

Chapter 14

Developing Research on PCK as a Community



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Abstract After its introduction, a group of scholars, led by Lee Shulman, performed several studies on PCK in a range of disciplines. Since the 1990s, PCK studies have become a prominent strand in science education research. Initially, most of these studies were done in the USA, but once PCK was picked up by science education researchers in other continents, a proliferation of conceptions and models of PCK, and instruments to study it, became apparent. This chapter describes the ways in which scholars in science education have communicated with each other, through books, articles, presentations at conferences and, significantly, the PCK Summits to continue the conversation around PCK. The chapter will focus on the process of developing a consensus model of PCK among the scholars that participated in the two PCK Summits, how they communicated with each other during and after the Summits, and with the broader community of researchers with an interest in PCK. The chapter includes personal reflective narratives to exemplify key features of the PCK Summit processes and outcomes and looks to offer insights into the impact and possible next steps post the Second (2nd) PCK Summit.

Introduction

After Lee Shulman introduced pedagogical content knowledge (PCK) in his 1986 presidential lecture for American Educational Research Association (AERA), he led a group of scholars who performed studies on PCK in disciplines ranging from language and social studies to mathematics and science. Since the 1990s, PCK studies have become a prominent strand of research, especially in the domains of mathematics and science education. Initially, most of these studies were conducted in the USA,

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A. Hume et al. (eds.), *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science*, https://doi.org/10.1007/978-981-13-5898-2_14

but once PCK was picked up by science education researchers in other continents, a variety of conceptions and models of PCK, and instruments to study it, was developed and subsequently disseminated through books, articles, joint projects, and presentations at seminars and conferences. This chapter focuses on the processes of sharing research methods and outcomes among the mostly science education scholars who participated in two international meetings known as the PCK Summits, including personal reflections by the authors as Summit participants. The chapter describes how attendees communicated with each other during and after the Summits, and with the broader community of researchers with an interest in PCK, to develop a shared language and arrive at a consensus about models and methods.

The processes of sharing research methods and outcomes should be seen in the broader context of academic research in the twenty-first century, which in all disciplines is a global enterprise. The numbers of international conferences, books, and journals have increased exponentially in the last decades. Publications and presentations are vital to share research and discuss how new research outcomes contribute to the field. Decisions about acceptance of papers are often based on considering what the community of researchers in the domain of the paper can learn from it or what the paper adds to the existing body of knowledge. At the same time, research output measured by publications and presentations has become very important for the careers of individual researchers and in the assessment of research institutes. The increase of scale comes with several challenges. Conferences with an attendance over 10,000 delegates have had to organise their schedules to accommodate as many presentations as possible, for instance, by limiting the time per presentation (5 talks per slot of 90 min is not unusual) and increasing the number of parallel sessions. Obviously, such measures compromise the opportunity for discussions about research. Not only the time to discuss is limited, but by organising a conference schedule around specific themes or strands (in divisions or Special Interest Groups) that run parallel in time, the chances to meet researchers from adjacent research areas are minimised. In addition, research journals increasingly tend to specialise on specific strands of research. As a result, groups of researchers tend to communicate within specific channels (e.g., Special Interest Groups and specialised journals) and are thus not always aware of what happens in other communities. This narrowing of communication lines is particularly problematic for multidisciplinary research, which thrives on connections between groups of specialists in different areas. To counter these problems, interactions between researchers are organised in a variety of ways, such as summer schools around a specific (multidisciplinary) theme or exchanges of staff and Ph.D. students between institutes, often facilitated by scholarships and sabbaticals.

The PCK Research Community: 1986–2010

The origins of research on PCK have been well documented. For instance, in an interview with Lee Shulman in 2007, he reflected on what was called the Teacher

Knowledge Project in the early 1980s, which came out of a growing concern about the role of content in teaching. The initial question for that project was:

‘How does somebody that really knows something, teach it to somebody who doesn’t?’ Simple as you can get. So, [...] somebody who really knows evolutionary theory, what do they do if they have to teach it to somebody that not only that doesn’t know, but if he or she did, wouldn’t believe it? Thinking like that meant that we had to do these studies subject by subject and it just happened that at Stanford we prepare teachers, all secondary, in Science, Math, English and Social Studies and I just happened to have wonderful doctoral students in each of those areas. (Shulman, quoted in Berry, Loughran, & Van Driel, 2008, p. 1274)

