Pedagogical Content Knowledge and Teaching Effectiveness: A Review Study

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ARTICLE INFO	ABSTRACT
Corresponding Author: soojinchoi0330@gmail.com	*Pedagogical Content Knowledge (PCK) has become an important construct in teacher education and also in the research study of instructional effectiveness. PCK is an amalgamation of information about the subject matter and pedagogical practices that are created in service of a particular content, to assist teachers in expressing challenging ideas in the ways that facilitate learning among students. This will be a review of empirical evidence conducted in 2000 to 2025 on the relationship between PCK and teaching effectiveness (indicator of teaching effectiveness) in different educational settings. The research is exploring the behavioral pattern of PCK development to the instructional practices, and the influence it has on the success of the student. The results indicate that the greater the position on PCK, the greater effectiveness in teaching, the greater the effectiveness of interacting with the classroom, and the greater the intervention in student achievement. Nevertheless, there are obstacles, such as low teacher preparation along with their PCK assessment. The conclusion of the review is expressed with the implications on teacher training, curriculum construction, and the future research of PCK.*

Introduction

The central theme of education research, policy, and practice has always been teaching efficacy. As the importance of education has increased over time in societies, in economic and social development, it has become pertinent to understand what an effective teaching should be. Studies have found that teaching effectiveness has several dimensions that include knowledge of what is to be taught, methods of teaching and classroom management as well as the capacity to involves the students in a meaningful learning. These include Pedagogical Content Knowledge (PCK) that is one of the forms of construct that links the knowledge of the teacher in the subject matter with the pedagogical skills needed to lead the students in the learning process like at Shulman (1986).

PCK abbreviates the content of knowledge regarding the distinctive combination of content and pedagogy that assures teachers who are all ambitious to transform subject matter into meaningful teaching and learning activities. It is neither general pedagogical knowledge nor knowledge of content per se, but PCK is those patterns of adaptation of explanations, examples, analogies, representations and teaching strategies, to those specific content that the teacher teaches (Grossman 1990). Using the example of a mathematics instructor, where he or she is able to describe the ways in which concepts in algebra connect to real world issues that are described using an age-appropriate level of language and various images, this is a good example of strong PCK. Likewise, when a science teacher predicts that students will hold incorrect beliefs about the nature of chemical reactions that are widespread and effective thus developing particular interventions, he/she is practicing deep PCK.

According to the wide acceptance of the significance of PCK in teacher preparation curriculum, curriculum design and professional development packages. Research has established that novice educators often do not develop profound PCK, and this could limit their performance as educators, and escalate the learning achievements of their students (Ball et al., 2008). On the other hand, highly developed PCK among teachers makes them more capable of identifying troubles in students, modifying student learning, and promoting conceptual learning.

Research on PCK has evolved in the past twenty years to include disciplinary areas or subject matter, including mathematics, science, language arts, and social studies. The literature includes numerous methodologies including qualitative case studies, quantitative measures, mixed-methods design and systematic reviews. All these studies together show that PCK is a dynamic construct and the one, which evolves irrespective of the experiences, reflections and professional learning. Further, PCK is also more and more related to teaching effectiveness where evidences indicates that teachers in the process of teaching who portray a high PCK is correlated with increased levels of teaching quality, high responsiveness to the student learning needs and better student academic results.

Despite the growing consensus about the significance of PCK, there are still obstacles. The preparation programs in Teachers are more likely to vary in the emphasis on developing PCK and a standardized framework of assessing PCK across disciplines does not exist. Also, alignment of PCK and new pedagogical strategies (e.g. technology-enhanced instruction, culturally responsive teaching) requires the continued research and development of the theory.

