Chapter 4
Reconciliation Between the Refined Consensus Model of PCK and Extant PCK Models for Advancing PCK Research in Science

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Abstract In this chapter, I discuss how two pedagogical content knowledge (PCK) models known as the pentagon model of PCK and the indispensable and idiosyncratic PCK model can be situated within the Refined Consensus Model (RCM) of PCK as I reflect on examples of my earlier research in science teacher education. To guide my previous research, I used the pentagon model of PCK to *capture* and *portray* PCK and the indispensable and idiosyncratic PCK model to *measure* and *assess* PCK. I also illustrate how research methods drawn from these two existing models, including approaches such as PCK mapping, in-depth analysis of PCK, PCK surveys, and PCK rubrics, align with the RCM and what insights the RCM provides for improving these methods and advancing PCK research. The body of this chapter is structured around four distinctive features of the RCM, compared to the earlier Consensus Model (CM), that emerged through a critical comparison of the new model with the two extant PCK models, i.e. the RCM's (1) emphasis on learning context for capturing PCK, (2) explicit visual representation of the link between PCK and the enactment of PCK, (3) distinction between personal PCK and collective PCK, and (4) shift in focus towards PCK development. Major methodological suggestions emerging from this critique for future research into science teacher education using the RCM include data collection encompassing the entire pedagogical cycle and greater attention to contextual factors, student learning, and pedagogical reasoning.

Introduction

As an outcome of the second pedagogical content knowledge (PCK) summit in 2016 and follow-up discussions, the participants developed the refined consensus model (RCM) of PCK, building on the 2012 consensus model of teacher professional knowledge and skills (Gess-Newsome, 2015) and incorporating new ideas that emerged during the summit. Whereas the former consensus model aimed to

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reach agreement in defining PCK, the RCM intends to help researchers identify areas to study for advancing PCK research through situating their studies within the context of teaching practices (see Chap. 2). In this chapter, I describe how my research on PCK for science teaching can be reimagined within the context of the RCM and the insights this updated model provides for future PCK research, especially those relating to research methodology. In particular, I look for areas of compatibility and differences between the RCM and two extant PCK models that have previously guided my research on PCK, i.e. the pentagon model of PCK (Park & Oliver, 2008a) and the indispensable and idiosyncratic PCK model (Park, Suh, & Seo, 2017). Then, drawing on areas where the PCK models diverge from one another, I discuss how the research methods used to portray and assess PCK, derived from the extant models, can be situated within and applied to the RCM.

The body of this chapter is structured according to four distinctive features of the RCM that emerged through critical comparison with the two extant PCK models: (1) emphasis on learning context in capturing PCK, (2) explicit visual representation of the link between PCK and the enactment of PCK, (3) distinction of personal PCK from collective PCK, and (4) shifted focus towards PCK development. While discussing each of the features highlighted by the RCM, important insights into the conceptualising of PCK for science teaching and methodological approaches to PCK research are also provided.

Emphasis on Learning Context in Capturing PCK

One critical difference between the RCM and the original Consensus Model (CM) (Gess-Newsome, 2015) is more explicit and greater emphasis on learning context as an amplifier and a filter of teacher PCK in science, as well as, a mediator for teacher actions. In the RCM, the learning context encompasses a wide range of factors influencing teacher PCK from the broader education sector to individual student attributes (see Chap. 2). The prominence of the learning context in the RCM suggests important implications for methodological approaches, especially for those that I have previously used to capture PCK. For example, the PCK map approach was developed to capture interactions among PCK constituent components by a series of quantifications and visualisations of PCK episodes (i.e. instances of a teacher's PCK in use) that were identified in science classroom observations and teacher interviews (Park & Chen, 2012).

The PCK map approach employs the pentagon model of PCK as both a conceptual and analytic framework that defines PCK as an integration of five constituent components, which are (1) orientations towards teaching science, (2) knowledge of students' understanding in science, (3) knowledge of science curriculum, (4) knowledge of instructional strategies and representations, and (5) knowledge of assessment of science learning (Park & Oliver, 2008a). To accentuate the interrelatedness among them, the components are presented in a pentagon shape in the model, as shown in

