full of uncertainty' (Barnett & Hodson, 2001), a universal activity (Duke, 1990), a problematic job (Borich, 1995; Loughran & Berry, 2005), an exciting but demanding job (Parkay & Standford, 1995), a lonely and insulated profession (Locks-Horsley, Stiles & Hewson, 1996; Schon, 1983), and a rewarding occupation yet tantalizing and challenging (Dillon & Maguire, 2001). It is also a job whereby its implementation often deviates from the initial planning (Loughran & Berry, 2005), an activity whereby the teachers and students working jointly (Shulman, 1986), an activity which provides opportunities for students to learn (Brown & Atkins, 1988), and the most difficult job in the world because "learning is the most complex phenomenon on the planet" (Stones, 1994, pp.312). From the various descriptions mentioned, one could see that teaching possesses many facets and complexity (Shulman, 1987) subsequently it is not easy to learn how to teach and become a professional teacher (Parkay & Standford, 1995).

Academicians reasoned that the complexity of teaching was because teachers used and integrated various types of knowledge simultaneously while teaching (Shulman, 1986b; Smith & Neale, 1989). Shulman (1987) argued that a teacher needed to have seven knowledge bases in order to teach effectively and successfully. The seven knowledge bases are (i) content knowledge; (ii) general pedagogical knowledge; (iii) curriculum knowledge; (iv) pedagogical content knowledge; (v) knowledge of learners and their characteristics; (vi) knowledge of educational contexts; and (vii) knowledge of educational ends, purposes, and values. On the other hand, Smith and Neale (1989) proposed that teachers needed to know subject matter, content knowledge, instructional strategies knowledge and student knowledge in order to teach.

Besides integrating the knowledge bases, teachers also integrate the knowledge bases with their actions in a multiple way while teaching (Duncan, 1998). In short, teachers perform multitasking. For instance, they have to attend to their students who are unique, varied and unpredictable individuals (Sockett, 1987), then they have to respond to the environmental distractions, diagnosing students' learning difficulties and spotting their misconceptions, monitoring their progress and making necessary adjustment, plus many other routine or non-routine works and duties (Armstrong, Henson, & Savage, 2005).

Borich (1995) considers teaching as problematic because school is organized by problems such as discipline problems, curriculum problems, resource problems, parent and family problems. While trying to cope with these problems, the teachers have to make many complex and quick decisions by "thinking on their feet" to give an immediate response in their hectic fast-paced classroom (Barnett & Hodson, 2001; Borich, 1995; Clark & Peterson, 1986; Tigchelaar & Korthagen, 2004; Wilson, Shulman, & Richert, 1987). In fact, on an average, a teacher makes a decision every two minutes during class time (Clark & Peterson, 1986). It was also found that three quarters of teachers' decisions were made on an unconscious basis (Yinger, 1986) and most of the decisions are 'new' and require immediate contextual judgement (Schon, 1983). Although the decisions made are purposeful and reasonable, many teachers in fact did not know why and how they made the decisions as teaching has become their second nature and is like 'breathing' to them and this has contributed to the complexity of teaching (Holly, 1989).

Teachers work in isolation in the process of preparing to teach. They have to figure out how to teach by interpreting, communicating within themselves about puzzles and insights, making adjustment of the curriculum to suit the students and finally, having to test the ideas in the classroom all by themselves (Brandt, 1992; Dillon & Maguire, 2001; Holly, 1989; Schon, 1983; Shulman, 1986b). On the other hand, teaching is unpredictable and contextualized as every class is a unique community on its own wherein both teacher and students having their personal preferences in teaching and learning respectively (Barnett & Hodson, 2001). More often than not, teachers have to make adjustments and changes in their planning in order to meet different students' needs and preferences, thus the implementation of the actual teaching often differs from the actual planning.

Many parties, both outside and within teacher education, see teaching merely as a delivery of curriculum. They assume teaching is a simple skill which is equal to telling. This 'dangerous view' has

oversimplified the teaching process (Stones, 1994). It is difficult to define what constitutes good teaching and 'no one method of teaching is superior" (Holly, 1989, pp. 103). Basically, a good teacher has the ability to adjust his/her teaching according to context, taking factors like students, subject matter, facilities, emotional climate and others into consideration and ensuring their students feel comfortable to learn (Barnett & Hodson, 2001). To Finlayson, Lock, Soares and Tebbutt (1998), a good Science teacher needs to have good competency, classroom management and a strong background knowledge of the subject. Studies show that teachers who lack content knowledge face difficulties and do not have confidence in their teaching (Finlayson et al., 1998; Hashweh, 1987).

