PEDAGOGICAL CONTENT KNOWLEDGE (PCK): EVOLUTION, MODELS AND RESEARCH METHODOLOGIES FOR A CASE STUDY

CONHECIMENTO PEDAGÓGICO DO CONTEÚDO (CPC): EVOLUÇÃO, MODELOS E METODOLOGIAS DE PESQUISA PARA UM ESTUDO DE CASO

EL CONOCIMIENTO DIDÁCTICO DEL CONTENIDO (PCK): EVOLUCIÓN, MODELOS Y METODOLOGÍAS DE INVESTIGACIÓN PARA UN ESTUDIO DE CASO

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ABSTRACT

This paper analyzes Lee Shulman's Pedagogical Content Knowledge (PCK), a fundamental construct for understanding the specificity of teacher knowledge. After reviewing its genealogy and the PCK Summits (2012, 2016) that refined the concept to the Refined Consensus Model (RCM), the study focuses on two major structural models: the hierarchical model of Magnusson et al. (1999) and the dynamic and integrative hexagonal model of Park and Oliver (2008), which incorporates teacher self-efficacy as a central affective component. Methodologically, Content Representations (CoRe) and PaP-eRs are highlighted for capturing collective PCK (cPCK), as well as the PCK map approach for visualizing interactions. Finally, conceptual inaccuracies are corrected, the affective and contextual dimension of PCK is emphasized, and future lines of research are proposed, such as longitudinal studies and technological integration (TPACK), for a situated and transformative understanding of professional teaching knowledge.

Keywords: Pedagogical Content Knowledge (PCK). Refined Consensus Model (RCM). Teacher Training. Content Representations (CoRe). Teacher Self-efficacy.

RESUMO

Este trabalho analisa o Conhecimento Didático do Conteúdo (PCK) de Lee Shulman, um construto fundamental para compreender a especificidade do saber docente. Após revisar sua genealogia e as Cúpulas do PCK (2012, 2016), que refinaram o conceito até o Modelo de Consenso Refinado (RCM), o estudo concentra-se em dois grandes modelos estruturais: o modelo hierárquico de Magnusson et al. (1999) e o modelo hexagonal dinâmico e integrador de Park e Oliver (2008), que incorpora a autoeficácia docente como componente afetivo central. Metodologicamente, destacam-se as Representações de Conteúdo (CoRe) e os PaP-eRs para captar o PCK coletivo (cPCK), bem como a abordagem do mapa PCK para visualizar interações. Por fim, corrigem-se imprecisões conceituais, ressalta-se a dimensão afetiva e contextual do PCK e propõem-se linhas futuras de pesquisa, como

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estudos longitudinais e a integração tecnológica (TPACK), para uma compreensão situada e transformadora do conhecimento profissional docente.

Palavras-chave: Conhecimento Didático do Conteúdo (PCK). Modelo de Consenso Refinado (RCM). Formação Docente. Representações de Conteúdo (CoRe). Autoeficácia Docente.

RESUMEN
Este trabajo analiza el Conocimiento Didáctico del Contenido (PCK) de Lee Shulman, un constructo fundamental para entender la especificidad del saber docente. Tras revisar su genealogía y las Cumbres del PCK (2012, 2016) que refinaron el concepto hasta el Modelo de Consenso Refinado (RCM), el estudio se centra en dos grandes modelos estructurales: el modelo jerárquico de Magnusson et al. (1999) y el dinámico e integrador modelo hexagonal de Park y Oliver (2008), que incorpora la autoeficacia docente como componente afectivo central. Metodológicamente, se destacan las Representaciones de Contenido (CoRe) y los PaP-eRs para capturar el PCK colectivo (cPCK), así como el enfoque del mapa PCK para visualizar interacciones. Finalmente, se corrigen imprecisiones conceptuales, se subraya la dimensión afectiva y contextual del PCK, y se proponen líneas futuras de investigación, como estudios longitudinales y la integración tecnológica (TPACK), para una comprensión situada y transformadora del conocimiento profesional docente.

Palabras clave: Conocimiento Didáctico del Contenido (PCK). Modelo de Consenso Refinado (RCM). Formación Docente. Representaciones de Contenido (CoRe). Autoeficacia Docente.