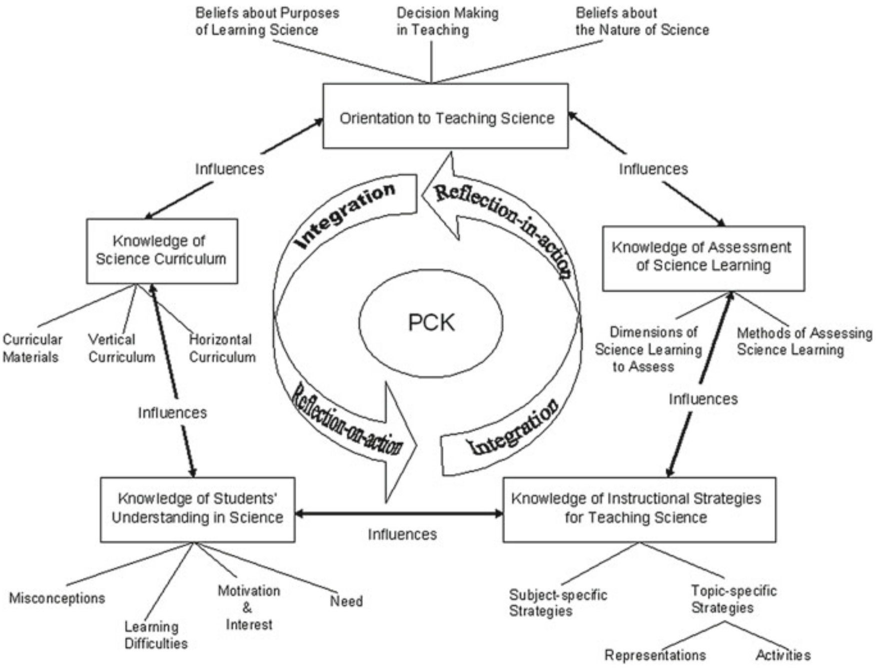

Fig. 4.1 Pentagon model of pedagogical content knowledge for teaching science (Park & Oliver, 2008b)

Fig. 4.1, instead of a linear manner. The components are integrated through complementary and ongoing readjustments by both reflection-in-action and reflection-on-action.

Given the interplay and integration of PCK components, the PCK map approach draws greater attention to individual science teachers' cognitive processes than to the teachers' interactions with contextual factors. Specifically, as shown in Fig. 4.2, during the first step of the PCK map approach, segments that include PCK components are identified from observation and interview data and then synthesised into a PCK episode through the in-depth analysis of explicit PCK. This analysis procedure involves both de-contextualisation and re-contextualisation of data (Tesch, 1990). In other words, extracting data segments that retain PCK components separates them from their original contexts (i.e. de-contextualisation), and these segmented data are then reassembled into a PCK episode through re-contextualisation (Coffey & Atkinson, 1996). As part of the re-contextualisation process, the PCK episode is assembled in terms of what was happening in the context in which the episode occurred and the PCK components involved in the episode. Interestingly, reflecting on this analysis procedure in the light of the RCM, I have come to realise that contextual factors included in the description of a PCK Episode were often limited to a specific classroom environment and did not include sufficient descriptions of broader contextual

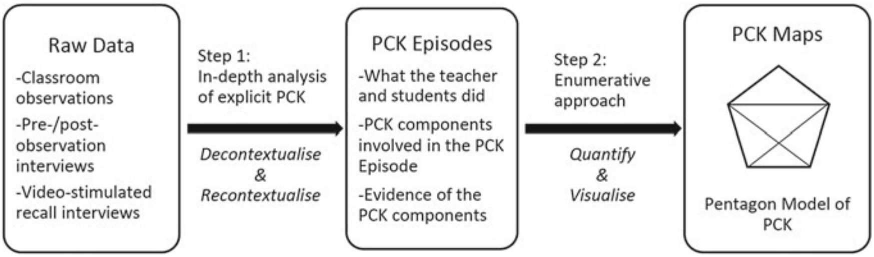

Fig. 4.2 Analysis procedures of the PCK map approach

factors like educational policies, school climate, administrative requirements, and peer interactions.

Once a PCK episode is described in the PCK map approach, interactions among the identified PCK components are represented using the pentagon model of PCK to create the outcome known as a PCK map (Park & Chen, 2012; Suh & Park, 2017). Since the PCK map approach was first developed to answer particular research questions related to interactions among the PCK components, this step centres on visualising only the components' relationships. Consequently, contextual factors associated with the PCK episode are not presented. Recognising the importance of the learning context in the RCM, I acknowledge that the PCK map, as the final product of this analytic method, may unintentionally reinforce a static view of PCK. The impression forms that teachers can develop and apply PCK independently from the learning context (Berry, Depaepe, & van Driel, 2016) even though the mapping process takes into consideration contextual factors. In this regard, modifications to how a PCK map is depicted are suggested to enable those contextual factors directly influencing the PCK components to be visually represented in the PCK map.

