Chapter 16
Pedagogical Content Knowledge in Science and Technology Education

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Abstract This chapter looks at a construct in teacher knowledge known as pedagogical content knowledge (PCK), which has been viewed by many to be the 'missing paradigm' in teacher education research. The history of PCK is presented, recent conceptualisations of PCK are explored and another construct, known as technological pedagogical content knowledge (TPACK), is introduced. The recent COVID-19 pandemic has led to opportunities for both students and teachers to work through online platforms, therefore development of TPACK would be viewed as more important now than ever.

Teaching strategies that show well-developed knowledge of how to teach scientific content are explored and ways of capturing and measuring PCK and TPACK are presented. Throughout the chapter, the author will engage in reflective consideration for how PCK, in particular, has shaped her knowledge of teaching and, to that end, presents a new model to conceptualise PCK that includes consideration of current trends in science and technology education.

Keywords Pedagogical content knowledge · Technological pedagogical content knowledge · Teaching and learning · Content representation

Introduction

Pedagogical Content Knowledge was originally defined by Shulman (1986) as:

'For 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 demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others' (Shulman, 1986, p. 9).

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PCK signifies not only the amount of knowledge that a teacher has of the content, but also the organisation of that knowledge (Shulman, 1986). It is an amalgamation of knowledge of content, but also how to teach that content to make it understandable to others. A scientist, for example, would have very well-developed content knowledge, but may not necessarily have the knowledge to teach that content to others, therefore PCK is unique to the province of teachers (Shulman, 1986).

This chapter will critically examine PCK, from its inception to its development in research, and will provide opportunities to look at evidence-based teaching strategies, which, when used efficiently, show well-developed PCK. The concept of technological PCK will be introduced.

The chapter then presents an example of a tool used widely to capture PCK and has been adapted in this chapter to focus on technological pedagogical content knowledge (TPACK). Critical discussion and reflection on PCK, current trends and why it is so important to consider it in the planning and delivery of lessons are provided throughout the chapter.

Pedagogical Content Knowledge (PCK): An Historic and Current Theoretical Construct

The construct of PCK was originally presented by Lee Shulman as the 'missing paradigm' in educational research in the Presidential Address at the 1985 Annual Meeting of the American Educational Research Association. In his address, he proposed that there was an absence of focus on subject matter knowledge and an emphasis on teaching practices in the historical research. Essential questions in relation to knowledge were being avoided: questions like *'how do teachers decide what to teach, how to represent it, how to question students about it and how to deal with problems of misunderstanding?'* (Shulman, 1986, p. 8). Furthermore, the knowledge components of subject matter knowledge and pedagogical knowledge were often considered in isolation from each other and both needed to be viewed as mutually inclusive in order to allow for the transformation of effective teaching and learning in the classroom – in other words, to make the material that you are teaching understandable to others (Shulman, 1986).

Since its original inception, it has informed the direction of significant research in education and has undergone transformations in terms of its reconceptualisation by many distinguished scholars involved in PCK research. In order to understand its evolution, it is crucial to present the components of PCK as envisaged by various scholars dedicated to the field of PCK research. The following (Table 16.1) presented by Lee and Luft (2008) provides a summary of such components, as scholars seek to find a conceptualisation of PCK that best provides for Shulman's original vision of what PCK is.

These are all very much historic conceptualisations of PCK. The model by Magnusson et al. (1999) has been used extensively in research and an adapted version will be presented at the end of this chapter, with consideration for technological applications.