Additionally, teaching can be generally categorised into three task domains, namely pre-active, interactive (Jackson as cited in Clark & Peterson, 1986) and post-active (Clark & Peterson, 1986). Although "the centre of teaching and learning is the interaction between the teacher and the learner" (Eble, 1976, pp. xi), the pre-active and post-active domains contribute to the success and the smooth running of the interactive domain. The pre-active task is mainly related to the preparing for the actual teaching episode whereby teachers need to comprehend, critique, adapt and plan content, materials and teaching methods (Reynolds, 1992; Shulman, 1987). During the interactive phase, teachers implement what they have planned, but make necessary adjustment of time and materials; at the same time, they also evaluate student understanding on what is taught. Reflection is the main focus in the post-active task, here, teachers reflect on the lesson and also the response of the students with the aim to improve future teaching.

The indicator of good teaching

Many people regard "more means better" and "results means everything" as the indicators of good teaching. Newton (2001) argued that the cost of chasing for high scores and quantity is a lack of understanding in learners. According to Herron and Nurrenbern (1999), students learn either by rote learning or by understanding and can be trained to give acceptable answers without understanding. They propose that teachers should give priority to learning by understanding as it has more potential than memorization. Newton (2000) further supports by saying that learning for understanding is "more sure, more durable, and more valuable for the learner" since the students have to make a connection of isolated pieces of knowledge, to think with flexibility and to solve problems. Gunter, Estes and Schwab (1999) also emphasized that good teaching is that learners can make connections between the new and old knowledge, thus teachers can assess students' understanding through asking questions or providing opportunities for the students to explain what they understood.

In brief, a few indicators were proposed in the past studies to assess the quality of teachers' teaching and students' understanding by assessing the students' abilities in (i) making connections between the isolated pieces of knowledge; (ii) making connections between the new and old knowledge; (iii) thinking with flexibility; and (iv) solving problems.

The knowledge bases of teaching

Basically, scholars believe in teachers need to possess some minimum knowledge bases in order to teach well. Knowledge base is defined "the secret of an expert system's expertise, the body of understanding, knowledge, skills, and dispositions that a teacher needs to perform effectively in a given teaching situation" (Wilson, Shulman, Richert, 1987, pp. 106). It was noted that the earlier knowledge base model emphasised on knowledge of self apart from the knowledge of the milieu of teaching, curriculum, pedagogy and subject matter.

Shulman (1987) rationalised that teachers need seven knowledge bases in order to teach effectively and successfully. The knowledge bases are content knowledge, general pedagogical knowledge, curriculum knowledge, PCK, knowledge of learners and their characteristics, knowledge of educational contest and knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. Grossman (1900) on the other hand, argued that it is sufficient for a teacher to possess four knowledge bases for teaching that is pedagogy, PCK, school contexts and subject matter. Barnett and Hodson (2001) advance that exemplary teachers use four kinds of knowledge in their teaching, namely: academic and research knowledge, PCK, professional knowledge, and classroom knowledge. Although different scholars expressed

different views on the knowledge bases of teachers, they did agree on some fundamental knowledge bases such as subject matter and pedagogy or in short PCK.

Pedagogical content knowledge (PCK)

The term pedagogical content knowledge (PCK) was introduced by Shulman in the 80's to represent the missing content paradigm that education researchers had been ignoring all this while. Since then it has drawn much attention from the educational researchers and successfully shifted the focus of educational research to the so-called 'missing paradigms'. This movement had strengthened the professionalizing of teaching (Carlson, 1999).

The research findings on PCK have added knowledge and expanded the available literature related to it. Subsequently, researchers identified inadequateness in Shulman's PCK conception and they began to refine, modify, expand and derive new PCK conceptions. Theoretically, PCK is an academic construct (Loughran, Mulhall & Berry, 2004). In the modified versions of its conceptions, constructs are added either singly or in a combined manner. Similar to teaching, PCK is also complex, difficult to define and articulate by the holders, thus, researchers often face great difficulty in capturing and documenting it (Loughran et al., 2004).

Conceptions of PCK

From the past studies, scholars had forwarded many definitions of PCK. Some of the scholars shared similar view with Shulman on the definition of PCK such as Smith and Neale (1989) and Cochran, DeRuiter and King (1993). Other scholars such as Veal and Makinster (1999), Cochran et. al (1993) and Grossman (1990) had forwarded some critiques on Shulman's model of PCK. Subsequently, they revised and refined Shulman's model.