Explicit Visual Representation of the Link Between Teachers' PCK and the Enactment of PCK

A central feature of the RCM is that it attempts to clearly illustrate PCK in practice (i.e., enacted PCK (ePCK)) as teachers' application of PCK during a pedagogical cycle (see Chap. 2). This effort to show the linkage directly responds to criticisms levelled at PCK research for its concentration on investigating what teachers know, without relating it to what teachers actually do and what students learn (Settlage, 2013). Recently, Shulman (2015) reminded us that PCK was not coined as a cognitive construct that resides in individual teachers' heads, but as a dynamic construct that describes the complex processes that teachers apply during the act of teaching particular subjects for particular purposes to particular students within particular settings. In this regard, the RCM signifies the idea that PCK comprises what a teacher does and the pedagogical reasoning that guides the teacher's actions, as well as what the teacher knows (Baxter & Lederman, 1999).

The conceptualisation of ePCK as a distinct form of PCK in the RCM is congruent with the conception underpinning the pentagon model of PCK; that is, PCK consists of two dimensions—understanding and enactment (Park, 2005). It can be argued that ePCK from the RCM conceptually corresponds to the enactment dimension of PCK in the pentagon model and pPCK (personal PCK) with the understanding dimension of PCK. However, there are significant differences in the way that the respective models define the relationships between ePCK and pPCK and the understanding dimension and the enactment dimension. In the RCM, ePCK is defined as *a subset* of pPCK that is manifested when a teacher utilises pPCK, not only when interacting directly with students through reflection-in-action, but also when planning instruction and reflecting on instruction and student outcomes through reflection-on-action. In this sense, PCK encompasses both knowledge and skills (see Chap. 2; Gess-Newsome, 2015). On the other hand, in the pentagon model, the understanding and enactment dimensions are described as *two complementary aspects* of a teacher's PCK that are demonstrated, rather than one being a part of the other. In other words, the two dimensions indicate different facets of PCK that constitute a teacher's whole PCK construct.

This conceptual variation necessitates different approaches to measuring PCK. The pentagon model of PCK suggests that measuring a teacher's PCK for science teaching requires measuring both cognitive and enacting dimensions of PCK. Consistent with this view, the PCK measures that my research team developed consisted of two types, each for measuring one of the two dimensions (Park & Suh, 2015). Specifically, the PCK survey directly measures "what teachers know" using teachers' responses to a paper–pencil-type survey, whereas the PCK rubric indirectly measures PCK through inferences from teachers' enacted PCK, focusing on "what teachers do" and their underlying pedagogical reasoning. Assuming that one measure only partially estimates an individual's PCK, individual teachers' PCK scores ought to be determined by the sum of their scores on both measures (Park et al., 2017).

On the other hand, the RCM suggests the possibility of estimating a teacher's science pPCK by measuring ePCK, given that ePCK is an expression of pPCK. How then can we measure ePCK? What data sources are necessary to measure ePCK? How should those data be analysed to estimate an individual's ePCK or pPCK in reliable and valid manners? Although those questions call for further empirical investigation, I believe that the RCM provides substantial direction for such research efforts. First, ePCK is manifested, evident, and utilised throughout the three phases of the pedagogical cycle: plan, enact, and reflect (see Chap. 2). This understanding of ePCK implies that data sources and collection methods should be planned to elicit PCK from each of the three stages. For example, teaching observations can capture elements of ePCK during the enact phase, while lesson plans, interviews on planning instruction, and reflective interviews can be useful to identify other elements of ePCK during the planning and reflection phases. Thus, to capture ePCK holistically, it is suggested researchers collect data from multiple sources at different points in time that span a full pedagogical cycle.