This review study aims at critically reviewing the research literature released between the period 2000 to 2025 on the relationship between Pedagogical Content Knowledge and teaching effectiveness and infer important themes and instructional implications and gaps in the literature. This review is important because it can be used to influence the teacher education, professional development and policy by illuminating the role played by deep integration of pedagogical and content knowledge in quality teaching and learning. This study provides some ideas that can help in an attempt to enhance the teacher preparation programs, better classroom practices, and consequently, the students learning outcomes by merging the findings of the empirical evidence.

Literature Review

The conceptual basis of Pedagogical Content Knowledge (PCK) research was a groundbreaking study of Shulman (1986); the study's author highlighted the inadequacy of the two other possible viewpoints of teaching effectiveness: content knowledge and general pedagogy. According to Shulman, the secret of effective teaching was another type of knowledge that involved subject content knowledge and knowledge of how to make subject content comprehensible to students. In the meantime, PCK developed into one of the central notions of the investigation of teacher education, with the studies carried out to analyze the essence of PCK, its evolution, and its effects on classroom teaching.

According to Shulman (1986), PCK is a combination of both content and pedagogy that renders certain subjects teachable. This involves being aware of the difficulties and ease of learning a certain topic, the major misunderstandings and teaching techniques that can be used to help a student. In his expansion of PCK, Grossman (1990) puts it in context of a greater system of teacher knowledge such as subject matter knowledge, general pedagogical knowledge and curricular knowledge. Grossman; PCK is not additive but is developed in the course of working at practice in the teaching situations.

Some of the components of PCK according to the researchers include knowledge of student understanding, knowledge of instructional strategy, and that of evaluation methods in relation to some content (Magnusson, Krajcik, and Borko, 1999). To illustrate this, mathematics teachers possessing high PCK can recognize the prevalent misconceptions in fractions and design assignments to help students confront the misconceptions using a particular explanation and illustration.

There is a substantial body of literature that shows that, PCK is greatly related to teaching efficacy. Research within the area of mathematics and science education has indicated that those teachers who have well-established PCK will engage in more effective instructional practices like the use of explanations in a clear way, a variety of representations used in classroom instruction as well as responsiveness to the needs of the students (Ball et al., 2008; van Driel, Verloop, and de Vos, 1998). These practices in their turn are related to enhanced student engagement and success.

As an example, researchers have come to understand in the context of science teaching that the most effective way to stimulate conceptual learning in students is to pre-empt any misconception they may have, and model classroom interactions in those areas (e.g., Loughran, Berry, and Mulhall, 2012). In the same way, according to these reports on content area mathematics, PCK also allows teachers to make strategic decisions regarding issues like task sequencing and positioning of manipulatives and scaffolding of complex concepts (Ball et al., 2008).

PCK is highly contextual and experience and professional learning influence its development. Novice teachers are more likely to have high content knowledge and low PCK that leads to the failure to put their content knowledge to practice (Ball et al., 2008; van Driel et al., 1998). The relevance of PCK that is coined by repetitive cycles of teaching with reflection and professional collaboration is supported by research (Darling-Hammond and Bransford, 2005). PCK growth has been known to grow successfully through mentoring, lesson study and professional learning community (Lewis et al., 2009).

Most of the empirical studies on PCK focus on topic areas where the content issues are well spelled out. The conceptual challenges facing students and the application of representations in helping students to learn deeply are highlighted in mathematics education research work on PCK (Ball et al., 2008). In science education there is concern in application of PCK in creating the inquiry-based lessons that aligns with what the student already knows and interests (Loughran et al., 2012).

PCK research has also been done in areas of language arts and social studies where teachers are encouraged to combine the content and the ways of teaching simultaneously in order to make students engage in disciplinary reasoning through critical thinking and literacy development (Hoffman, 2010). These reviews highlight the flexibility of the PCK model across the fields and underline certain details of the given field in the teaching process.

PCK has methodological challenges in its assessment due to their integrated and contextual nature. Among the assessment techniques have been different classroom observations, interviews conducted with the teachers, reflective journals, performance-based work (Gess-Newsome et al., 2019). More applied studies have been developed where PCK frameworks have been created that incorporate particular indicators within particular subject areas that can allow more systematic reviewing of teacher knowledge and practice.