1 INTRODUCTION

The study of teacher thinking has traveled a long and winding road, from the initial identification of teaching with a set of observable technical skills to the current recognition of the teaching profession as a complex, situated, and deeply ethical cognitive activity. On this epistemological journey, few constructs have been as fruitful and, at the same time, as debated as Didactic Content Knowledge (PCK). Introduced by Lee S. Shulman in 1986, the PCK emerged as a forceful response to the ancient and artificial dichotomy between the discipline's expert knowledge (content knowledge) and generic knowledge about how to teach (pedagogical knowledge). Shulman postulated that the effective teacher is not a mere applicator of techniques or a specialist who "pours" his knowledge into empty containers, but a professional who possesses a form of knowledge amalgamated and transformed: a knowledge that allows him to represent the most complex ideas of his discipline in a way that is accessible and culturally relevant to his students, anticipating their difficulties, valuing their alternative conceptions and weaving bridges between what they know and what they must learn.

However, the very power of the construct led to a growing divergence in its interpretation and operationalization. For almost three decades, the PCK was understood in such diverse ways that it threatened to fragment the field of research. In response to this problem, the international community of researchers in science education organized two fundamental summits (Colorado Springs, 2012; Leiden, 2016) that managed to establish a Refined Consensus Model (RCM). This model not only unified criteria, but also introduced a crucial tripartite distinction: the collective PCK (cPCK), shared by a professional community; the personal PCK (pPCK), built by each teacher based on his or her experience; and the promulgated PCK (ePCK), the knowledge that is effectively manifested in the action of teaching.

This paper aims to carry out a systematic and critical review of the theoretical and methodological foundations of the PCK, with a special emphasis on the structural models that have guided research during the last two decades. In particular, the evolution from the hierarchical model of Magnusson, Krajcik and Borko (1999) to the innovative integrative model of Park and Oliver (2008) will be analyzed in depth, which breaks with hierarchical rigidity to conceive the PCK as a dynamic system of six interrelated components —including, in a pioneering way, teacher self-efficacy as a mediating affective element—, with content knowledge (CK) as an integrating center. Likewise, the main methodological tools for the capture of the PCK, such as Content Representations (CoRe) and PCK maps, will be examined, highlighting their power and limitations. Finally, the conceptual inaccuracies that still persist will be discussed, the affective and contextual dimension of teaching knowledge will be vindicated, and future lines of research will be outlined that point towards a situated, transformative understanding that is more linked to student learning.

2 INTRODUCTION. GENEALOGY AND JUSTIFICATION OF THE PCK CONSTRUCT

2.1 INTRODUCTION: THE SPECIFICITY OF TEACHING KNOWLEDGE

Pedagogical Content Knowledge *(PCK)* is one of the most influential constructs in research on teacher education and science teaching in the last three decades. Introduced by Lee S. Shulman in 1986, the PCK emerged as a critical response to the artificial separation between discipline knowledge (content knowledge) and generic teaching knowledge (pedagogical knowledge). Shulman (1986, 1987) postulated that the effective teacher possesses a unique and transformed form of *amalgamated* knowledge, which allows him or her to represent and formulate disciplinary content in a way that is understandable to students, considering their preconceptions, difficulties and contexts.

2.2 THE NEED FOR A COMMUNITY OF CONSENSUS: THE CPK SUMMITS (2012 AND 2016)

Despite its wide acceptance, the PCK construct has faced considerable divergence in its interpretation and methodological application (Berry, Friedrichsen, & Loughran, 2015). This diversity, while enriching, threatened to fragment the field. In response to this problem, two international summits were organized that marked fundamental milestones in the PCK's research.

2.2.1 First CPK Summit (Colorado Springs, 2012)

In October 2012, a group of approximately 30 leading researchers in science and mathematics education, from seven countries, met in Colorado Springs with the purpose of "strengthening the concept itself, as well as strengthening the research community" (Berry et al., 2015, p. 28). As Julie Gess-Newsome put it in her keynote address, the field recognized that "something was not playing right," and there was an urgent need to find a unifying definition or, at least, a common theoretical basis that would drive measurement and evaluation techniques.

The main outcome of this summit was the formulation of the Consensus Model (CM) of Teacher Professional Knowledge and Skill (TPK&S), published in the volume Re-examining Pedagogical Content Knowledge (Berry et al., 2015). This model established a fundamental distinction between (generic) professional knowledge bases and the PCK as transformed and topic-specific knowledge (Gess-Newsome, 2015).

2.2.2 Second CPK Summit (Leiden, 2016)

As a consequence of the work started in 2012, in December 2016, twenty-four researchers met in Leiden (Netherlands) to continue the debate, but with a substantially different focus: data analysis. The Second Summit focused on critically examining the instruments and procedures of data collection and analysis to capture the PCK, promoting multi-method study designs.