Table 16.1 Historic conceptualisations of PCK adapted from Lee and Luft (2008, p. 1346)

Knowledge of								
	Subject matter	Representations and instructional strategies	Student learning and conceptions	General pedagogy	Curriculum and media	Context	Purpose	Assessment
Shulman (1987)	a	PCK	PCK	a	a	a	a	b
Tamir (1988)	a	PCK	PCK	a	PCK	b	b	PCK
Grossman (1990)	a	PCK	PCK	a	PCK	a	PCK	b
Marks (1990)	PCK	PCK	PCK	b	PCK	b	b	b
Cochran et al. (1993)	PCKg	b	PCKg	PCKg	b	PCKg	b	b
Fernandez-Balboa and Stiehl (1995)	PCK	PCK	PCK	b	b	PCK	PCK	b
Magnusson et al. (1999)	a	PCK	PCK	a	PCK	a	PCK	PCK
Carlsen (1999)	a	PCK	PCK	a	PCK	a	PCK	b
Loughran et al. (2001)	b	PCK	PCK	b	PCK	b	PCK	PCK

a distinct category in the knowledge base for teaching, *b* not discussed explicitly, *PCK* Pedagogical Content Knowledge, *PCKg* Pedagogical Content Knowing

There have been many recent expansions and interpretations of the model of PCK, so much so that Barrett and Green (2009) state that there are as many variations of the term PCK as there are researchers interested in it. Indeed Loughran et al. (2006) consider that some examples of PCK bear little resemblance to the construct originally developed by Shulman (1986). While the above table provides historical conceptualisations that have been presented in the literature on PCK since its inception into the research realm, Table 16.2 below developed by Lehane (2016) provides

Table 16.2 Recent conceptualisations of PCK (Lehane, 2016)

Literature source	**PCK components**
Ball, Thames and Phelps	Knowledge of: (a) subject area, for example being able to write up a report for a laboratory experiment; (b) content and students, which refers to knowing the students, for example their commonly held misconceptions as well as knowing the subject matter; and (c) content and teaching.
Henze, van Driel and Verloop	Knowledge of: (a) instructional strategies; (b) knowledge about students' understanding; (c) knowledge about ways to assess students' understanding; and (d) knowledge about goals and objectives of the topic in the curriculum.
Park and Oliver	Orientations towards science teaching. Knowledge of: (a) students' understanding of science; (b) science curriculum; (c) instructional strategies and representations; and (d) assessment of science learning. Teacher efficacy. Model reflects interactivity and coherence between components. This model is referred to as the ***hexagon model***.
Hagevik, Veal, Brownstein, Allan, Ezrailson and Sean	Knowledge of: (a) context, curriculum and assessment; (b) instructional strategies and representations of teaching science; (c) student learning; and (d) knowledge of student understanding about science concepts.
Mavhunga	Knowledge of: (a) students' prior knowledge including misconceptions; (b) curricular saliency; (c) what makes a topic easy or difficult to understand; (d) representations including analogies; and (e) conceptual teaching strategies.
Types of PCK	
Veal and McKinster	General PCK, Domain-specific PCK and Topic-specific PCK.
Lee and Luft (2008) – drew on the work of Gess-Newsome	Transformative (synthesis of all the knowledge required to be an effective teacher) versus Integrative PCK (the knowledge domains of subject matter, pedagogy and context exist as separate entities).
Daehler and Heller	Espoused (teacher knowledge) and enacted PCK (what happens in the classroom). A teacher's espoused PCK does not necessarily mean that it will be enacted in the classroom (Aydeniz & Kirbulut, 2011). Park, Jang, Chen and Jung (2011) considered two similar dimensions of PCK: understanding (what a teacher knows) and enactment (what a teacher does in the classroom).

a summary of some of the more recent conceptualisations and types of PCK found within the relevant literature:

The varying conceptualisations of PCK presented in both tables highlight the complexities around defining and understanding what teacher knowledge is and on what the focus should be.

In recent years, the concept of technological pedagogical content knowledge (TPACK) has been developed and utilised in research and practice and will be discussed in more detail later on in the chapter. It must be mentioned that, while science and technology education are the focus of this chapter, PCK as a construct can be considered in the teaching of all subjects.

Pedagogical Content Knowledge: Why Is It Important?