In the Teacher Knowledge Project, about a dozen research projects were conducted across areas as diverse as English, mathematics, history, science, and social studies. In later years, research on PCK spreads around the globe; however, most research in PCK since the 1990s has focused on the domains of mathematics and science. A recent review of the literature on PCK in the context of pre-service education (Berry, Depaepe, & Van Driel, 2016) found 66 empirical studies, the large majority of which were located in mathematics (34) and science (24). The remaining eight studies were conducted in the domains of physical education (3), language (2), history (1), geography (1), and drama education (1). The numbers of studies in elementary and secondary pre-service teacher education were more or less the same. The review revealed that researchers in mathematics and science education have developed different conceptual models of PCK and associated methods to study PCK. More problematic, these researchers typically publish and present in different journals and conferences, with a focus on either mathematics or science education and very rarely cross-reference each others’ work.

Research on PCK in science education, until 2000, was mostly done in the USA and presented at conferences such as National Association for Research on Science Teaching (NARST) and Association for the Education of Teachers in Science (AETS). Some of this research was brought together in a book *Examining Pedagogical Content Knowledge*, edited by Gess-Newsome and Lederman (1999), commonly referred to as “the purple book”. This volume included a section called “The literature”, with chapters on conceptual models of teacher knowledge, as well as sections with reports of empirical studies on PCK and their impact on the development of teacher education programs. The PCK model presented in a chapter by Magnusson, Krajcik, and Borko (1999) became very influential (over 1900 cites in Google Scholar to date) and has informed many PCK studies in science education in the last 20 years (Friedrichsen, Van Driel, & Abell, 2011). In the 2000s, research on PCK in science education proliferated across the globe with concentrations in a number of places, in particular Monash University, Australia (Loughran and colleagues); University of Missouri at Columbia (Abell and colleagues); BSCS, Colorado (Carlson and colleagues); University of Leiden, the Netherlands (Van Driel and colleagues); University of the Witwatersrand, South Africa (Rollnick and colleagues); UNAM-Mexico (Garritz and colleagues); and University of Duisburg-Essen, Germany (Fischer and colleagues). These researchers met at conferences, especially NARST and European Science Education Research Association (ESERA), and jointly organised symposia. Also, researchers from these groups visited each other’s institutes, lead-

ing to joint projects and publications. In 2008, a special issue of the *International Journal of Science Education* appeared, edited by Berry, Loughran and Van Driel. This issue contained eight contributions from the aforementioned research groups, most of which were based on presentations during symposia at ESERA 2005 and NARST 2006.

The First PCK Summit: Colorado Springs, USA, October 2012

The 1st PCK Summit was an initiative from a group of US scholars led by Gess-Newsome, Carlson, and Gardner. The main purpose was to bring a group of around 25 PCK researchers together for a number of days to share and discuss their work, with the aim of forming “a professional learning community to explore the potential of a consensus model of PCK to guide science education research in this area through multiple research approaches” and to identify “specific next steps that would move the field forward” (Carlson, Stokes, Helms, Gess-Newsome, & Gardner, 2015, p. 15).

The organisers decided to invite a combination of senior and junior researchers, mostly from the groups mentioned in the previous section, rather than individuals. In addition, a small number of researchers from the domain of mathematics education were invited. The participants were asked to submit an abstract summarising the PCK research in their group several months prior to the Summit. These summaries were published on a website that was specifically created for the Summit. Somewhat later, each group was asked to write an elaborated version of their summary following a particular template. To prepare for the Summit, participants were asked to read the extended summaries of all groups. The website, <http://pcksummit.bsccs.org/>, which was initially only accessible to participants, has been made public after the Summit and gives access to the Summit agenda (including papers and presentations), online study modules, and a discussion forum.

The Summit began with a presentation via Skype from Lee Shulman, who reflected on the context in which PCK had been introduced and the history of PCK research and gave his opinion about the relevance of PCK research today. Next, short group presentations followed from the participants. Rather than talking about their own (past) research, each group was asked to address a certain theme. The presentations basically served as a framework for a discussion with all participants about the theme. These discussions were led by two convenors (Taylor and Settlage), both of whom were science education researchers, however, not PCK specialists. During the second half of the Summit, most time was spent in subgroups of 4–5 participants who explored certain issues in depth, such as the relevance of PCK research for policy and practice. Finally, all groups were asked to produce a conceptual model of PCK. During the final session, these models were compared and discussed, working towards an outcome, that is, a consensus model of PCK.

