education sciences

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Teachers' Pedagogical Content Knowledge Within Gifted and Talented Education in the Context of Inquiry-Based Instruction

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Abstract

Inquiry-based instruction is an effective instructional approach, generally in education and notably in gifted, creative, and talented education (GCT). The knowledge and skills teachers require to effectively facilitate learning are captured in the concept of pedagogical content knowledge (PCK). However, PCK has mostly focused on its core types of equally important and interacting teacher knowledge: content, pedagogy, and students. This paper extends the consideration of PCK to three interconnected parts of instruction—planning, teaching enactment, and assessment—through a historical overview of how additional elements were added to the founding elements of PCK, the ways an inquiry-based approach adds to each in terms of expanded opportunities, and challenges that can facilitate talent development and the development of learners' expertise. A three-by-three grid summarizes this inquiry-based perspective of PCK focused on GCT teachers.

Keywords: pedagogical content knowledge (PCK); inquiry; teacher knowledge; teacher expertise; planning for instruction; assessment; gifted, creative, and talented education (GCT)

1. Introduction

The instructional literature regarding gifted, creative, and talented (GCT) learners has leaned heavily on characteristics of the learners and on teacher variables related to the depth and level of subject-matter mastery, the pace of the curriculum, and the inclusion of opportunities for student-initiated inquiry. Teaching in gifted education or for talent development also depends on a knowledge base well aligned with inquiry- and expertise-based conceptions of teaching, learning, and knowledge utilization (Birlean & Shore, 2018). However, the GCT literature has been relatively quiet about pedagogical content knowledge (PCK) and its implications for teachers and teaching.

There are many definitions of giftedness, creativity, talent, and inquiry. Their meanings also vary across disciplines or groups of disciplines. We explore these briefly in the text that follows. PCK also presents challenges for our purposes, especially because of the size of the literature. Checking indexing databases for citations of PCK in June 2026, ERIC added over a thousand documents from 2007 to early 2026, Web of Science catalogued almost 12,500 citations, Scopus tallied over 146,000, and wide-reaching Google Scholar yielded almost 4 million results and about a quarter as many for "PCK Inquiry." Accessing and utilizing this overwhelming number of studies, reviews, commentaries, guides, and models

Check for updates

Academic Editor: Jonathan Glazzard

Received: 24 April 2026
Revised: 17 September 2026
Accepted: 24 September 2026
Published: 21 October 2026

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is probably impossible, and even more challenging in inquiry-based instruction because of the additional elements compared with other teaching and learning approaches.

Our overview addresses the gap regarding PCK in GCT education in part by enhancing the connections between PCK and three interconnected parts of instruction: planning, teaching enactment, and assessment. Enactment and assessment, in particular, are explicitly emphasized in several contemporary PCK models (also addressed below). Our additional emphasis on planning arises from research on inquiry and active learning that are core to GCT.

2. A Short History of PCK

The idea of PCK has evolved and been elaborated over recent decades. Interrelated instructional events and their respective teachers' knowledge bases (as well as beliefs that are beyond the present discussion) of planning, teaching enactment, and assessment have been added. Similarly, these same three instructional foci have become more explicit in inquiry-based instruction (cf. Aulls & Shore, 2008), and in their specific relevance to GCT education.

In an example of a later, integrated PCK model, specifically a consensus model generated by a conference of PCK researchers, PCK was broadly defined as "the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes" (Gess-Newsome, 2015, p. 36). Recognizing, however, that different teachers address these same goals differently and often equally effectively, this model was elaborated by her and 25 other authors (Carlson et al., 2019) as the Refined Consensus Model that included both planning and assessment. It distinguished different kinds of PCK, namely, collective (cPCK), personal (pPCK), and enacted (ePCK). cPCK addresses shared professional knowledge, for example, in the present instance, how to engage students in high-level questioning or about giftedness or the subject matter. pPCK refers to the unique personal instructional repertoire gained over years by individual teachers. ePCK is what Gess-Newsome described in her 2015 definition.

The most important caveat with regard to these models is that they were created specifically in the context of science education. This might deter specialists in other disciplinary groups from considering these ideas, but it should not. We could not discern anything about the model that constrains its general applicability to other disciplines, across disciplines, or to any GCT population. The attention to "particular students for enhanced student outcomes" should resonate well with GCT concerns that the particular needs of GCT students are not broadly met. Using a PCK model, rather than a proprietary GCT model, for such differentiation also helps connect GCT to important developments in general education, potentially to mutual benefit.