In Shulman's address, he discussed the negative association with teaching and referenced George Bernard Shaw's infamous aphorism that 'He who can, does. He who cannot, teaches' (Shaw, 1903, cited in Shulman, 1986). Shulman's research led him to decipher a distinction between content knowledge and pedagogical method in the hope that the findings of his research would reverse the current negative associations with teaching, so that it could be viewed as the complex activity that it is (Shulman, 1986).

In order to be able to distinguish the knowledge of, say, a scientist from that of a science teacher, it is important to consider what enhanced knowledge a science teacher may have that a scientist does not necessarily possess. The ability to be able to provide understandable explanations to specific students, to be able to address diverse needs in the classroom and to provide opportunities for specific pedagogies that enhance the learning of students, is an example of how a scientist's knowledge may vary from that of a science teacher, effectively their knowledge of science content and how to teach that content to make it understandable to others, and that is PCK. Such knowledge is fundamental to the students' learning experience and that is why it is so important to consider it in both initial teacher education and for in-service teachers out on practice.

From a pre-service teacher's perspective, this author has worked in initial teacher education for 12 years, using PCK as the central tenet in her teaching. She continually tries to emphasise the equal importance of understanding the content that one is to teach, but how to teach it in such a way that it is made comprehensible to others – this is the essence of PCK. Despite her attempts, pre-service teachers struggle to focus on that amalgamation of different knowledge domains and therefore it is necessary to find concrete ways of making PCK part of a pre-service teacher's consideration for how they plan to teach. Later in this chapter, a tool to capture PCK will be examined.

PCK is, of course, crucial for in-service teachers; however, with the limited classroom experience that pre-service teachers have on the 'other side of the classroom desk', and their often-tenuous journey transitioning from a student to a teacher, having a framework to guide their developing knowledge of how to teach is warranted.

Introducing Technological Pedagogical Content Knowledge (TPCK/TPACK)

Technological pedagogical content knowledge (TPCK), which is now referred to TPACK (technology, pedagogy **and** content knowledge), is a more recent concept that is effectively an extended conceptualisation of PCK to include technology knowledge (Harris et al., 2009). The three bodies of knowledge of content, pedagogy and technology knowledge, and how they interact with each other, produces a flexible approach to teaching that allows for the purposeful integration of technology into a teacher's repertoire.

It is considered crucial for effective teaching with technology, both in science and technology education, as interaction with technology can promote critical thinking and other key skills synonymous with both science and technology as school subjects. The recent COVID-19 pandemic and the subsequent switch to online teaching has illustrated the need to include technological applications in our pedagogical approaches, regardless of whether the setting is within a school context or not. However, the swift nature of having to adapt to online teaching has led to teachers' TPACK being tested, with varied impact on student learning. Significant research has already taken place on the impact of online teaching on student learning, and perspectives of both teachers and students show mainly negative associations with online teaching (Nambiar, 2020). The key question is, why can both students and teachers hold negative orientations towards online teaching? It can be suggested that the pedagogical approaches employed by the teachers and the low levels of self-efficacy with using online platforms can affect the experiences of both teachers and students, both of which are intimately linked to TPACK.

There are also additional challenges in teaching with technology, as identified by Harris et al. (2009). Social and contextual factors, such as poor infrastructure around technology available to students both at home and within the classroom, would be seen as particular challenges, and something that the use of online teaching due to school closures during the COVID-19 pandemic identified was the social gap of technology accessible to different students. What is only now becoming apparent is the social divide and, as a result, the learning divide between students with and without appropriate access.

An additional challenge presented by Harris et al. (2009) is the experience of teachers of using technology, which is in effect their TPACK. TPACK, like PCK, develops with experience and reflection on experience so, if teachers are to develop their TPACK, they need to use professional learning opportunities to engage in reflection.

Examining How PCK and TPACK Relate to Science and Technology Teaching

Significant research has looked at ways of conceptualising PCK, and measuring and capturing PCK, with more recent research looking at particular aspects of PCK. For example, Lehane (2019) examined how a tool used to capture PCK, known as the content representation (CoRe) tool, could capture pre-service teachers' understanding of nature of science. Other research has focused on the teaching of particular topics (e.g., Gencer and Akkus (2021), who focused on the interactions between chemical species and states of matter through a PCK lens), or in the teaching of particular scientific process skills (e.g., Lehane, 2016).