In the following personal narrative, Cooper (one of the authors of this chapter) shares some of her experiences as one of the early career researchers at the 1st PCK Summit.

Intermezzo 1: The PCK Journey of an Early Career Researcher

The 1st PCK Summit presented an exciting and challenging opportunity for me [Cooper] as an early career researcher. At the time that I was invited, I had just completed writing up the first draft of my Ph.D. research and submitted it to my supervisor. Initially, my research was looking to investigate the development of PCK in science teacher educators, but as the research progressed it became clear to me that my thinking about PCK did not align with what I was inferring from my collected data. To me, PCK was about the knowledge that teachers develop over time through experience related to teaching particular content in particular ways to enhance student learning (Loughran, Berry, & Mulhall, 2012). However, the data I collected from the participants in my research was not focused on science content but more on pedagogy and sharing expertise for teaching using science as a context for this practice. Thus, I felt that it was more appropriate to infer pedagogical knowledge (PK) from my data, and so I changed frameworks and worked with Morine-Dershimer and Kent's model for pedagogical knowledge (Morine-Dershimer & Kent, 1999). Looking back, this was the right decision because I was better able to represent the participants' experiences through the facets of this model and to analyse them in ways that offered reasonable and justifiable insights in my thesis.

One of the outcomes of the 1st PCK Summit was an agreed-upon definition for PCK; i.e., "PCK is the knowledge of, reasoning behind, and enactment of the teaching of particular topics in a particular way with particular students for particular reasons for enhanced student outcomes" (Carlson et al., 2015). As I was part of the creative process leading to its development, this definition resonated with my understanding of PCK and also lent further support to my decision to shift to PK for my thesis. This experience and understanding gave me the confidence to describe my own research with clarity and to be sure of how and why it was not PCK that I was studying. In addition to the agreed-upon definition, a consensus model of teacher professional knowledge and skill, including PCK (CM) and influences on classroom practice and student outcomes, was developed. In order to arrive at these shared understandings, there were many in-depth discussions borne out of group activities and inspired by presentations by other participants, as outlined in the previous section. To be an active part of the discussions, I needed to be brave and articulate my thoughts. I needed to think about how my research aligned with what was being discussed at the Summit and how it might influence my own thinking and that of other participants. One of the discussions centred either on what is and what is not PCK, or when knowledge is and is not PCK. Participating in this discussion challenged me to elaborate on my stance

for my research and why I was investigating PK and not PCK. Having to participate this way in the Summit helped me recognise that to be an academic and a part of the PCK research community, then I needed to contribute my arguments, be willing to justify my stance and be open to the critique and comments of others. Further, I was going to need to find productive ways to work with this feedback and turn it into productive deliberations that would further my thinking and thus my research agenda.

The 1st PCK Summit not only introduced me to other researchers but also to their research in a more detailed way. While I had read the work of many great researchers, several of whom were at the Summit, it was not until I met them and had time to explore and discuss their research that I realised what it truly meant to be an academic pursuing a research agenda. The researchers that I met were very willing to share their expertise and to share the evolution of their work and the progress of their thinking around PCK, which I found so helpful and inspirational. It left me thinking how could I work on my research, shaping it so that it continues my agenda but also becomes a significant contribution to the PCK research community? It made me realise that becoming an academic involves becoming a part of the bigger picture and thus a member of a research community that you contribute to through networking, reviewing, researching, and collaborating. To contribute in all these forums, I needed to be clear about what my research goals were and how they formed part of that bigger picture of PCK research.

After the First PCK Summit

It has been the experience of the authors of this chapter that maintaining the momentum when everyone returns home after a research meeting like the PCK Summit is vital. It is easy to leave after such an experience and become immersed in work at home. Technology can help as outlined earlier, but there is value in continuing to meet. The participants of the 1st Summit regularly arranged to meet while attending the major international science education conferences. These meetings were often held in the afternoon and followed with dinner where a participant would chair discussion, following a brief agenda, to continue the focused conversation. Often, rapid progress was made and participants left with a clear understanding of what needed to be followed up on or done, by when, and how to keep track of the shifts in thinking and discussion in order to continue to move forward.