The most significant product of this meeting was the Refined Consensus Model (RCM), which introduced a tripartite distinction of the PCK into three interrelated domains: collective (cPCK), personal (pPCK), and enacted (ePCK) (Carlson & Daehler, 2019). This refinement made it possible to more precisely situate the objects of study and overcome previous dichotomies between "owned" knowledge and "in action" knowledge.

3 THEORETICAL FOUNDATIONS. STRUCTURAL MODELS OF THE CPK

3.1 THE MAGNUSSON, KRAJCIK AND BORKO MODEL (1999)

The model most frequently cited in the literature is the one proposed by Magnusson, Krajcik, and Borko (1999), who conceived of the PCK as a construct composed of five fundamental components: (1) orientations towards science teaching, (2) knowledge of the science curriculum, (3) knowledge of students' understanding of science, (4) knowledge of science assessment, and (5) knowledge of instructional strategies and representations. This model, hierarchical in nature, laid the foundations for the subsequent development of analytical instruments and frameworks.

3.2 THE PARK AND OLIVER MODEL: FROM HIERARCHICAL STRUCTURE TO DYNAMIC INTEGRATION

3.2.1 Background: The Need for an Integrative Model (2006-2008)

Prior to the seminal work of 2008, Park and Oliver (2006) identified a critical limitation in existing models of the PCK, particularly the one proposed by Magnusson et al. (1999). While Magnusson's model was widely cited, its hierarchical and relatively static structure failed to capture the **dynamic and interactive nature** of the PCK in actual teaching practice. Park and Oliver (2006) argued that the PCK is not a simple collection of isolated components, but a complex system where knowledge is fluidly integrated during the act of teaching.

Their first qualitative studies with science teachers in National Board Certification contexts revealed that effective teachers did not activate components sequentially, but **simultaneously integrated** their knowledge of content, students, strategies, and context into brief episodes of instruction. This finding led to the need to reconceptualize the PCK as an *emergent* and *situated construct*, laying the groundwork for the model they would publish in 2008.

3.2.2 Park and Oliver's (2008) Hexagonal Model: Fundamentals and Structure

In their article *Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals* (Park & Oliver, 2008), the authors proposed a radical reconceptualization of the PCK that moved away from the previous hierarchical vision. The distinctive characteristics of this model are:

a) Non-Hierarchical and Integrative Structure

Unlike the model of Magnusson et al. (1999), where orientations towards teaching occupied a hierarchically superior place, Park and Oliver (2008) postulated that **all components interact on an equal footing**. The model is visually represented as a hexagon (or pentagon, depending on the version) with Content Awareness (CK) at the center, connected to six peripheral components that interact with each other.

b) Incorporation of the Affective Component: Teacher Self-Efficacy

The most significant contribution of Park and Oliver's model was the explicit inclusion of teacher efficacy *as a central component of the CPK. Inspired by the work of Bandura (1997) and Tschannen-Moran and Hoy (2001), the authors argued that:*

"Teachers' beliefs about their ability to organize and execute courses of action necessary to achieve specific learning outcomes, even with difficult or unmotivated students, are critical to PCK integration" (Park & Oliver, 2008, p. 272).

This affective component acts as a **mediator** that influences how teachers select strategies, interpret students' difficulties, and persist in the face of instructional challenges. Self-efficacy is not just another component, but a *filter* that amplifies or attenuates the connections between the other components.

In Table 1. We have an illustration of each of the components of the Park and Oliver Model.

c) The Six Components of the Park-Oliver Model

Table 1

Park-Oliver Model Components

Component (abbreviation)	Extended Description
Orientations towards science education (OTS)	Conceptions about the aims and purposes of science teaching. Includes beliefs about the nature of science, the role of the teacher, and how students learn. They can range from transmissive approaches to constructivist or inquiry-based views.
Knowledge of Instructional Strategies and Representations (KISR)	Know how to represent content in understandable ways (analogies, models, examples, demonstrations) and which instructional sequences are most effective in teaching specific scientific concepts.
Knowledge of Student Understanding (KSU)	Understanding of alternative conceptions, learning difficulties, cognitive requirements, and sources of confusion that students bring to the classroom about particular scientific concepts.
Science Curriculum Knowledge (KSC)	Mastery of curricular materials, study programs, content sequencing, and vertical and horizontal relationships between concepts throughout the school years.
Knowledge of Science Learning Assessment (KAs)	Know how to assess students' conceptual understanding beyond memorization, including formative and summative assessment strategies specific to scientific content.
Teacher self-efficacy (context and specific domain) (TSE)	The teacher's beliefs about his or her ability to effectively teach a specific topic in a particular context. It includes the confidence to address difficulties, motivate students, and achieve meaningful learning.