Other research has looked at the idea of enacted PCK versus espoused PCK, in which the former looks at PCK in action in the classroom, while the latter examines teachers' perceived PCK, which may not necessarily transfer into classroom practice (Lehane, 2016).

More recent studies have begun to use the CoRe tool to investigate early childhood teachers' collective PCK and personal PCK (Buldu & Buldu, 2021). The CoRe tool is often used in group settings where teachers collectively present their ideas of how they would teach particular topics, and the very nature of this collaborative effort and sharing of ideas can enhance their own PCK construction (Lehane, 2016).

Ways of measuring PCK have been a key focus of research over the years, with new instruments being developed and validated (see He et al., 2021). The overarching rationale for finding ways to capture and measure PCK is that it is an elusive construct and, in order for a teacher's PCK to result in impact in the classroom, it is crucial to find ways of making it visible.

The research into teachers' PCK is tending to focus more recently on pre-service teachers, rather than in-service teachers, perhaps indicating the need to view this as a necessary framework to develop their understanding of the key knowledge components needed to be an effective classroom practitioner.

Teaching Strategies that Suggest Well-Developed PCK and TPACK

The use of evidence-based teaching strategies in the classroom would suggest high levels of PCK and TPACK. The following section presents and describes some strategies that can be used that can have a technology focus in their implementation. All of these strategies would be seen as having high effect sizes according to Petty (2009), which show evidence of enhanced achievement levels of learners engaged in such strategies, compared to other learners.

- ***Jigsaw methodology***
- The jigsaw methodology is a co-operative learning activity where students work in 'expert groups' to complete a task assigned to them, often engaging in a problem-solving approach (see Chap. 18). They then return to their 'home groups' and share their learning from the information garnered from engaging in the task in their respective expert group. Each member of a 'home group' has come from their own 'expert group', where they have completed their own individual task to provide the other members of the 'home group' with key information from same. The key benefit of the jigsaw methodology is that students are constructing their own knowledge while working in groups, learning key skills such as communication and working with others. Additionally, it provides students with a sense of responsibility that they bring back accurate information to their 'home group' members. Finally, due to the fact that each task results in different information being generated and summarized, the jigsaw methodology can be used to teach a significant amount of content. From a technology perspective, breakout rooms on learning platforms can be used to assist with this. Also, tasks could involve online research for specific tasks.
- ***Interactive video methods***
- A key technology-based methodology would be the use of interactive videos, which can be used in tangent with other teaching strategies such as note-taking and summarizing, both described in due course.
- ***Concept mapping***
- Concept maps are graphical organizers, which provide a way of representing students' knowledge. The content related to a particular topic is presented in a hierarchical structure, from general to more specific concepts (both presented in nodes) related to a topic, with linking phrases, cross-links and propositions between the concepts. A concept map could be used to summarize information garnered from online research conducted by the students. Like all graphical organizers, concept maps summarize and synthesize key concepts related to a topic, but the presence of linking phrases, cross-phrases, etc., where one has to make a connection between one concept and another, requires deeper thinking and a well-developed knowledge of the topic.
- As well as being used at the end of a research task, they could also be potentially used as a study tool or an assessment tool, for example.
- ***Note-taking and summarizing***
- Note-taking is a crucial skill for students to learn, but often it is approached in a didactic way by students taking down notes that the teacher has provided, without opportunity for students to think about what they are writing down. Changing this approach slightly by having students making notes in their own words allows for them to process the information learned in their own way. From a technological perspective, students can engage in online research and, from this, create

their own summary notes. Additionally, online platforms could then be used to share these notes, allowing the teacher to provide appropriate feedback.