Second, a two-way knowledge exchange between pPCK and ePCK should be considered as a critical component of ePCK. Particularly, the pedagogical reasoning behind a teacher's use and synthesis of pPCK into a form of ePCK ought to be considered in gauging the teacher's PCK. Interviews anchored to videotaped lessons or reflection journal entries are examples of data sources from which to draw understanding of a teacher's pedagogical reasoning through both reflection-in-action and reflection-on-action (Schön, 1983). Finally, measuring PCK necessitates a normative stance in which some forms of PCK are more highly regarded than others (Park & Suh, 2015). The RCM recommends that impact on students' science learning should be counted towards norms for determining the quality of PCK. Building on the conceptualisation of personal PCK and skills in the original CM (Gess-Newsome, 2015), ePCK is a representation of personal PCK (pPCK) in the act of teaching a particular science topic in a particular way for a particular *purpose* to particular students for enhanced *student outcomes* (see Chap. 2). This conceptualisation indicates that comparative judgments made about teacher PCK in science need to include their students' science learning outcomes in relation to the teaching purpose. In this regard, I propose a modification to the PCK rubric that includes student learning outcomes as a component by which a teacher's enacted PCK in science is determined. To this end, how to measure student learning outcomes, in relation to teacher PCK, in reliable and valid ways must be a central question driving my future research involving the measuring of PCK. Besides measuring PCK, research studies that aim to portray PCK should also expand their scope of study, embracing the influence that a teacher's PCK in science exerts on his or her students' science learning.

Distinction of Personal PCK from Collective PCK

Another unique feature of the RCM to emerge is the differentiation between personal PCK (pPCK) and collective PCK (cPCK). Collective PCK in science represents a compendium of knowledge held by a group that extends beyond the knowledge of an individual science teacher and embodies more than what is known from research about teaching particular science subject matter to particular students in a particular learning context (see Chap. 2). Stated differently, cPCK is a collection of pPCK shared by a group of teaching professionals related to teaching a specific discipline, a specific topic, or a specific concept. For pPCK to become cPCK, the RCM requires sharing, articulation, and communication of that personal knowledge amongst a group of professionals. Although there is no explicit mention of validation of this shared knowledge through standardised processes, the RCM differentiates cPCK from pPCK and ePCK by virtue of the vetting of this knowledge by peers and other professionals through formal and informal channels. In this regard, cPCK in science comes to signify the perspective of PCK as knowledge *for* teachers (i.e. what teachers need to know) rather than knowledge *of* teachers (i.e. what teachers know) (Fenstermacher, 1994). With that said, cPCK is likely to be assessed in a comparative and normative way (Berry et al., 2016).

The concept of cPCK reflects the idea of indispensable PCK as illustrated in the indispensable and idiosyncratic model of PCK (Park et al., 2017). As shown in Fig. 4.3, the model distinctly incorporates both the personal idiosyncratic knowledge *of* individual science teachers, along with the indispensable knowledge *for* teachers that is necessary to execute effective instruction. Specifically, the indispensable PCK refers to the aspects of PCK for effective teaching of subject matter that are considered necessary across different teachers and a variety of educational contexts (Park & Suh, 2015). Thus, the indispensable PCK is measurable in a normative way, distinguishing between teachers with sophisticated and shallow PCK for teaching science. To clarify norms for determining the quality of the indispensable PCK for teaching science, the indispensable and idiosyncratic PCK model posits two major criteria: (1) appropriate representation of canonical science and (2) purposeful application of empirically supported consensus knowledge about effective instruction grounded in research on learners and learning (Donovan & Bransford, 2005). Both the PCK survey and PCK rubric tools target the measurement of indispensable PCK (Park et al., 2017).

I consider idiosyncratic PCK in science as an essential part of teacher knowledge that exemplifies teachers' professionalism, demonstrating their autonomy and ability to be responsive to diverse students within a specific social, cultural, and educational context, through adapting and tailoring instructional materials and strategies (Barnett