Sometime after the 1st Summit, the participants agreed to produce a book, titled, *Re-examining Pedagogical Content Knowledge in Science Education* (Berry, Friedrichsen, & Loughran, 2015), but affectionately known as “the blue book”. As part of the Summit workshops, participants sorted themselves into small groups that focused on topics that had been raised during the Summit (such as assessment of PCK, or the role of PCK research in policy initiatives). The chapters in Part III of the “blue book”, called *Emerging themes*, were written by teams comprising two to five co-authors from different institutes, emerging from the small groups formed

at the Summit. Teams often used Skype to stay in touch with each other to discuss their writing and to continue conversations and progress their thinking. Some writing teams also used email exchanges to continue the writing process. Others employed Google Docs, which enabled them to write collaboratively and save time by not having to maintain versions of documents and wait for email replies.

As follow up, presenting as groups at conferences (NARST 2013, ESERA 2013) assisted in maintaining the momentum and helped us, the Summit participants, to articulate our thinking so that it could be shared with the broader educational research community. Further, it meant that we could incorporate the feedback provided by those who attended our conference presentations into our future work. In fact, this chapter was inspired by feedback we, the authors of this chapter, received at a conference presentation.

The discussions during these conferences ultimately led us to question whether another Summit was needed, and if so, why, and for what purpose? How would it build on what had already been done so we wouldn't keep doing the same thing?

The Second PCK Summit: Leiden, the Netherlands, December 2016

Preparing for the Second (2nd) PCK Summit

Preparations for the 2nd Summit were made by a team consisting of Van Driel, Berry, Kirschner, Borowski, and Carlson (who had been one of the organisers of the first summit). After much discussion, it was agreed that the focus for the 2nd Summit should be on sharing data and instruments. The idea was to build an understanding of each other's research and to consider how scholars infer PCK from their data. In addition, the organising group made it a priority to bring in new Summit participants, both senior and beginning, in an effort to broaden the thinking of the group and to continue sharing the experience of the PCK Summit with more members of the PCK research community. In total, 25 participants were invited to this Summit.

The Second (2nd) PCK Summit

The 2nd PCK Summit was designed to provide international researchers working on PCK in general science, biology, chemistry, and physics education the opportunity to share (1) how their data from PCK studies were collected, (2) the different kinds of instruments used to collect these data, and (3) the procedures used to infer PCK from these data. The aims of this Summit were to: develop a shared set of criteria to identify PCK for each kind of instrument through collectively analysing data that were obtained with the respective instrument; make accessible and comprehensible these

instruments to the wider PCK research community; and reach consensus on a model of PCK that is strongly connected with empirical data of varying nature and can be used as a framework for the design of future PCK studies. The Summit consisted of sessions where participants worked in small groups with a focused task, alternated with whole-group sessions. The focused tasks were determined by the two facilitators of the Summit (Loughran and Cooper), in consultation with the Summit organisers. The tasks included interrogating data sets from participants' research projects, comparing and contrasting data collected using similar instruments, and analysing processes for inferring PCK for multiple data sets. These tasks were strongly driven by the discussions and outcomes of previous sessions to ensure that progress was made over the course of the Summit. The whole-group sessions were moderated by the two facilitators during the first half of the Summit; however, these sessions evolved and followed a more open format during the second half of the Summit. The whole-group sessions were an opportunity to discuss what had happened in the small groups sessions and focused more on the outcomes of these sessions. The Summit concluded with a model-building session that included all participants. One of the small groups was focused on working towards building the consensus model, and the whole group was given the opportunity later to continue their work. The whole-group model-building session was powerful in that it provided an opportunity for collective thought on a model to unify PCK research in science education and offer the beginning of a shared language for portraying PCK.

Immediately after the model-building session, a post-Summit meeting took place. A group of around 20 local researchers, most of who were doing a Ph.D. with a focus on PCK in science education or other disciplines, met with the Summit participants. In mixed groups of six to eight people, the local researchers presented their studies and received feedback from the Summit participants. This feedback led to lively discussions in all groups, and at the end of the session, there was a consensus that the presentations had been a great opportunity for both parties to share ideas and learn about each other's research.