Source: Authors (2025).

d) Content Knowledge (CK) as an Integrating Center

A distinctive aspect of Park and Oliver's model is that **Content Awareness** (CK) is not just another peripheral component, but the **center** around which the other components are organized and integrated. As the authors point out:

"The CK is the knowledge that teachers have about the subject they teach. This knowledge is fundamental because, without a deep understanding of the content, teachers cannot transform it into pedagogically powerful representations. The CK acts as the anchor that gives coherence to the other components" (Park & Oliver, 2008, p. 268).

This centrality of the CK responds to a frequent criticism of previous versions of the CPK that, by emphasizing pedagogy, could dilute the importance of deep disciplinary mastery.

3.2.3The Pentagon Model: Visual Representation and Evolution

In the same year, Park and Oliver (2008b) presented a more synthetic visual representation of the model, dubbed the **"Pentagon Model of the CPK"** (Figure 1), which was subsequently refined by Park and Chen (2012) and Park and Suh (2019).

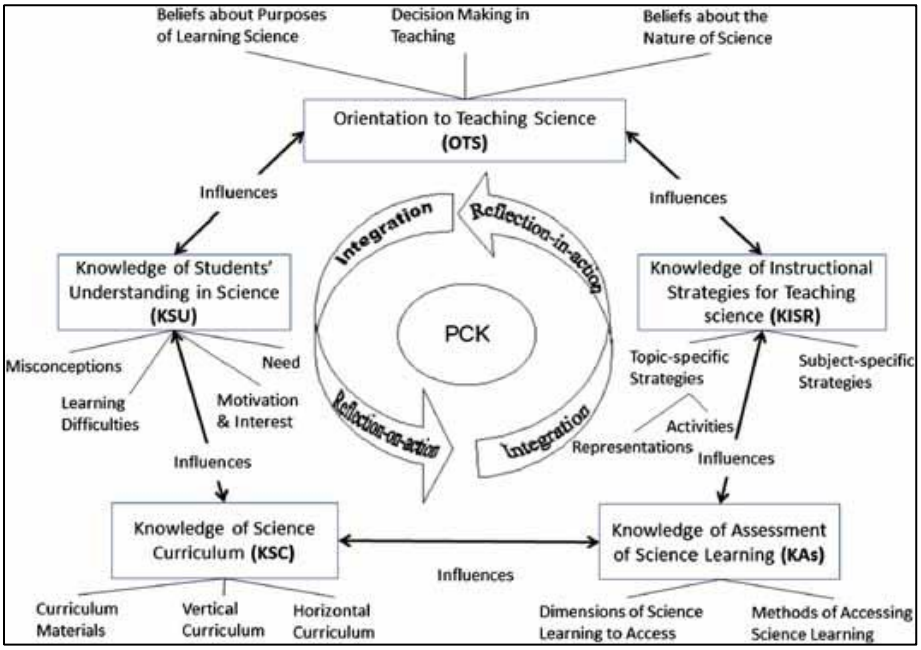
Description of the Pentagon Diagram (Park & Chen, 2012, p. 925)

In Figure 1. We can see the diagram which is structured as follows:

1. **Center:** A circle or ellipse that represents **Pedagogical Content Knowledge (PCK).** This center is connected by lines to all the vertices of the pentagon, indicating that each component is integrated with disciplinary knowledge.
2. **Pentagon Vertices:** Five of the components are located at each vertex:
   - Teaching Guidelines (OTS)
   - Knowledge of Instructional Strategies (KISR)
   - Knowledge of Student Understanding (KSU)
   - Knowledge of Curriculum (KSC)
   - Assessment Knowledge (KAs)
3. **Interactions between vertices:** The pentagon not only has radial connections to the center, but also **lines that connect each vertex with the others**, forming a network of interactions. Each line represents the possibility of integration between two components during pedagogical reasoning.
4. **Outer circle or "cloud":** In some versions (Park & Suh, 2019), an outer dotted circle is added that represents the **educational context** (school policies, community, available resources) that influences all internal interactions.
5. **Self-efficacy as a cross-cutting element:** Although in the pentagon version self-efficacy does not appear as an independent vertex, Park and Oliver (2008) emphasize that it acts as a **mediating element** that "colors" all connections. In later versions (Park & Suh, 2019), self-efficacy is incorporated as a sixth vertex, transforming the pentagon into a hexagon.