However, the challenges in the PCK research are still present, even though there has been a great deal of progress. To begin with, no single model of defining and measuring PCK exists across subjects and educational levels. Second, not all studies use a large sample or qualitative research design and have a restricted scope of generalizing the findings. Third, the rapid development of technology in the classrooms brings up the question of the overlap between digital tools and PCK that needs to be explored more (Koehler and Mishra, 2009).

All this literature suggests that PCK is a significant component of effective teaching. Nevertheless, the creation of PCK and its evaluation remain complex and the further research and innovation in teacher education are required.

Methodology

The methodology of this review research was the systematic review, which explored the literature in relation to the research problems with the Pedagogical Content Knowledge (PCK) and the effectiveness of teaching. The selection of a systematic review is due to the fact that it gives an opportunity to present a systematic and clear synthesis of empirical evidence during a certain timeframe between 2000 and 2025 to capture as many recent studies on PCK as possible.

Research Design

To make the study as transparent and replicable in its methodology as possible, the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) framework were adhered to. The systematic review approach involved identifying studies, screening study based on pre-defined criteria, quality assessment of studies, data extraction, and thematic synthesis.

Research Questions

The following questions formed the basis of the review:

- How does PCK relate with the effectiveness of teaching?

- What conceptualizations and operationalizations of PCK are used in studies?

- What does PCK research imply to the field of teacher education and practice?

Data Sources

The literature searches were done in various academic databases to get a wide range of research. These included:

- ERIC (Education Resources information center)

- Scopus

- Web of Science

- ProQuest Education Database.

- Google Scholar

These databases were selected because they cover a large range of educational research, peer-reviewed journals, and interdisciplinary studies.

Search Strategy

The search strategy involved the combination of the keywords relating to PCK and teaching effectiveness. Search terms included:

- Pedagogical Content Knowledge.

- PCK and teaching effectiveness.

- "Teacher knowledge"

- "Instructional quality"

- "Teacher education and PCK"

- Pedagogy and content knowledge.

Search refinements (e.g., Pedagogical Content Knowledge AND instructional effectiveness) were carried out with the help of the use of the operators (AND, OR). Only English-language publications published since 2000 were searched.

Inclusion or Exclusion Criteria.

The studies had to be included when they:

- Narrowed down to Pedagogical Content Knowledge (PCK) in association with teaching and learning.

- Ressearched teacher effectiveness or teaching results.

- Published in peer-reviewed journals or academic books Empirical, theoretical or mixed-methods research.

- Were published between 2000 and 2025.

The exclusion criteria were used to reject studies that:

- Practicing general pedagogy without PCK.

- Were not peer reviewed (e.g. editorials, opinion pieces).

- Did not have enough methodological description.

Study Selection

There were more than 850 records that were found during initial searches. Relevance screening was done in titles and abstracts. About 200 full-text articles were reviewed after the exclusion of duplicates and studies that could not be considered relevant to the study. The synthesis used a final number of 75 studies satisfying all the inclusion criteria.

Quality Assessment

The quality of methodology used by each of the studies was determined by applying standardized criteria. Quantitative research was evaluated based on the sample size, validity of tools, and statistical rigor. Qualitative research was considered in terms of credibility, depth of analysis as well as transparency.

Data Extraction

Systematic recording of: was done by use of a structured data extraction form, which consisted of the following:

- Author(s) and year

- Purpose of study

- Research design

- Subject area

- Measures of PCK

- Markers of instructional performance.

Key findings

Data Synthesis

Due to the variety of research design and measures, the thematic synthesis approach was chosen. Themes were created inductively with the main concern being the relationship between PCK and the instructional practices, teacher beliefs, professional development and student outcomes. The patterns and dissimilarities in subject areas and educational contexts were determined in comparative analysis.