In the following personal narrative, the other author of this chapter [Van Driel] shares some of his PCK research journey, including the influence of the PCK Summits.

Intermezzo 2: The PCK Journey of a Senior Researcher

In my first year as a chemistry teacher, I (Van Driel) was very lucky to be supervised by a senior colleague who generously shared his expertise on the teaching and learning of chemistry. He was able to explain in much detail how students would respond to certain teaching approaches and the conceptual struggles that students often would experience. This mentoring took place in the mid-1980s, and when I read Shulman's seminal PCK papers years later, I immediately recognised the expert knowledge my colleague had developed as PCK. That is, knowledge about student learning of particular subject matter and knowledge of specific teaching strategies

that potentially help students to develop their knowledge and skills about this subject matter. In my Ph.D. (1985–1990), I was mostly focused on developing students' conceptual understanding of chemistry topics through specific lesson materials; however, I became increasingly interested in the different ways teachers implemented these materials in their practice. PCK provided a powerful framework to analyse the practical knowledge that teachers drew upon for this implementation. This interest resulted in a publication that helped to establish my reputation as a PCK researcher (Van Driel, Verloop, & De Vos, 1998).

In the next decade, I was involved in several PCK projects, collaborating with colleagues, Ph.D. students, and post-docs. During this period, I experienced the importance and benefits of communicating with international colleagues through a variety of modes. In particular, conference presentations (followed by direct interactions with colleagues) and publications, often with the same colleagues (followed by reactions and questions via email), have been extremely important to get feedback and inspiration for future research. Although some of these interactions led to ongoing collaborations (and personal friendships), in most cases, interactions were brief and limited in terms of depth. Mostly, these were fleeting interactions due to limitations of email and the length and frequency of conferences. I was therefore very happy when Julie Gess-Newsome introduced the idea of a PCK Summit to me. Participating in the 2012 Summit in Colorado was an incredible experience: the opportunity to talk and think for 5 days with a group of very committed and open colleagues about basically “everything you always wanted to know about PCK” will stay with me as a career highlight.

It was only natural for me to stay involved in the following developments (presenting at conferences and contributing to the “blue book”), and as soon as the idea of a 2nd Summit was proposed, I was keen to be involved in its organisation. Having direct access to the facility in Leiden (the Lorentz Center; <http://www.lorentzcenter.nl/>) made it logical for me to take the lead in the logistics of this Summit. After roughly a year of preparation (together with Kirschner, Borowski, Berry and Carlson), it was wonderful to see the actual meeting happen. Although organisational issues had to be attended to, I was able to concentrate on the discussions with the whole group and in the smaller working groups. I feel strongly that we made progress during this Summit, compared to the first one. In my view, elements that contributed to the success were (1) most of the participants knew each other's research quite well, and for some time, whereas (2) new participants brought new perspectives, and (3) the facilitators did a wonderful job, sensing very well where discussions were going and deciding, often on the spot, how progress could best be fostered. In addition, the physical layout of the facility and the support of its staff helped to keep everyone focused and distractions to a minimum.

After the Second (2nd) PCK Summit

Moving with the Momentum

The focus of the ongoing discussions for the participants post the 2nd PCK Summit concentrated on a revised consensus model of PCK, to be published in this book! As mentioned earlier, the final whole-group session at the 2nd PCK Summit was a model-building session. While the participants reached a somewhat final point, it was decided that it would be helpful to have a graphic designer to turn our rough sketches into a more coherent visual representation. Two participants (Carlson and Daehler) graciously took responsibility for this task. The visual representation, along with a comprehensive explanation, was shared with all participants of the 2nd PCK Summit using Google Docs, which allowed for the conversation around the model development to continue. In addition to electronic communication, an ad hoc meeting took place during NARST 2017 to discuss the revisions of the model and its visual representation. Fourteen participants of the 2nd Summit were present during this meeting. This ongoing development also fostered the preparation of more conference presentations (ESERA 2017, ASERA 2017, NARST 2018).

Sharing the Outcomes

Sharing the outcomes of the PCK Summit in relation to the progressing of PCK research is really important, and the time immediately post to the 2nd Summit was focused on opening up the revised consensus model for discussion. This discussion opportunity was also about sharing the data collection tools and processes for analysis and inferring PCK. In addition to sharing the research-focused outcomes, it became apparent that we had a broader story to tell that focused on the process of the Summit and the development of the research community. The existence of this story became evident at the end of a conference presentation (ASERA 2017) where the questions asked by the audience were delving further into the processes behind the planning and happenings at the Summits.