- ***Reciprocal teaching***
- This is a strategy used to develop reading comprehension skills and follows a particular cycle during a reading task. It includes five stages: predicting, silently reading, questioning, clarifying and summarizing.
- First, the classroom teacher predicts the content of a paragraph within a piece of text; they then get all students to read a piece of text silently. The teacher then questions the students on particular content in the text, which is followed by the teacher clarifying any misconceptions that the students may have. Next, the teacher summarizes the paragraph in a short phrase or sentence. After this, a student acts as the 'teacher' and the whole cycle starts again with the next paragraph, where they first predict what they think the focus of the next paragraph will be.
- This is an excellent approach to use both in the physical and online classroom environment. Additionally, if used online, the piece of text can be shared on screen and key points highlighted to help guide the readers as they work through the text.
- ***Decisions, decisions***
- This teaching strategy is a series of learning games that are sometimes called 'manipulatives'. Students are given a set of cards containing words, visuals, numbers, etc.; they are then asked to sort, sequence, match, group and classify. From a virtual perspective, students could drag and drop text boxes and diagrams, etc. The management of this activity can vary, with students either completing these tasks individually or in pairs. Online platforms provide breakout rooms where respective students can work together and then come back to the main room to share their findings.
- ***Flipped classrooms***
- The flipped classroom approach is widely used internationally. It consists of students engaging in specific homework tasks, for example, getting students to research information on a particular concept, e.g., to research the effect of pH and temperature on the rate of enzyme activity, which is commonly found on biology syllabi internationally. Students then, in class, present their findings from looking at secondary data available online. With the flipped classroom approach, the majority of work is done by the student independent of the classroom environment, which is subsequently used to share what they have learned. The flipped classroom, from a psychology of learning perspective, also has the benefit of providing students with autonomous learning opportunities where they construct their own knowledge and, therefore, it enhances their understanding of a particular idea according to relevant research in the area.

Examining the Place of PCK and TPACK in Initial Teacher Education

This section will explore how PCK awareness can be used to foster the professional development of pre-service teachers in initial teacher education.

A previous section has referred to a PCK tool developed by Loughran et al. (2006) to capture PCK. A CoRe is completed for individual topics. It contains a number of pedagogical prompts on the left-hand side, and consideration of all of these in a teacher's planning and delivery of a topic can significantly enhance the students' learning experience. The person or persons completing the CoRe need to firstly identify what they believe are the 'Big Ideas' in a particular topic, and the pedagogical prompts unpack the Big Ideas. Big Ideas refer to the science ideas that teachers view as crucial for students to develop their own understanding of a particular topic. An example of a Big Idea from the topic of chemical reactions would be: ***'A chemical reaction is when 2 or more substances come together and have an effect on one another to produce different products'*** (Lehane, 2016).

The CoRe tool has been adapted in several studies for different research purposes; for example, Lehane (2016) adapted the CoRe tool to have a scientific enquiry focus. To that end, this author would suggest that the CoRe could be adapted to focus on developing TPACK and is presented in Fig. 16.1 below.

Other research has focused on measuring PCK through tools such as surveys and tests. However, in terms of effectiveness, it can be argued that capturing PCK would have a more significant impact on teachers' professional development and in turn student learning. The reason for this is that tools such as CoRe make visible teachers' knowledge of teaching particular topics. It captures all aspects both of a teacher's pedagogical and content knowledge. Additionally, the CoRe can be completed by teachers in groups, thereby allowing CoRe construction to be a professional learning opportunity as teachers listen to each other's contributions (Lehane, 2016).