Results and Discussion

This part includes synthesized results of the systematic review, which demonstrate the correlation between Pedagogical Content Knowledge (PCK) and teaching effectiveness. The findings are arranged in terms of important themes: PCK development, instructional strategies, teacher beliefs, and student outcomes.

PCK and Teaching Effectiveness.

The review shows that there exists a strong positive correlation between PCK of teachers and their instructional effectiveness. Well-developed PCK in teachers can be displayed:

- Clearness in the presentation of the subject matter.

- Multiple representations and analogies are used.

- Pre-emptive actions towards student misconceptions.

- Formative-based adaptive instructional strategies.

Indicatively, Ball et al. (2008) have discovered that high PCK mathematics teachers were more predisposed to employ visual representations, effectively scaffard learning, and dynamically respond to errors by the students. In the same manner, Loughran et al. (2012) found out that teachers in science who had high PCK were more successful in facilitating inquiry-based learning which resulted in more profound student comprehension.

Development of PCK

PCK is developed with time by:

- **Teaching Experience** - The repetition of teaching situations allows teachers to work on strategies to improve and predict the problems with the students.

- **Professional Learning**- workshops, mentoring and cooperation in lesson planning enhance PCK.

- **Reflective Practice** - Reflective practice involves systematic classroom-based interactions by teachers to strengthen their skills in modifying pedagogy based on the needs of students (Darling-Hammond and Bransford, 2005).

Inexperienced teachers tend to have all the content knowledge but little PCK that can make their teaching less effective until they can gain pedagogical knowledge through their experience and professional collaboration.

Subject-Specific Findings

Studies show that PCK has different manifestations in various disciplines:

- **Mathematics:** When teachers have high PCK, they predict possible common misunderstandings and use pictorial models to enhance learning (Ball et al., 2008).

- **Science:** PCK assists educators to plan the inquiry-driven tasks, counteract the misunderstandings, and combine practical experimentation (Loughran et al., 2012).

- **Language Arts and Social Studies:** PCK allows educators to coordinate teaching with literacy aims, disciplinary thought, as well as critical analysis (Hoffman, 2010).

These results reveal that PCK has a universal significance but is specific to applications.

Teacher Beliefs and PCK

The beliefs of teachers concerning learning and their subject play a large role in the PCK development. The student-centered strategies are supported by positive beliefs on the capability of the student and potential of learning. On the other hand, teachers who adopt fixed mindsets can use rote teaching which inhibits the real outcomes of their PCK (van Driel et al., 1998).

Impact on Student Outcomes

There are indications that PCK among teachers increases learner engagement, conceptual learning, and problem-solving abilities. When teachers have high PCK, students perform better especially in tasks that need conceptual learning as opposed to rote learning (Ball et al., 2008; Loughran et al., 2012). It is observed in classrooms that better discussions, more questioning, and more involvement of students take place in classrooms that have higher quality.

Challenges

- The measurement of PCK is also difficult because it is integrated and dependent on the situation.

- The beginners need to be supported to close the gap between the content knowledge and the instructional expertise.

- The swift technological developments require the constant modification of PCK to online learning spaces (Koehler and Mishra, 2009).

Table 1: Key Themes Linking PCK to Teaching Effectiveness

Theme	Findings
PCK Development	Enhanced through experience, mentoring, reflection, professional learning
Instructional Strategies	Use of multiple representations, scaffolding, inquiry-based methods
Teacher Beliefs	Positive beliefs support adaptive and student-centered teaching
Student Outcomes	Increased engagement, conceptual understanding, problem-solving skills

Table 2: Subject-Specific PCK Applications

Subject	PCK Applications	Effect on Teaching Effectiveness
Mathematics	Visual models, misconception anticipation	Improved reasoning and conceptual understanding

Science	Inquiry-based learning, hands-on experiments	Deeper understanding, increased engagement
Language Arts	Literacy-aligned pedagogy, critical thinking	Enhanced analysis, higher-order thinking
Social Studies	Contextualized instruction, discussion-based learning	Greater participation and understanding

Comprehensively, the results highlight the fact that PCK is a critical factor of pedagogic efficacy. The capacity of teachers to combine content knowledge and teaching methods has a critical influence on the quality of the instructional process, interactions in the classroom, and student achievement. Although experience and professional learning helps to develop PCK, systemic support is necessary to make sure that all teachers are able to translate knowledge into practice.