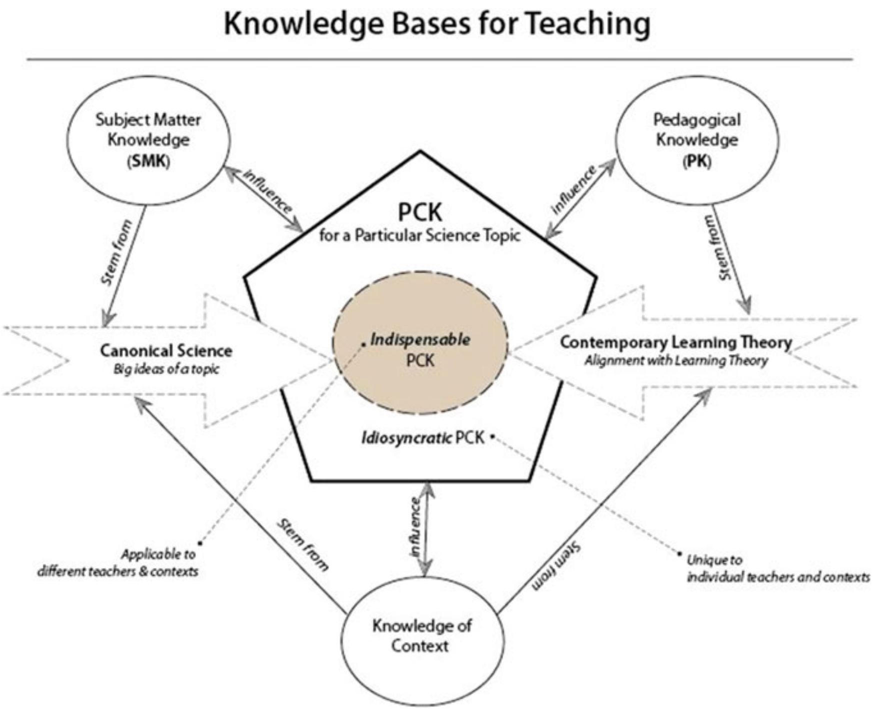

Fig. 4.3 Conceptual model of indispensable PCK and idiosyncratic PCK (Park et al., 2017)

& Hodson, 2000; Donnelly, 2001; Park & Oliver, 2008b). However, I also assume the presence of a collection of PCK in science that cuts across diverse contexts and which serves as foundational knowledge upon which teachers build the personal idiosyncratic PCK for science teaching that is unique to the learning context where their knowledge base is put into practice. This indispensable PCK is what cPCK intends to capture in the RCM.

However, I contend that in its current form, the RCM does not sufficiently unpack the meaning of cPCK in a way that will help conceptualise standards against which individual teachers' PCK in science is compared. Well-defined conceptualisations of PCK must be central to determining what is to be assessed, how it is to be assessed, and theorising important assumptions about the outcomes of PCK measures (Park & Suh, 2015). Hence, in order to better guide a line of research on measuring PCK, further clarification and articulation of cPCK that encapsulate the notions of knowledge *for* teachers of science and what constitutes indispensable PCK are imperative.

Nonetheless, I believe that the inception of cPCK by the RCM is a noteworthy step forward in advancing PCK research, in that it sheds light on the public aspect of PCK that transcends the knowledge bases of individual teachers of science. Professional knowledge must be public and represented in a form that enables it to be accumulated and shared with others (Hiebert, Gallimore, & Stigler, 2002). cPCK is, indeed, the core of PCK as the professional knowledge of teachers. Yet, professional knowledge also requires a system for verification and improvement (Hiebert et al., 2002). As I mentioned before, however, the knowledge exchanges in the RCM do not clearly demonstrate mechanisms through which shared pPCK can be publicly examined, verified, refuted, or modified. Clarification on those procedures will fill the gaps in our understanding about how pPCK becomes the profession's collective canonical knowledge of effective science teaching.

Shifted Focus Towards PCK Development

The last and most important feature highlighted by the RCM is the shift in focus from *what PCK is* towards *how PCK develops*. Accordingly, the model offers a different way to think about how teachers develop PCK for effective science teaching. Specifically, it draws special attention to the importance of colleagues, students, professional organisations, and contextual factors in developing PCK. By doing so, the RCM underscores that the development of PCK goes beyond individual science teachers' cognitive processes and requires their social interactions with colleagues, students, and others when negotiating the complexities of the learning context.

In this regard, the RCM suggests three new directions for science teacher education research on PCK, especially the development of PCK that has been a dominant line of PCK research (Depaepe, Verschaffel, & Kelchtermans, 2013). First, researchers need to further consider relevant external and contextual factors closely associated with pPCK and ePCK development to fully understand how teachers grow and change in their PCK in science over time. Previous studies about factors that influence the development of PCK primarily focused on those more proximal to teacher knowledge and practice, such as teaching experience, students, mentors, and professional development programmes (Park, 2005). Few researchers have examined broad and distal factors in relation to PCK such as federal policy, ministry requirements, national/state standards, school culture, and collegial dynamics that are also crucial components of the whole learning context. As the RCM indicates, a teacher develops and applies PCK through complex processes mediated by a multitude of factors. However, it is neither easy nor feasible to consider all factors in a single study. Close attention to these under-researched factors will contribute to building a complete picture of how multiple factors interact in shaping the development of teachers' PCK in science and provide significant implications for the design of interventions to improve PCK.