Shulman (1986b) defines PCK as the unique knowledge of teaching possessed by teachers, 'the particular form of content knowledge that embodies the aspects of content most germane to its teachability', he wrote:

….pedagogical content knowledge, which goes beyond knowledge of the subject matter per se to the dimension of the subject matter of teaching. The category of pedagogical content knowledge includes the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstration – in a word, ways of representing and formulating the subject that make it comprehensible to others …. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topic easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (pp. 9-10).

It is noted that Shulman's PCK conception consists of two main elements that is how teachers represent the content knowledge and their knowledge about the difficulties faced by students while learning a particular topic in the content (Loughran et al., 2004). A teacher is said to teach with his/her PCK when he/she has gone beyond understanding the content subject, is capable of restructuring the subject content and present it in a form suited to the diverse interests and abilities of the students based on their preconceptions and difficulties encountered (Shulman, 1986b, 1987). Smith and Neale (1989) also shared the similar view as they also believe that teachers with good PCK are aware of their students' typical errors in a particular topic. As such, they are able to prepare their lessons with suitable strategies and effective elaboration which lead to students' conceptual understanding. Cochran et al. (1993) further express that "PCK concerns the manner in which teachers relate their subject matter knowledge (what they know about what they teach) to their pedagogical knowledge (what they know about teaching) and how subject matter knowledge is a part of the process of pedagogical reasoning" (pp. 263). The abilities of restructuring the subject matter knowledge to suit the diversities of the students further distinguished a teacher from a content specialist and verify PCK as the knowledge of teaching (Cochran et al., 1993; Shulman, 1987; Veal & Makinster, 1999).

Based on research findings, Grossman (1990) argues that teachers draw upon more than subject matter knowledge and general pedagogical knowledge while teaching. According to Baxter and Lederman (1999), general pedagogical knowledge is the knowledge of how to organize a classroom and manage

students during instruction. Grossman (1990) further expands PCK conception to include four central components, namely: (1) knowledge and beliefs about the purposes of teaching a subject at different grade levels; (2) knowledge of students' understanding, conceptions, and misconceptions of particular topics in a subject matter; (3) curricular knowledge which includes knowledge of curriculum materials available for teaching particular subject matter, knowledge about both the horizontal and vertical curricula for a subject; and (4) knowledge of instructional strategies and representations for teaching particular topics (pp. 8-9). She further emphasized that the knowledge and beliefs about the purposes of teaching a subject is the "overarching conceptions" of teachers' teaching and is often reflected in their teaching goals. Teachers with student knowledge will ensure the appropriateness of the content and instructional strategies used in their teaching. An appropriately planned lesson is one which takes into consideration students' characteristics such as their prior knowledge and ability hence leading to meaningful and effective learning.

Cochran et al. (1993) commented that the Shulman's PCK conception is compartmentalised and static. They argued that teachers' knowledge on teaching should be dynamic, developing and growing continuously. Based on this constructivist view; they named their refined version of PCK pedagogical content knowing (PCKg) which means the expertise of teaching with a dynamic nature. PCKg is an integration of four types of teacher knowledge, namely subject matter knowledge, knowledge of pedagogy, knowledge of students, and knowledge of environmental contexts. The emphasis is on the last two components with teachers' understandings of their students as a central role in teaching. The assumption underlining this conception is that as teachers' experience grows, all the four components in PCKg grow too. The components may grow in an integrated manner if the teachers experience the four components simultaneously, otherwise the growth of the components may not be always equal. PCKg development is often accompanied by conceptual change and conception integration as a result of thousands of hours of teaching, observing and reflecting by teachers on their own as well as others' teaching. As PCKg develops and expands the distinction between the various constructs will blur out (Tuan, Jeng, Whang & Kaou, 1995).

Veal and MaKinster (1999) pointed out the lack of hierarchical relationship amongst the attributes in the PCK conceptions thus they designed a PCK taxonomy which displays relationship and connections among the attributes or components. The taxonomy consists of three levels with increasing specificity, namely general PCK, domain specific PCK and topic specific PCK as in the teaching of Chemistry (Figure 1).