Impact and Next Steps

Sharing with the Broader PCK Research Community

Participation in both PCK Summits was by invitation only. Thus, while initially access to the discussions and offering of the summits was only provided to a small number of participants, these invited participants have a responsibility to provide access for

the broader PCK research community. It has always been a priority of the organisers and the participants at large to share the outcomes and as much of the discussions from the Summit as possible. The 1st Summit managed this dissemination of ideas effectively through the creation and maintenance of a publicly available website, as mentioned earlier, but the website does not provide an indication of how what happened at the conference has influenced further research. Thus, it is a priority of Summit participants to present regularly at a variety of conferences to ensure that the Summit ideas are shared with and questioned by the broader PCK research community. Taking these ideas and questions further, there also are publications (i.e. the “blue book” and this current volume and an upcoming special issue of the *International Journal of Science Education*) that may not specifically address the proceedings during the Summits but do offer readers some insights into how the Summit has re-directed, influenced, or forwarded continuing PCK research. Speaking to the broader PCK research community has ensured that ideas have been articulated beyond that of the participants in attendance so that these ideas are shared, opened for discussion, and explored by more than those who were present. It has meant that other PCK researchers have had the opportunity to take the ideas and issues raised at the Summits and apply them to their own work, should they wish to do so, to progress their PCK research.

New Connections for Research and Writing

The Summits have been influential in generating new ideas to progress both individual and community research. It has provided the opportunity for robust discussion around individual researcher’s plans and assisted them to further their research in more ambitious yet coherent ways. This expansion of their ambition is possible because their research has been more thoroughly critiqued before it even started, simply because they have been able to hear from other researchers at the Summits. There has been more cohesion to the research, in that the resulting research is better aligned in terms of the theory and models used. These alignments are important in building a genuine research community that can have conversations based on shared understanding of the foundations of their research to strengthen both individual and community research agendas and to forge new understandings.

Sharing the Evolution of PCK Research

The Summits have made it a priority to bring new researchers into the science PCK community to work alongside more experienced researchers and offer them networking and mentoring opportunities. The Summits have helped new researchers to better appreciate the genealogy of the PCK research field and become acclimatised to the

PCK research environment. These new researchers can therefore progress the field in science education with a genuine pursuit of new knowledge because they are well attuned to where progress is needed and why.

Sustaining a PCK Research Community

Further benefits include the significance of the processes involved in planning and carrying out the Summits. These processes are valuable in relation to the sustainability and cohesion of a research community so that there is consistency around the quality, validity, and reliability of research in the field. Keeping the number of participants at the Summit small is part of what made the Summits work so well, so it is never going to be a big event. However, the processes and understandings should be shared widely, as outlined previously, with all those in the PCK research community and beyond.

This chapter opens discussion around the processes underpinning the planning and implementing of PCK Summits and the communication prior, between, and after these Summits, in relation to the contribution the processes and ideas around continual communication between participants can make to the wider PCK research community. This contribution offers not only greater cohesion, but clarity around future thinking related to research in the PCK field. This approach may serve as a model or example for research in other fields/domains, especially when researchers are using a variety of models and methods to explore the same territory.

As part of their aims, both Summits included experienced and early career PCK researchers as participants, offering an opportunity for early career PCK researchers to be introduced to more experienced members of the PCK research community. As an international research community, the PCK research community in science education is forward thinking about the future of research in this area and assisting early career researchers to better plan and appreciate the trajectory of research in this field. Now, the science PCK research community needs to think about how to continue this conversation with Summit participants and the broader research community. This ongoing conversation will help to decide whether a third PCK Summit, in a couple of years from now, is necessary or useful to further research in the field and sustain the PCK research community.

References

- Berry, A., Depaepe, F., & Van Driel, J. H. (2016). Pedagogical content knowledge in teacher education. In J. Loughran & M. L. Hamilton (Eds.), *International handbook of teacher education* (pp. 347–386). Dordrecht: Springer.
- Berry, A., Friedrichsen, P., & Loughran, J. J. (2015). *Re-examining pedagogical content knowledge in science education*. New York, London: Routledge.