Figure 1

Pentagon model of the CPK



Source: (adapted from Park & Chen, 2012, p. 925) – Authors (2025).
Note: [KSC] = Knowledge of the Curriculum; [KISR] = Knowledge of Instructional Strategies and Representations; [KSU] = Knowledge of Student Understanding; [KAs] = Knowledge of Assessment; [OTS] = Orientations to Teaching. Solid lines represent possible interactions between components. The center (PCK) is connected to all vertices.

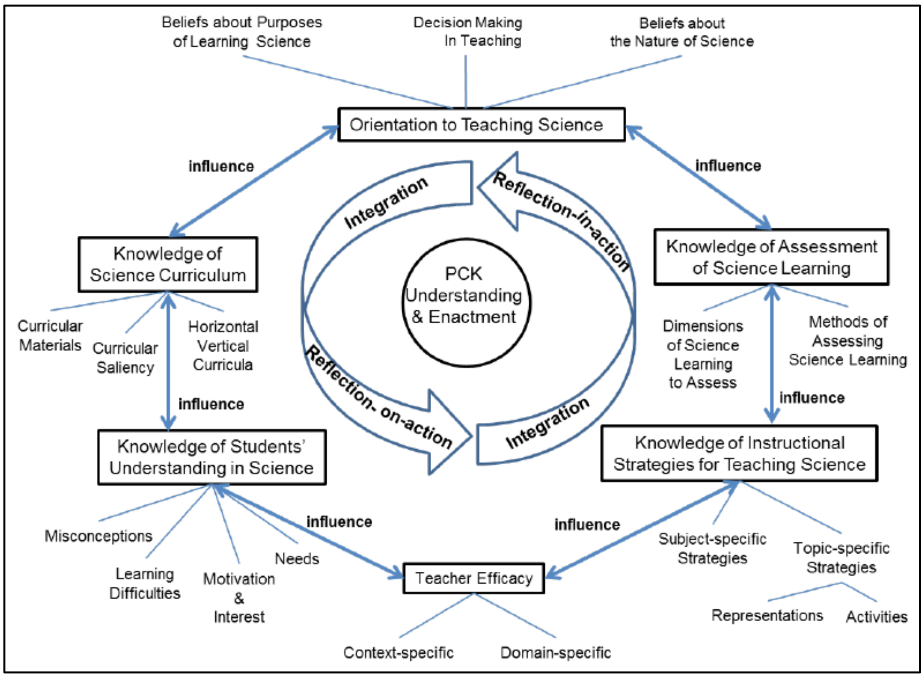
3.2.4 The Hexagonal Model for Inquiry-Based Teaching (Suh & Park, 2017)

A further evolution of the model was proposed by Suh and Park (2017) for specific contexts of *Argument-Based Inquiry (ABI*) teaching. In this adaptation (Figure 2), the authors:

- They rewrote the first component as **"Orientation to Specialized Science Teaching for Argument-Based Inquiry" (OTS-A).**
- They incorporated three epistemological orientations as subcomponents:
  - Beliefs about *how students learn*.
  - Beliefs about *what science is* (nature of science).
  - Beliefs about the *use of language* in the implementation of inquiry.
- They maintained the hexagonal structure with the CK at the center, but emphasized that **self-efficacy** (TSE) acquires particular relevance when teachers implement innovative approaches such as inquiry, since these demand greater confidence in the ability to manage uncertainty and open learning.

Figure 2

Hexagonal Model for ABI



Source: (adapted from Suh & Park, 2017, p. 249) – Authors (2025).

Description of the Hexagonal Diagram for ABI (Suh & Park, 2017, p. 249)

The hexagonal diagram is organized with:

- **Centre:** PCK (Pedagogical Knowledge of the Specific Content for Inquiry).
- **Six vertices:**

1. OTS-A (Specialized Guidelines for Argumentative Inquiry)
2. KISR (Strategies to facilitate scientific argumentation and discourse)
3. KSU (Understanding How Students Construct Arguments and Handle Evidence)
4. KSC (Curriculum Integrating Inquiry Practices)
5. KAs (Evaluation of the Quality of Arguments and Use of Evidence)
6. TSE (Self-efficacy to implement open inquiry)