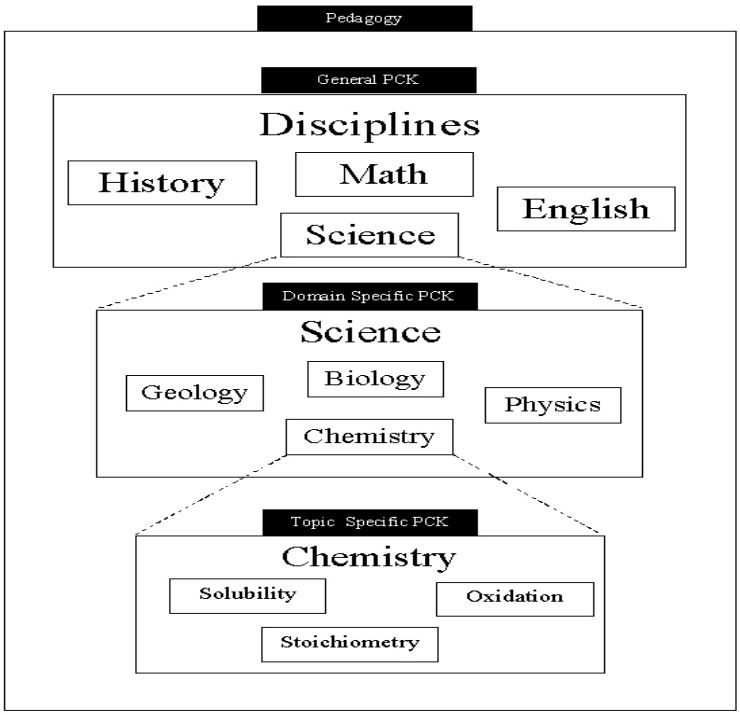

Figure 1. The taxonomy of PCK Veal and MaKinster (1999)

As a branch of science, the general PCK refers to the knowledge of concepts and strategies specific to the teaching of science. Besides Chemistry, there are other branches of science such as Biology and physics, therefore there is domain specific PCK for Biology, Chemistry and Physics respectively. Subsequently, although each of the scientific domains involves laboratory work, the Chemistry laboratory work uses more chemicals and involves titrations which is distinctive from the Biology and Physics laboratory work. Additionally, common concepts taught in different domain often have a different emphasis and require different teaching styles and teaching methods. For instance, both Physics and Chemistry curriculum teach the concept of an atom, particle and thermodynamics, yet these concepts are taught from different perspectives with different emphases in their respective domain. Similar to the PCK conception of Cochran et al. (1993), the PCK taxonomy of Veal and MaKinster (1999) is developmental too. Besides the various levels of PCK are hierarchical, the attributes in the PCK conception are hierarchical as well (Figure 2).

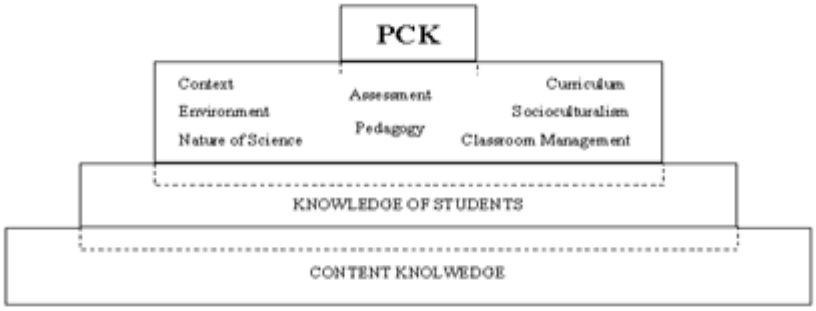

Figure 2. The taxonomy of PCK attributes of Veal and MaKinster (1999)

There are ten attributes in the PCK taxonomy of Veal and MaKinster (1999). The different levels in the PCK taxonomy indicate different priorities. The most significant attribute is the subject content knowledge which is situated at the base of the pyramid implying a strong subject content knowledge is vital for the development of PCK. The second level is the knowledge of students. The third level of the taxonomy that is the tip of the pyramid contains eight embedded attributes such as pedagogy, curriculum, classroom management, nature of science, environment, context, assessment and socioculturalism. The eight attributes are of equal significance, but are less significant compared to the subject content knowledge and student knowledge. The different attributes of PCK within the same layer are not necessarily arranged in a hierarchical manner. According to Veal and MaKinster (1999), teachers need to possess a thorough understanding of the knowledge of subject content and student knowledge before they learn and develop minor attribute in the PCK taxonomy. They also shared similar view that the development of one attribute may also lead to the development of the others wherein the attributes integrate with each other and may develop separately or collectively. They caution that the layering of the attributes in a 'pyramid of knowledge' does not imply a linear process for a teacher to become an effective teacher, rather the pyramid will grow in size with time.