2.1. Knowledge of Content and Pedagogy, and Enactment of Teaching

PCK originated with Shulman (1986, 1987), who examined the information or knowledge teachers used when making decisions about and enacting instruction. Teachers' knowledge and skills ranged from the taught subject matter to repertoires of teaching skills and information about the learners. He especially identified two prominent knowledge categories in teaching enactment: knowledge of content (KC) and knowledge of pedagogy (KP). He labeled their integration PCK.

Initially, PCK incorporated two forms of KC. First, teachers have a collection of facts, information, principles, and concepts in a knowledge domain. Second, teachers learn how these elements are organized in the subject, grouped under headings, and related to each other. Concept maps are one way to envision this. Textbook chapter titles or review article

headings are another. What connects concepts at this level of organization is not directly or fully evident to novice teachers (or learners). Furthermore, knowledge in different subjects is differently organized. For example, key science concepts are often subdivided within hierarchical categories, but core ideas in humanities and social sciences are more evenly clustered (Donald, 1983).

KP included the pedagogical knowledge and skills repertoire teachers invoke to help learners acquire the content (inquiry's emphasis on learning how new knowledge is created came later). Some pedagogical practices are general or widely applicable; others are favored in specific domains. Shulman (1986) explicitly acknowledged the importance of knowledge about learners (KL) for effective teaching but emphasized KC and KP in the idea of PCK. He was also aware of the importance of curriculum and lesson planning, the emerging emphasis on inquiry-based instruction, and the importance of assessment. However, perhaps due to his research program's focus on teachers' instructional decision making, these three were subsumed within KC and KP, not separately articulated in the initial conceptualization of PCK. Focused on teaching enactment, Shulman (1986) wrote the following:

> Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations–in a word, the ways of representing and formulating the subject that make it comprehensible to others. . . [PCK] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning. (p. 9)

2.2. Planning as an Explicit Part of Teaching Enactment

Leinhardt and her colleagues especially articulated the role of planning. Leinhardt et al.'s (1991) PCK model connected interactive classroom enactment portions of PCK, notably instructional explanations and representations designed with learners in mind, to two key features of advanced planning: agendas and curriculum scripts. In practice, these four components are interconnected. Agendas are the teacher's dynamic plan for a specific lesson, dynamic because elements are modified during instruction. They include goals and actions for the lesson, and strategies to be used. They can be captured by asking the following: What are you going to do? What do you expect will happen? Curriculum scripts provide structure in terms of the sequence of ideas to be presented that enables content cohesiveness during enactment of a topic (Leinhardt & Putnam, 1987), as well as actions that accompany these sequences, driven by the common goal of helping students build desired and meaningful knowledge structures. The teacher's role throughout the enactment of curriculum scripts is to continuously monitor students' performance and verify whether the acquisition of content or procedures has succeeded. If students do not learn the desired concepts or procedures, the teacher modifies the curriculum script by elaborating or re-presenting the concept or procedure.

Assessment and evaluation are closely aligned with planning. Emphasis has remained on enactment of planning and teaching. Few studies have distinguished PCK that informs teaching practices from PCK that explicitly informs both planning and teaching (exceptions include Barendsen & Henze, 2019; Chan, 2022; Mavhunga & van der Merwe, 2020; Park & Chen, 2012). However, according to Leinhardt et al. (1991), instruction includes both teacher and student actions. These could be teacher-led, student-led, or jointly led by both. This re-envisions classrooms and PCK in action more consistently with active learning and inquiry-based instruction.

Instructors' course and lesson planning, ongoing student-learning evaluation and feedback, and student roles, especially being called upon to explain what they are learning to each other and the instructor, most clearly distinguished inquiry-based instruction for 16 observed education professors (Aulls et al., 2015) and active learning in four university science classes, in which KC typically exceeds KP (Aulls et al., 2026) from more traditional instruction. Leinhardt's work highlighted teachers' roles. Aulls et al. (2026), however, found that just one student role uniquely distinguished the active-learning classes: students explaining concepts and their interrelations. Instructor planning is necessary for both the lesson agenda and scripts to engage students in providing explanations in class. For example, teachers need to schedule when in a lesson and on what topics to solicit student explanations and build a repertoire of instructions and encouragements to help students acquire that skill plus confidence doing so.