The lines represent specific integrations for teaching inquiry, such as the connection between OTS-A and KISR to design authentic argumentation tasks

3.3 THE REFINED CONSENSUS MODEL (RCM)

The RCM (Carlson & Daehler, 2019) currently represents the most comprehensive and accepted framework within the international community. Represented as a globe of five concentric layers (Figure 1), the model states:

1. **Professional Knowledge Bases (external layer):** They constitute the indispensable foundations: knowledge of scientific content, pedagogical knowledge, knowledge of students, curricular knowledge and knowledge of evaluation.
2. **PCK Collective (cPCK):** An amalgamation of multiple contributions from science educators, shared and articulated by a professional community. It is the canonical knowledge of the profession to teach a specific topic.
3. **Learning Context:** It acts as a filter and amplifier of teaching, ranging from educational policies to individual attributes of students.
4. **PCK Personal (pPCK):** A cumulative and dynamic knowledge of an individual teacher, built from his or her own teaching, learning experiences, and the contributions of colleagues and specialists.
5. **Promulgated PCK (ePCK) (core):** Specific knowledge and skills used by a teacher in a particular setting, with particular students, for the teaching of a specific concept. The ePCK is the PCK in action, manifested in pedagogical reasoning during planning, teaching, and reflection.

A key contribution of RCM is the explanation of the bidirectional flows of knowledge between these layers, as well as the recognition that teachers' beliefs and attitudes amplify or filter the development of pPCK and the manifestation of ePCK.

4 RESEARCH METHODOLOGIES. ANALYTICAL INSTRUMENTS AND STRATEGIES FOR CATCHING THE CPK

The PCK's research has moved from one-dimensional approaches (questionnaires) to multi-method methodologies that allow capturing its tacit, situated, and dynamic nature.

4.1 DATA SOURCES FOR CHARACTERIZING THE PCK

In the specialized literature, four main types of data sources are identified (Hume, Cooper & Borowski, 2019):

1. **Written tests, surveys, and quizzes:** These include multiple-choice, true/false, and open-ended questions.
2. **Interviews:** Generally semi-structured, based on the components of the PCK or on guiding questions of the Content Representations.
3. **Instruments from teaching tasks:** Lesson plans, student work, written reflections and curricular materials designed by the teacher.
4. **Lesson observations:** Video recordings of the classroom that allow practice to be analysed in real time, combined with stimulated recall interviews.

4.2 CONTENT REPRESENTATIONS (CORE): METHODOLOGY FOR CAPTURING THE COLLECTIVE PCK

4.2.1 Origins and Foundations of CoReS

Content Representations (CoRe) were developed by John Loughran, Amanda Berry, and Pamela Mulhall at Monash University, Australia, as an answer to the question: *how can we make the professional knowledge of science teachers visible?* (Loughran, Berry & Mulhall, 2004, 2012).

Loughran and his team's starting point was a critical observation: much of the knowledge that teachers possess is **tacit, implicit, and difficult to articulate**. Teachers know much more than they can explicitly say about their practice. CoRe's were designed as a **methodological scaffolding** that allows this tacit knowledge to be externalized, transforming it into a structured and shareable representation.

4.2.2 The Structure of a CoRe: Big Ideas and Guiding Questions

A CoRe is essentially a **two-dimensional matrix** (Table 1) that organizes professional knowledge around the "big ideas" of a specific topic. The process of building a CoRe follows two fundamental steps:

Step 1: Identify the Big Ideas

A group of teachers (ideally a community of practice) meets to agree on the central concepts, the structuring ideas that students need to deeply understand about a topic. For example, for the teaching of "photosynthesis," the big ideas might be:

- Photosynthesis is a process of energy transformation.
- Photosynthesis requires raw material (water, carbon dioxide) and produces glucose and oxygen.
- Photosynthesis occurs in specific organelles (chloroplasts) mediated by pigments (chlorophyll).

Step 2: Answering the Guiding Questions for Each Great Idea

For each big idea, teachers collectively answer a set of **eight guiding questions** that capture the key dimensions of the PCK (Loughran, Berry, & Mulhall, 2012). Table 2 shows a Content Representation Structure (CoRE).