Barnett and Hodson (2001) believe that good teachers employ four categories PCK in their teaching, which are: (1) knowledge of learners' existing knowledge; (2) knowledge of effective teaching/learning strategies according to particular content; (3) alternative ways of representing the subject matter; and (4) curricular saliency. Knowledge on curricular saliency enables the teacher to determine the depth of the content and contextualisation. Their components of PCK are similar to those suggested by Marks (1990) in the teaching of mathematics. Table 1 shows a summary of the attributes of various conceptions of PCK.

Table 1 Summary of Some of the Definitions and Concepts of PCK

Attributes & components of PCK	Definition and concept of PCK						
	Shulman 1986	Smith & Neale 1989	Grossman 1990	Marks 1990	Cochran et al. 1993	Veal & MaKinster 1999	Barnett & Hodson 2001
SMK		√		√	√	√	√
SK	√	√	√	√	√	√	√
RIS	√	√	√	√			√
Context					√	√	
CK			√	√		√	√
PTSM			√				
Ass						√	
GP					√	√	
NS						√	
CM						√	
Soc.						√	
SMK – Subject matter knowledge		RIS - Representations and instructional strategies			SK – Student knowledge		
CK - Curricular knowledge		PTSM – Purpose for teaching subject matter			ASS – assessment GP - General pedagogy		
NS – Nature of Science		CM – Classroom management			Soc. – Socioculturalism		

Source: adapted from Figure 2 Domains of teacher knowledge: Four alternatives (Carlson, 1999, pp. 137).

With the increasing integration of the digital technology in teaching, Mishra and Koehler (2006) forwarded another type of PCK namely, technological pedagogical content knowledge (TPCK) which was built on Shulman's formulation of PCK. Mishra and Koehler (2006) argued that teachers require TPCK in order to attain thoughtful pedagogical uses of technology in their teaching.

Three attributes seem to dominate in most of the PCK conceptions in Table1; namely: student knowledge, subject matter knowledge and knowledge of instructional strategies. The PCK conception proposed by Veal and MaKinster (1999) seems to have the most number of attributes. Although some of the conceptions may contain fewer attributes compared to that of Veal and MaKinster (1999), in fact, many of the minor attributes are either clustered under an attribute as in the PCK definition of Cochran et al. (1993) and Grossman (1990) or as the knowledge bases upon which teachers draw when they teach, as in the PCK definition of Shulman (1986b).

PCK seems to demonstrate certain characteristics. First, similar to teaching, it is complex and difficult to define explicitly. Second, it is a construct made up of attributes. The attributes are interrelated and connected with each other, they also integrate with each other and operate collectively (Cochran et al., 1993), overlapping with each other and become undistinctive (Grossman, 1990), finally the resulting PCK differs from the attributes (Baxter & Lederman, 1999; Cochran et al., 1993). The integration of PCK attributes is vital to effective science teaching; in fact the more integrated the attributes, stronger and more developed is the PCK (Smith & Neale, 1989; Tuan et al., 1995). Third, the attributes are expected to develop and expand continuously. Fourth, PCK is only useful when it is applied (Davis, 2004). The growth and the development of these attributes can happen in stages, collectively or individually and at different rates. Often the development of one attribute triggers the growth of other attributes (Cochran et al., 1993; Veal & MaKinster, 1999).

PCK is expected to expand and grow with the teaching experience of a teacher. It is generally agreed that experienced teachers tend to have a richer repertoire of instructional strategies, a good understanding about the students and confidence in the content that they teach. However, it is not

uncommon that under certain situations, experienced teachers may have little or no PCK, particularly when they have to teach a subject outside their subject areas (Hasweh, 1987; Marks, 1990; van Driel, Verloop & De Vos, 1998) and also when the teachers fail to learn from their experience because they do little or no reflection on their teaching (Berliner, 1987). Berliner (1987) claimed that experience is not a synonym for expertise. Teachers are encouraged to practice lifelong learning in order to develop PCK throughout their teaching career (Shulman, 1986b; Veal & MaKinster, 1999).

The importance of PCK in teacher education is noted from the recurring suggestions from researchers to teach it explicitly in the teacher training program (Anderson & Mitchener, 1994; Geddis, Onslow, Beynon & Oesch, 1993; Shulman, 1986a, 1986b). Geddis et al. (1993) termed it crucial for student teachers to learn this knowledge of experienced teachers or "wisdom of practice" while learning to teach, and at the same time bridging the gap between the pedagogical and content aspects of science teacher preparation.