	Big Idea	**Big Idea**	**Big Idea**	**Big Idea**
What do you intend students to learn about this idea?				
Why is it important for students to know this – <u>consider specific relevance to everyday life</u>				
What else do you know about this idea (that you do not intend students...)?				
Difficulties/limitations connected with teaching this idea				
Knowledge about students' thinking that influences your teaching of this idea. <u>Consider students' understanding of information technology in your response</u>				
Other factors that influence your teaching of this idea				
Teaching procedures <u>with specific ICT focus</u>				
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses)				

Fig. 16.1 Adapted CoRe

Author's Reflection on Working in PCK Research

I have work in PCK research with pre-service teachers for 12 years. My work has mainly looked at using the PCK tool, CoRe (described earlier on in the chapter), as a lens to capture their PCK, but also to allow the pre-service teachers to socially construct and develop their PCK through working within a group. Pre-service teachers involved in their CoRe sessions have identified significant benefits from their involvement. These benefits include viewing a CoRe as a lesson planning tool to assist them in thinking about how they would represent material to make it comprehensible to others (Lehane, 2016). Pre-service teachers also identified it as a means to document their progress as they develop their own teacher identity, and as a way to think critically by working together as opposed to being given the information by their teacher educators (Lehane, 2016).

Interestingly, I have worked in two universities since becoming a teacher educator and what remains the dominant concern for pre-service teachers is the teaching practicum experience. Despite this concern, those involved in my studies have vocalised that, because of their enhanced understanding of PCK, they can now make the informed connection between what to teach and how to teach it.

There are however some challenges associated with having PCK as the guiding framework for teacher training. I would argue that a teacher's PCK and TPACK need to develop organically; teachers need to see the value in understanding the importance of PCK in enhancing student learning, thereby teacher attitude and motivation to develop can be seen as a significant challenge. Teachers need to be aware of what their own PCK looks like and the CoRe tool can make visible their knowledge of the content and how to teach that content. It can however be a discomforting experience to reflect on your own knowledge as a teacher, but it is a necessary practice in order to enhance the learning of students. We talk about self-assessment as being a crucial part of formative assessment for students, yet we do not seem to routinely self-assess our own knowledge. I would argue that this should become a more routine practice in our own professional development.

Summary Thoughts

Since its inception, PCK has been a key focus of both research and curriculum policy, but the question is, where can we go now with PCK and, indeed, TPACK? John Settlage, in 2013, wrote an article entitled *On Acknowledging PCK's Shortcomings* and provided some interesting perspectives on how PCK is a *'persistent but unfulfilling notion'*, writing that it sparkles but offers little substance (Settlage, 2013, p. 2). Rarely has the literature critically examined PCK and offered negative perspectives. He does concede, however, that when one focuses on student learning as opposed to teacher learning with respect to PCK, this does have some merit (Settlage, 2013).

Reading the work of Settlage has provided me with a reflexive positioning on whether or not I truly believe that PCK needs to be at the heart of pre-service teacher education. Does PCK have a future in our practice? I would argue yes, but I agree with Settlage in terms of its need to be at the fore of documents specifying exemplar tools and practices for science teachers (Settlage, 2013), and that is where tools such as the CoRe tool can be used to draw out PCK and ultimately do what Settlage considers is missing from PCK research – the focus on student learning.

It is also necessary to discuss the model of an initial teacher education programme. For example, when I was training over a four-year concurrent training programme, I was taught pedagogy and content separately and, as a result, I did not see the importance of considering this amalgam of knowing the content and how to teach it. I was often learning the scientific content with students from other courses, therefore, there was no opportunity for discussion of how particular content could be taught in the classroom, i.e., how a teacher could make the material comprehensible to others.

If it had been explained to me while training, I believe that I would have seen the value in such considerations. That is perhaps something to consider going forward, breaking down the wall of theory and practice and allowing pre-service teachers to recognise the importance of their own knowledge development, without the 'academic tagline' that can sometimes be a barrier to their learning.

Furthermore, PCK as a construct is crucial for practicing teachers, particularly with an ever-changing understanding of how students learn. For example, inclusive education is viewed as being the gold standard of a teacher's planning and delivery in the classroom, but is an evolving framework. Therefore, PCK awareness needs to diversify to consider the current trends in education and I think that, by re-conceptualising PCK, this can be achieved.