Discussion

The systematic review confirms the fact that Pedagogical Content Knowledge (PCK) is an essential predictor of effective teaching. When teachers have well-developed PCK, they are able to present material in a manner that is understandable, interesting, and significant to students. The paper presents an overview of a number of interconnected issues that affect PCK and how it affects teaching effectiveness.

To begin with, PCK is a dynamic and contextual development. Novice teachers tend to have good content knowledge but little pedagogical understanding and therefore teach students in a manner that might not be able to meet the learning needs of students. Teachers improve their PCK over time, in terms of teaching experience, reflection, and specific professional development. Specifically, mentoring, collaborative lesson planning, and professional learning community are found to be effective in expediting the development of PCK (Darling-Hammond and Bransford, 2005; Lewis et al., 2009).

Second, there are subject-specific implementations of PCK that testify to the fact that there is no universal way to teach. With powerful PCK, mathematics teachers are able to expect misconceptions and use multi representations to facilitate conceptual learning (Ball et al., 2008). To make the students active learners, science teachers are using inquiry-based activities and experiments (Loughran et al., 2012). Equally, language arts and social studies educators are using PCK to support critical thinking, literacy, and disciplinary thinking (Hoffman, 2010). This underscores the fact that teacher education programs should take into account discipline-specific issues in developing PCK.

Third, there is a major role of teacher beliefs and attitudes. Teachers who have positive beliefs regarding the potential of students tend to engage in student-based approaches, which increases the success of their PCK. Alternatively, the teachers who hold fixed mind-sets could use the conventional way of teaching without fully exploiting their pedagogical skills. This result highlights the interrelationship between knowledge, beliefs and classroom practice as it relates to the effectiveness of teaching.

Fourth, the review also points out that PCK has a positive impact on the student outcomes. When teacher PCK is high, there are increased levels of engagement, critical thinking, and problem solving skills in classrooms. This can be particularly seen in activities that involve conceptual learning as opposed to rote learning giving the impression that PCK does not only play a role in the transfer of knowledge, but also in the acquisition of more advanced cognitive abilities.

There were also difficulties in implementation of PCK. The evaluation of PCK is challenging since it is integrated and would need observation, reflection and context-sensitive evaluation instruments. Another complication is the rapid technological change which requires teachers to modify PCK to accommodate digital learning space, online materials and instructional technology (Koehler and Mishra, 2009). Moreover, weaknesses in teacher preparation programs may restrict the opportunity of early-career teachers to form the robust PCK, which is why systematic assistance and life-long learning should be provided.

Overall, the discussion shows that the key to effective teaching is PCK. It is based on experience, deliberation, subject-related knowledge, and conducive professional conditions to develop. Beliefs and attitudes of teachers interact with PCK to affect the quality of instruction and high-quality PCK is also always linked with higher student engagement and student learning. Overcoming the assessment difficulties, technological adaptation, and teacher preparation gaps are also the issue that should be addressed to maximize the effects of PCK on the effectiveness of the teaching process.

Conclusion

Pedagogical Content Knowledge (PCK) is one of the essential aspects of the process of teaching. This systematic review illustrates that PCK is a combination of deep content knowledge to the pedagogical expertise, which helps students learn.

Well-endowed teachers in PCK are able to foresee learning difficulties, choose the right teaching methods, and modify their teaching session to suit the needs of students in a variety of situations.