Sockett (1987) critiques Shulman's PCK conception for overlooking the tacit knowledge of experienced teachers. He argues that experienced teachers do not necessarily articulate all their wisdom and experience at a particular moment as tacit knowledge is often difficult to articulate. However, one may not deny the preciseness with which Shulman describes PCK as the best knowledge of teaching which lies "at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (Sockett, 1987, pp.15).

Development of teacher's PCK

Student teachers enter teacher training college with some amount of PCK. Their perceptions and ideas on teaching (Davis, 2004) and the subject matter knowledge which they learned in school and university form the foundation of their PCK. Although little is known about how teachers develop their PCK, two ingredients are assumed to contribute to its development, that is, subject matter knowledge and teaching experience (Lederman, Gess-Newsome & Latz, 1994; Tuan et al., 1995; van Driel, De Jong & Verloop, 2002; van Driel et al., 1998) whereby adequate subject matter knowledge is a prerequisite (van Driel et al., 1998). Basically, the development of PCK is perceived as the integration of subject matter knowledge and pedagogy knowledge (Marks, 1990) and as a synthesis from the simultaneous development of the various domains (van Driel et al., 1998). Thus the prospective and novice teachers tend to have inadequate or no PCK at their disposal.

Many researchers do agree that the development of PCK is embedded in classroom practice (van Driel et al., 1998) because teachers derive PCK from their own practice and also from formal training. They suggest that successful teachers have "well-developed' PCK and that it is possible to enhance novice teachers" PCK through intensive intervention with short-term skills-oriented workshops (Clermont, Krajcik & Borko, 1993).

As knowledge of teaching, PCK therefore is influenced by factors which affect teaching such as personal learning history, beliefs, conception of teaching and learning, teaching preferences or values, teacher education, teaching practice experience, reflection, students and others (Berliner, 1987; Grossman, 1990; Gudmundsdottir, 1990; Hauge, 2000; van Driel et al., 1998; Tuan et al., 1995). Some of the factors are complex and sometimes even competing, some are explicit such as curriculum and others implicit, such as teacher's intention and beliefs about the teaching and learning of science.

Shulman (1987) had identified six processes in his Pedagogical Reasoning and Action Model (PRA Model) that generate PCK and support the development of PCK among teachers. The six processes are comprehension, transformation (preparation, representation, selection, adaptation and tailoring to student characteristics), instruction, evaluation, reflection and new comprehension (Figure 3).

No.	Process	Description
1	Comprehension	Of purpose, subject matter structures, ideas within and outside the discipline
2	Transformation	
	(i) Preparation	Critical interpretation and analysis of texts, structuring and segmenting, development of a curricular repertoire, and clarification of purposes
	(ii) Representation	Use of a representational repertoire which includes analogies, metaphors, examples, demonstrations, explanations, and so forth
	(iii) Selection	Choice from among an instructional repertoire which includes modes of teaching, organizing, managing, and arranging
	(iv) Adaptation and tailoring to student characteristics	Consideration of conceptions, misconceptions, and difficulties, language, culture, and motivations, social class, gender, age, ability, aptitude, interests, self-concepts, and attention
3	Instruction	Management, presentations, interactions, group work, discipline, humour, questioning, and other aspects of active teaching, discovery or inquiry instruction, and the observable forms of classroom teaching
4	Evaluation	Checking for student understanding during interactive teaching. Testing student understanding at the end of lessons or units. Evaluating one's own performance, and adjusting for experiences
5	Reflection	Reviewing, reconstructing, re-enacting and critically analysing one's own and the class's performance, and grounding explanations in evidence
6	New Comprehension	Of purposes, subject matter, students, teaching, and self. Consolidation of new understandings, and leanings from experience

Source: Shulman (1987, p. 15)

Figure 3. A Model of Pedagogical Reasoning and Action

Comprehension

Comprehension refers to the comprehension of the subject matter knowledge one is going to teach. Teachers need to understand subject matter knowledge in order to carry out good teaching and enhance student understanding (Cochran, King & DeRuiter, 1991). Hasweh (1987) refers teaching as an interaction between at least three elements that is teachers, students and subject matter and a teacher needs to know the content he or she is going to teach in order to teach adequately. Shulman (1986b) argues that "comprehension alone is not sufficient as the usefulness of such knowledge lies in its value of judgments and action" (pp. 14). Teachers with more subject matter knowledge are capable in reorganizing material in the textbook to match with their own understanding and spotting misleading or poorly articulated themes. They are more sensitive to students' misconceptions and made more intra-disciplinary connections in the instruction (Hasweh, 1987). According to Resnick (as cited in Wilson et al., 1987) "to understand something is to know the relationships. Human knowledge is stored in clusters and organized into schemata that people use both to interpret familiar situations and to reason about new ones" (pp. 477).