To that end, I have provided a re-conceptualised model of PCK for consideration, which is an extension of the model developed by Magnusson et al. (1999) and is presented in Fig. 16.2 on the next page.

I have presented the above figure in a cylindrical model, as I feel this represents the relationship between all of the components of PCK and how one component informs another. A teacher may have very good knowledge of student-led, evidence-based teaching strategies, but this would need to be informed by their knowledge of students' understanding of science, for example.

Knowledge of context is an important consideration here, as a teacher's PCK can vary with different class groups, class settings and the challenges and opportunities that some groups or settings present. PCK develops with experience, but there is a need to consider both reflection *of* action and reflection *in* action in promoting PCK development. Reflection of action is looking back after an experience, while reflection in action is about looking at one's practice during the experience. Both are crucial for PCK development.

It is hoped that this chapter has provided the reader with some awareness of the importance of considering PCK in teachers' practice, both planning and delivery. It is important to think about your experiences as a student: who did you perceive to be the 'good' teacher? Was it the teacher who was patient or kind, or who

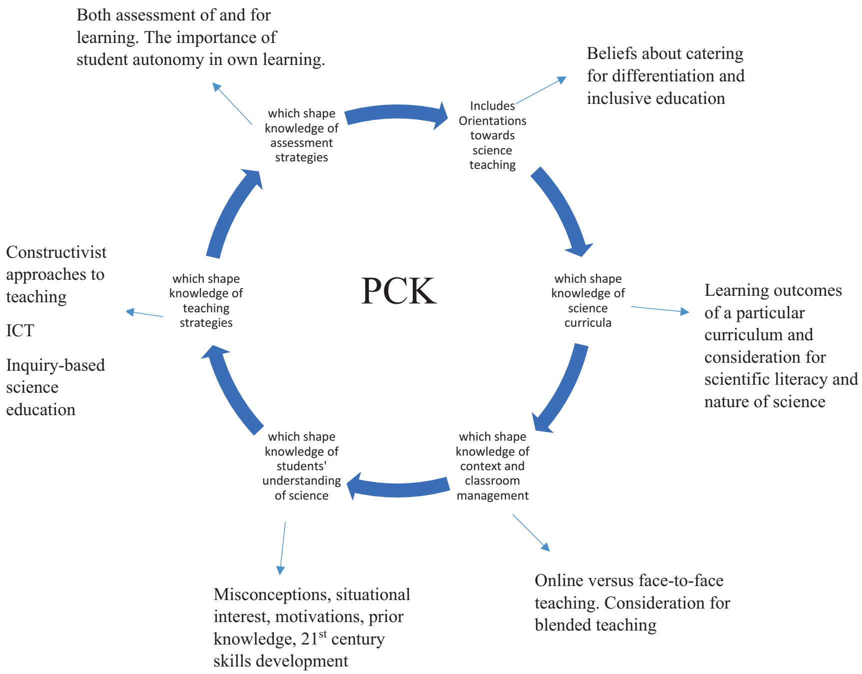

Fig. 16.2 PCK model. (Adapted from Magnusson et al. (1999))

demonstrated knowledge on the content, or who controlled the class well, or who made science fun? Was it a combination of some or all of these, perhaps? That is in essence what PCK is but, crucially, a good teacher does not just come to class and teach; an effective teacher recognises the complex nature of the learning experience and I truly believe that using the CoRe tool can help teachers plan appropriately and where, in turn, each learner can learn to the best of their ability.

Summary

In this chapter, I have discussed the meaning and origins of PCK as an academic construct. I have also focused on the different types of PCK and the importance of understanding PCK and how it can be practically considered in the classroom context. I then moved on to technological PCK (TPACK) and used presented an adapted PCK framework to consider TPACK. The discussion moved on to how both TPACK and PCK can be considered in science and technology teaching as well as in initial teacher education. Finally, the chapter looked at PCK research and the author's experience of working in same and where the research can now evolve and how PCK conceptualisations can be adapted to consider technology within same, through the presentation of an adapted model of PCK.

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