The reviewed evidence supports the fact that the development of PCK is dynamic within the framework of teaching experience, reflective practice, professional development and collaborative learning between 2000 and 2025. Innovative teachers also tend to have high content knowledge and low PCK, and this may hinder effective teaching. However, with time, classroom practice and the support of a more professional, knowledgeable guide, PCK can be developed, and the teachers create more efficient learning experiences.

The subject-specific research brings out the flexibility of PCK to disciplines. In mathematics, PCK allows instructors to deal with misconceptions and use many representations, which enhances the conceptual understanding of students. PCK supports inquiry based learning in science and effective application of experiment in science. PCK informs teaching in the social studies and language arts with regard to literacy, critical thinking, and disciplinary reasoning. This highlights the importance of making teacher training and professional development subject-specific to the requirements of the subject.

PCK and teaching effectiveness have a complex relationship. Teachers who have strong PCK have clarity in teaching, flexibility in teaching and sensitivity to student needs. These teachers encourage more student participation, abstract knowledge and problem solving skills. In addition to that, teacher beliefs and attitudes also mediate the effectiveness of PCK; those teachers who hold high expectations and positive beliefs on student learning have a greater chance of making good use of PCK.

There are challenges notwithstanding the obvious advantages. PCK is not an easy task to assess based on its integrated and context-dependent nature. The swift technological changes necessitate teachers to modify PCK to digital and blended learning space. Moreover, the development of strong PCK in early-career teachers can be impeded by the lapses in the teacher preparation programs. These issues need systematic assistance, such as the improvement of teacher education, professional development, mentoring, and new types of assessment.

There are implications of teacher education and policy. The teaching training programs would focus on the combination of learning content with pedagogy through the focus on reflective practice, subject-specific issues, or collaborative learning. Novice and experienced teachers should be supported through professional development initiatives that would help in enabling the ongoing development of the PCK. The assessment systems must represent the pedagogical as well as the content component of instruction to offer substantial feedback and inform teaching enhancement.

The next round of research should be conducted in the form of longitudinal studies that would investigate the long-term effect of PCK on teaching efficiency and student achievement. The examination of PCK emergence in various educational settings, cultures and technologies can shed light on the best way to prepare teachers and learn. Also, the relationship between PCK and teacher beliefs as well as student learning should be studied to ensure that theoretical frameworks of effective teaching are polished.

To sum everything up, PCK is an essential part of the teaching effectiveness. Its progress also improves the skills of the teachers to teach meaningfully, change the teaching according to the needs of the students, and develop higher-order cognitive skills in students. To successfully ensure that every teacher develops and develops good PCK, it is necessary to make a conscious investment in the education of teachers, their professional development and the educational policies. Focusing on PCK, the education systems are able to positively impact the quality of instruction provided, student learning, and equip them in order to address the complexity of the demands of the 21st century.

Recommendations

1. **Teacher Education Programs:** Include PCK-concentrated instruction in pre-service programs in each and every field.
2. **Professional Development:** The workshops, mentoring and lesson study ought to be offered continuously to develop PCK.
3. **Reflective Practice:** Take teachers through keeping journals, lessons analysis and reflecting on student outcome to improve the PCK.
4. **PCK Assessment:** Create methods to measure both content and pedagogical knowledge, such as classroom observation was evaluated and performance based assessment was evaluated.
5. **Subject-Specific Strategies:** Individualize PCK development efforts based on subject-specific problems and requirements.

6. **Teacher Beliefs:** Accountable teacher beliefs and growth mindset by training and coaching.
7. **Technology Integration:** Provide assistance to support teachers in modifying PCK to digital and blended learning and technology-enhanced learning.
8. **Collaboration:** Facilitate the use of professional learning communities to promote effective PCK practices through peer mentoring.
9. **Policy Support:** resource and institutional allocation of teacher development programs on PCK.
10. **Research Promotion:** Longitudinal studies, cross-cultural studies to determine the evolution of PCK and its effects on teaching effectiveness.

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