Transformation

According to Shulman (1987), teachers often reflect critically on and interpret the subject matter before transforming their understanding of the content they are going to teach into a form understood by the students. Teachers are likely to engage in the following four processes while doing transformation: preparation, selection, representation and adapting and tailoring to students' characteristics. The four processes may occur either concurrently, at different sequence or be missing altogether. During the preparation, teachers try to interpret critically and understand the content. They interpret the curricular materials such as the syllabus, curriculum specification and textbook. At the same time, they also try to detect errors in the curricular materials, structure and segment the content, and make necessary adjustments guided by curricular goals and purpose.

The objective of education is to ensure students acquire and retain information delivered by teachers. In order to ensure learning takes place, ideas should be presented with support structures and not as isolated facts and information. Experienced teachers are more familiar with the most effective ways of helping students learn the information which they need to know (Arends, 1994), though the novice teachers may be less familiar, they do have their own specific representations about the ideas and concepts in the content and their limited repertoire of representations will grow with experience (Wilson et al., 1987).

It is important for teachers to represent the subject matter at the same time taking into account the representations students are constructing as a means of understanding the content taught (Wilson et al., 1987). Successful teachers must be able to transform their understanding in ways of representation understood by students. In brief, teachers need to possess two types of knowledge that is, knowledge of the subject matter and knowledge of communicating the subject matter in a way understood by the students (Dewey as cited in Wilson, Shulman, & Richert, 1987). Dewey called this ability to transform understanding, as teachers had 'psychologised' or transformed the subject matter for the purpose of teaching.

Shulman (1986b) stated 'learners are unlikely to appear before them [teachers] as blank slates' (p. 10). As a result of interacting with the surrounding world, students make observations of physical phenomena and have their own explanation for the phenomena and they bring these preconceptions which are often misconceptions to the class. If teachers are to be fruitful in their chosen strategies in their teaching, they have to reorganise the understanding of the students, and be aware of students' misconceptions (Chin, Lee, Boo & Lee, 2002; Shulman, 1986b). Based on the misconceptions identified, they create opportunities for students to reorganise and restructure their existing knowledge and at the same time accommodate the new knowledge by integrating the new knowledge with the existing knowledge. This process of constructing and reorganising these conceptions is normally a slow one (Stavridou & Solomonidou, 1998). The teachers need to sequence their teaching so as to match with the students' progress.

Apart from knowing students' learning difficulties, teachers need to take into consideration other factors such as students' expectations, prior knowledge, ability, gender, language and motivations while choosing the types of representations for the class. Even with a sound understanding of the content the teachers are going to teach and student knowledge, teachers need to decide the amount of content they are going to teach to the class besides selecting suitable representations for the instruction. It is impossible for the teachers to teach everything in the content to everyone (Gunter et al., 1999).

Instruction

Instruction is the central component of teaching and it is aimed at transmitting knowledge and understanding to students (Wilson et al., 1987). It is a step-by-step procedure that was designed to achieve specific learning outcomes. At the same time, it is essential to place the concern for students as the foundation of all instructional planning (Gunter et al., 1999). To Shulman (1987), instruction includes "organising and managing the classroom; presenting clear explanations and vivid descriptions; assigning and checking work; and interacting effectively with students through questions and probes, answers and reactions, and praise and criticism" (pp. 17).

Gunter et al. (1999) suggest three guidelines for planning an instruction. First, teachers must be clear on "the needs of the students and the goals of education" (pp. xv); second, it is essential to formulate objectives and evaluation procedures while planning for the instruction; and finally, teachers need to choose suitable materials and procedures to deliver the content. Additionally, learners develop their potential by learning in more than one way. Thus, it is essential for teachers to use a variety of approaches in their

teaching in order to enhance students' potential. They describe the characteristics of effective instructional models as those allowing students to participate actively in the learning process and learn in a sequence.