1. **What do you intend for students to learn about this idea?** (Learning Objectives)
2. **Why is it important for students to know this?** (Curricular justification and relevance)

3. **What else could you know about this idea that you don't intend students to know yet?** (Expanding the teacher's knowledge beyond what he teaches)
4. **What difficulties or limitations are related to the teaching of this idea?** (Knowledge of alternative conceptions and learning obstacles)
5. **What do students know about this idea that influences their teaching?** (Knowledge of prior knowledge and preconceptions)
6. **What other factors influence your teaching of this idea?** (Context: time, resources, group characteristics)
7. **What instructional strategies will you use and why?** (Knowledge of representations and strategies)
8. **How will you monitor students' understanding or confusion around this idea?** (Knowledge of formative assessment)

Table 2

Structure of a Content Representation (CoRe)

Great Ideas Questions	Big Idea 1: [Name]	Big Idea 2: [Name]	Big Idea 3: [Name]	...
1. What do you want students to learn?	...	...	...	...
2. Why is it important?	...	...	...	...
3. What else do you know that you do not intend to teach?	...	...	...	...
4. What difficulties are related?	...	...	...	...
5. What do students know that influences?	...	...	...	...
6. What other factors influence?	...	...	...	...
7. What strategies will you use and why?	...	...	...	...
8. How will you monitor comprehension?	...	...	...	...

Source: Authors (2025).

4.2.3 CoRe as a Tool for Capturing cPCKs and Developing Professionally

Within the framework of the Refined Consensus Model (RCM) (Carlson & Daehler, 2019), CoRes are recognized as a privileged instrument for capturing the **Collective PCK (cPCK).** The cPCK is the specialized knowledge shared by a community of educators about teaching a specific topic. A collaboratively generated CoRe represents precisely that amalgam of knowledge and experiences that transcend the individual teacher.

In addition to their function as a research instrument, CoReS have a **powerful educational value**. Numerous studies have documented that the collaborative construction process of CoRe:

- It promotes **metacognitive reflection** on one's own practice.
- It facilitates the **articulation of tacit knowledge**.
- It generates a **shared language** among teachers to discuss teaching.
- It creates a **lasting artifact** that can be reviewed, enriched, and transferred to other teachers.

4.2.4 The PaP-eRs: Narrative Complement of the CoRe

Loughran, Berry, and Mulhall (2004) also developed **PaP-eRs** (*Pedagogical and Professional experience repertoires*) as a narrative complement to CoRe. While CoRe provides a **conceptual structure** of professional knowledge, PaP-eRs illustrate **how that knowledge manifests itself in practice**.

A PaP-eR is typically a **short narrative vignette** that describes an actual teaching episode, highlighting:

- The pedagogical reasoning of the teacher.
- Specific instructional decisions.
- Interaction with students.
- Reflection on learning outcomes.

The combination of CoRe (collective declarative knowledge) and PaP-eRs (situated procedural knowledge) allows for a more holistic and authentic understanding of the PCK from teachers.

4.3 THE PCK MAP APPROACH: INTERACTION ANALYSIS

Park and Chen (2012) developed the **PCK map** approach as an analytical device for visualizing the interactions between PCK components in pedagogical reasoning and the ePCK. This approach follows three systematic steps:

1. **In-depth analysis of the explicit PCK:** Teaching *segments* are identified that indicate the presence of two or more components of the PCK, which are labeled as *PCK Episodes*. Each episode is described in detail.
2. **Enumerative approach:** The connections between the components identified in each episode are recorded. Each connection is assumed to have the same strength, and

the connection frequencies between pairs of components are added together to generate a visual representation (map).

3. **Constant comparative method:** PCK maps are compared with the emerging patterns of the qualitative analysis of interviews and observations to achieve methodological triangulation.

Despite its analytical power, Park and Suh (2019) recognize limitations in the PCK map approach, such as the difficulty in differentiating the strength of connections and insufficient attention to contextual and affective factors, which has led to subsequent modifications that explicitly incorporate these elements.

4.4 INTEGRATION OF CORE AND PCK MAPS IN MULTIMETHOD STUDIES

Contemporary research on PCK recommends the **integration of multiple instruments** to capture construct complexity. A particularly potent combination is:

1. **CoRe** to capture cPCK (collective knowledge shared by a community).
2. **Semi-structured and video-stimulated interviews to** capture the pPCK (personal knowledge of the teacher) and the ePCK (knowledge in action).
3. **PCK maps** (Park & Chen, 2012) to visually analyze the interactions between components during specific teaching episodes.

This multi-method approach allows the findings to be triangulated and to offer a richer and more reliable image of the professional teaching knowledge.