Second, considering knowledge exchanges between different components in the RCM, researchers need to attend to the causes of PCK growth and mechanisms of the cause–effect relationship. In particular, a clear understanding of the factors that can be best leveraged to create changes in PCK and the mechanisms through which they work will advance our understanding of how to design learning opportunities for teachers of science and how to assess teacher PCK in science. Last, the RCM represents PCK development for teaching science embedded in the larger milieu of the learning context, interaction with students and colleagues, and interplay among broader professional knowledge bases (see Chap. 2). This embedded nature of PCK development implies that every aspect of teachers' daily work in the rich, complex, and constantly changing environments where they are situated impacts their PCK to varying degrees. Consequently, individual teachers may not always experience steady incremental growth in PCK along their career trajectory (Schneider & Plasman, 2011). Having said that, I postulate that we should view PCK development for effective science teaching as continual change across a broad span of time, rather than as a series of discrete changes resulting from particular training experiences or critical classroom incidents. In this respect, longitudinal studies are needed to illuminate pathways that teachers move through as they develop more sophisticated PCK through experience in contextualised situations. Those studies will provide invaluable insights into how to design professional development programmes and experiences that support teachers' continued PCK growth through different stages of their career.

Closing Remarks

I have discussed implications for research methodology and future research on PCK in the field of science education drawn from the RCM, concentrating on four unique and significant features of the model, which are the emphasis on learning context, acknowledgement of ePCK (PCK in practice), recognition of cPCK, and the focus on PCK development. To recap, regardless of the focus of the study, any study that intends to examine PCK should consider that a multitude of contextual factors exerts profound influence on PCK and design data collection and analysis methods that sufficiently capture the influence of these contextual factors. Moreover, data sources and data collection methods to elicit PCK need to encompass the entire pedagogical cycle, because PCK is applied and used in every phase of the cycle from planning a lesson, to enactment of the planned lesson, to reflection on the enacted lesson.

The RCM implies several directions for methodological work, especially for the line of research focused on measuring and assessing teachers' PCK in science. ePCK should be the target in measuring PCK, with careful attention paid to how PCK manifests itself as teacher actions and practices in the classroom, rather than treating PCK solely as a cognitive construct. Given the complementary, two-way knowledge exchange between pPCK and ePCK, methodological approaches to measuring ePCK will need to address the pedagogical reasoning behind a teacher's actions. Data collection methods to tap into pedagogical reasoning may include interviews combined with observations, video-stimulated recall interviews about critical classroom incidents, or written reflections. Scoring rubrics or checklists are the most prevalent analytical tools for quantifying those qualitative data when measuring PCK (Park, Jang, Chen, & Jung, 2011), but researchers are encouraged to devote more effort to developing innovative, yet robust, analytic methods to discriminate between different levels of sophistication in pedagogical reasoning and ePCK. Most importantly, students' science learning outcomes should take precedence over other measures in determining the quality of an individual teacher's PCK for science teaching. However, given the diversity of students, standardising the assessment process for variables associated with student learning will be a challenging but necessary task that requires rigorous scholarly endeavour. Similarly, research focusing on describing and capturing PCK should also give ample consideration to PCK contextualised in practice and the associated contextual factors; pedagogical reasoning for instructional decisions and actions; and student learning outcomes in relation to PCK.

A significant insight to research on teachers' PCK for science teaching drawn from the RCM is the importance of professional communities and shared expertise to the development of PCK. This insight implies collaborative interactions among teachers become essential for the development of a teacher's PCK for science teaching because those interactions encourage teachers to make their knowledge public and understood by colleagues. However, little is known about how teachers' PCK evolves through interactions with other members of the profession and through feedback loops between classroom experience and professional contributions. In addition, there is a significant need for longitudinal studies with in-service teachers of science to better understand how to support teachers as lifelong learners who continuously advance to higher levels of PCK. Finally, more research on mechanisms that disentangle complex relations among the components within the RCM will propel the field forward in building a theoretical model of PCK rooted in firm empirical evidence that explains how to improve science learning for all students through promoting teachers' PCK and practice in science teaching (Park & Suh, 2015).

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