Evaluation

There were two types of evaluation – formative or summative. According to Shulman (1987), the main purpose of doing evaluation is to find out the learning progress of students, whether they understand the content taught and also as a tool to grade and rate the students for certification. Besides the checking for understanding and misunderstanding, teachers evaluate their own teaching as well by looking at the lesson and materials employed. Tan, Yap & Wan (2002) state that a "good lesson preparation and planning is not complete without an evaluation of students' understanding and the self-reflection of the teacher" (pp.118). They further argue that a fair and accurate evaluation is extremely important to provide an accurate report about students' learning. Evaluation in the class can take various forms such as questioning, individual or group work, quizzes, written reports, tests and others.

Reflection

According to Holly (1989), when a teacher does reflection, he or she asks about the 'why' and 'what' of doing thing, and how a decision was made, based on what grounds and why a certain decision was preferred. According to Berliner (1987), an experience that is reflected upon is of value to teachers to improve their practice. To reflect, teachers have to question themselves on what they were doing, to monitor, to seek alternatives, to solve problems, to evaluate, to identify their weaknesses and strengths and make necessary adjustments for future teaching. Scholars believe that only teachers who do reflection over their own teaching are able to make changes to their teaching, thus improving their practice.

New comprehension

Upon going through the whole process, from preparation to the implementation of a teaching episode, teachers are expected to achieve new comprehension of curricular goals, content, students and the pedagogical processes (Shulman, 1987). A new insight and a new understanding of the whole teaching and learning process is going to improve the teaching of the same topic in the future.

Shulman (1987) pointed out that although the six processes in the PRA Model are listed in sequence, it is not necessary for them to happen in that order. Some processes may not happen at all and some may be more dominant and more elaborated.

Methods used to assess PCK

Shulman (1987) advances the Pedagogical Reasoning and Action Model which consists of six processes that generate PCK. These processes involve mental processes of reasoning and understanding, therefore it is essential to look into the cognitive structure of teachers which is embedded in the long-term memory while assessing the processes. The outcomes of the processes can be accessed via documents such as lesson planning and concept mapping.

Baxter and Lederman (1999) view PCK as both an internal and external construct because "it constitutes what a teacher knows, what a teacher does, and the reasons for the teacher's actions' (pp. 158). The internal construct of PCK is situated in the long-term memory of the teachers. It is referred as the "teachers' understanding of content-specific examples that best represent specific topics, and knowledge of common student difficulties with specific topics" (pp. 148). As a cognitive structure, PCK cannot be observed directly, furthermore not all of the teachers' knowledge is retrieved during a specific teaching episode. Therefore, a combination of approaches is needed to gather information about what teachers know, what teachers believe and their reasoning. In fact, the view of PCK obtained from any one approach is likely to produce an incomplete and distorted picture about PCK. In order to obtain a better picture of the teachers' PCK, it is crucial for them to articulate in a language of their own.

Mulhall et al. (2003) use classroom observations, individual and group interviews to study a group of experienced science teachers. They asked the teachers to explain how they were going to teach the big ideas and principles in Science. Loughran et al. (2004) comment that due to the tacit nature of PCK, it is difficult to categorise and exceptionally difficult for teachers to articulate. As a result, data collection methods such as interviews and classroom observations are unable to portray and document the actual account of PCK. They

had derived alternative methods called 'PaP-eR and CoRe' as a tool to reveal PCK (Eames, Williams, Hume & Lockley, n.d.; Loughran, Mulhall & Berry, 2008).

A wide array of methodologies was used to measure and assess PCK. Among some of the widely used data-collecting techniques are paper and pencil tests (Loughran et al., 2008; Muhammad Abd Hadi Bunyamin & Fatin Aliah Phang, 2012), concept maps, pictorial representation, classroom observations and interviews. Multi-methods seem to be a common practice (Baxter & Lederman, 1999). Tuan et al. (1995) discussed the advantage of using a few of the data collecting techniques. For instance, semi-structured interviews allow researchers to do in-depth probing on the interviewees thus enabling to rich data to support classroom observations. Post teaching interviews allow a researcher to view the nature of PCK. Written documents such as course work assignments, journals, and lesson plans do provide a rich source of data too.

CONCLUSION

After about three decades since its introduction, is PCK remains useful? As a science teacher educator, Abell (2008) argued that PCK still remains a useful idea because it helps her to understand teaching process and generate viable instructional strategies in her methods courses. Berry, Loughran and van Driel (2008) further stressed that though PCK as teacher professional knowledge was difficult to define, categorise, articulate and document, it is increasingly important to do so as PCK is the professional knowledge of teachers. Additionally, the collection of the successful teaching of the experienced and expert teachers from the research on topic specific PCK can be used as guidelines to enlighten teaching and learning and as teaching materials in teacher education programs.

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