5 DISCUSSION AND FUTURE PERSPECTIVES. TOWARDS SITUATED AND TRANSFORMATIVE RESEARCH

5.1 CORRECTION OF CONCEPTUAL INACCURACIES

From the review of the literature presented, it is necessary to correct limited interpretations of the PCK that still persist. The PCK is not:

- **The sum of content knowledge and pedagogical knowledge:** It is an emergent transformation, not an addition.
- **A static and decontextualized knowledge:** It is dynamic, situated and co-constructed in communities of practice.
- **Exclusively cognitive:** The models of Park and Oliver (2008) and the RCM explicitly incorporate affective components (self-efficacy, beliefs) as amplifiers or filters.

5.2 THE AFFECTIVE AND CONTEXTUAL DIMENSION

One of the most consistent criticisms of Shulman's (1986) original formulation was its lack of attention to the affective, emotional, motivational, and moral aspects of teaching. Contemporary research has shown that the CPK is intrinsically linked to teachers' beliefs about their ability to achieve learning (self-efficacy) and their sensitivity to the students' sociocultural context, including factors such as language, identity, and community environment.

5.3 FUTURE LINES OF RESEARCH

The following lines are suggested to advance in the field:

1. **Longitudinal studies** that analyze the development trajectory of pPCK from initial training to expert practice, considering the mechanisms of amplification and filtering.
2. **Research on the cPCK and its relationship with teacher professional development** in collaborative learning communities.
3. **Technology integration:** Deepen the didactic technological knowledge of content (TPACK) as a situated extension of the PCK in digital environments.
4. **Multi-method methodologies** that combine PCK maps, video analytics, and measurement of student learning outcomes to establish more robust links between the ePCK and student achievement.

REFERENCES

Bandura, A. (1997). Self-efficacy: The exercise of control. Freeman.

Berry, A., Friedrichsen, P. J., & Loughran, J. (Eds.). (2015). Re-examining pedagogical content knowledge in science education (Vol. 395). Routledge.

Calderhead, J. (1981). Stimulated recall: A method for research on teaching. British Journal of Educational Psychology, 51(2), 211–217.

Carlson, J., & Daehler, K. R. (2019). The refined consensus model of pedagogical content knowledge in science education. In A. Hume, R. Cooper, & A. Borowski (Eds.), Repositioning pedagogical content knowledge in teachers' knowledge for teaching science (pp. 77–92). Springer.

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), Re-examining pedagogical content knowledge in science education (pp. 28–42). Routledge.

Grossman, P. L. (1990). The making of a teacher: Teacher knowledge and teacher education. Teachers College Press.

Hume, A., Cooper, R., & Borowski, A. (Eds.). (2019). Repositioning pedagogical content knowledge in teachers' knowledge for teaching science. Springer.

Loughran, J., Berry, A., & Mulhall, P. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. Journal of Research in Science Teaching, 41(4), 370–391.

Loughran, J., Berry, A., & Mulhall, P. (2012). Understanding and developing science teachers' pedagogical content knowledge (2nd ed.). Sense Publishers.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), Examining pedagogical content knowledge (pp. 95–132). Kluwer.

Park, S., & Chen, Y.-C. (2012). Mapping out the integration of the components of pedagogical content knowledge (PCK) for teaching photosynthesis and heredity. Journal of Research in Science Teaching, 49(7), 922–941.

Park, S., Jang, J. Y., Chen, Y.-C., & Jung, J. (2011). Is pedagogical content knowledge (PCK) necessary for reformed science teaching? Evidence from an empirical study. Research in Science Education, 41, 245–260.

Park, S., & Oliver, J. S. (2006). An investigation of the relationship between pedagogical content knowledge and teacher efficacy in science teaching [Paper presentation]. Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. Research in Science Education, 38(3), 261–284.

Park, S., & Oliver, J. S. (2008b). National Board Certification (NBC) as a catalyst for teachers' learning about teaching: The effects of the NBC process on candidate teachers' PCK development. Journal of Research in Science Teaching, 45(7), 812–834.

Park, S., & Suh, J. (2019). The PCK map approach to capturing the complexity of enacted PCK (ePCK) and pedagogical reasoning. In A. Hume, R. Cooper, & A. Borowski (Eds.), Repositioning pedagogical content knowledge in teachers' knowledge for teaching science (pp. 185–197). Springer.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1–22.

Suh, J., & Park, S. (2017). Exploring the relationship between pedagogical content knowledge (PCK) and sustainability of an innovative science teaching approach. Teaching and Teacher Education, 64, 246–259.

Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. Teaching and Teacher Education, 17(7), 783–805.