2.3. Assessment as an Explicit Part of Teaching Enactment

Teachers' KC, KP, and KS are important in planning for instruction, enacting it, and ensuring formative and summative assessment of student progress. Assessment was present within Shulman's and Leinhardt's conceptualizations and descriptions, but PCK was primarily discussed within one part of that cycle, the observable act of teaching. To reflect the growing general literature on assessment integrated within instruction, assessment needed to be elevated to equality with planning and teaching enactment.

Tamir (1988) was among the first to highlight the pedagogical importance of assessment, soon after Shulman (1986, 1987) conceptualized PCK. Tamir emphasized content or subject-matter knowledge as an end-product of instruction to evaluate learning, not previously fully articulated as ongoing (e.g., formative) within PCK. Addressing both the content of the subject matter and how knowledge is created and utilized in the field anticipated a bridge to PCK in an inquiry-based context. The US National Research Council (NRC, 2000) introduced a more global perspective of assessment related to PCK. Assessment design and practice could be enhanced by stages with assessment executed recursively, so later stages in the assessment process (e.g., reporting) could impact decisions about earlier stages (e.g., task design, within planning). Assessments should include a purpose statement, a definition of the content domain being measured, and the goal to combine existing theoretical descriptions of learning to create a holistic picture of student performance. This perspective presaged the interweaving of planning, KC, KP, KS, and assessment within an expanded conceptualization of PCK.

Park and Oliver (2008) and Park and Chen (2012) built on previous work by Grossman (1990), Tamir (1988), and others to emphasize the need for all PCK elements from planning to assessment to be cyclical and mutually interconnected rather than a sequence of steps, beginning with (a) orientations toward teaching the subject matter, (b) knowledge of students' understanding on the subject (part of KS but less focused on general development or, for example, students' possibly relevant but unconnected experiences in other domains), (c) knowledge of the subject curriculum (a subset of KC), (d) knowledge of instructional strategies and representations (close to KP), and (e) knowledge of assessment of learning. Each of these five elements contributes equally. In our proposed conceptualization, assessment is not presented as another form of teacher knowledge, but as a third key element of instruction alongside planning and teaching enactment.

Teachers' assessment reasoning is often constrained by prior conceptions of student learning and assessment (Otero, 2006) and beliefs about fairness (Yung, 2001). Assessment practices can also mirror beliefs about assessment as a tool to measure achievement rather than to reveal deep student understanding and improve learning (Gioka, 2009; Shepard, 2000). Aydin et al. (2015) demonstrated the idiosyncratic nature of novice teachers' PCK

and weak links between assessment and instructional strategies revealed in concept maps, although there were better connections with knowledge of the curriculum and of learners, as well as teaching orientation. Even during preservice education, these connections and PCK can be enhanced by mentoring. Experienced teachers' beliefs and values about assessment and the purposes for assessment also determine how and what they assess. Teachers effectively diagnose students' difficulties, assess them, and then enact instructional strategies aligned with what they learned about students' thinking. Assessment is, therefore, complex and requires profound reflection to shape the interactions among PCK components, a serious challenge for inexperienced teachers (Krepf et al., 2018), especially with children presenting special needs or talents.

Assessment must align with planning and teaching and inform these processes while helping the teacher and students to continuously monitor the learning process and products. Diverse needs of learners such as abilities, interests, readiness levels, prior knowledge, and learning and expression skills and preferences should be actively sought and used to inform instruction. Assessment intersects all parts of PCK.

2.4. Knowledge About Students

Shulman perceived teaching as transformation of understanding of subject matter into content accessible to students (Neumann et al., 2019). In addition to the three originally proposed types of teacher knowledge needed to realize such transformation—KC, KP, and PCK (the integration of KC and KP)—Shulman (1987) expanded the repertoire of teacher knowledge to seven types with these additions:

- General pedagogical knowledge (strategies for classroom organization and management);
- Knowledge of learners and their characteristics;
- Knowledge of educational contexts ranging from classroom level to school districts, communities, and cultures;
- Knowledge of educational goals and purposes.

Shulman re-emphasized the critical importance of PCK to the teaching profession, noting that PCK distinguishes the content specialist from the professional pedagogue, a point elaborated by Park and Oliver (2008) and demonstrated by Syer et al. (2013). Senior education undergraduates who learned about inquiry as pedagogy and senior psychology students who did inquiry projects were similar in valuing elements of doing inquiry, but the education students better prescribed how to engage new learners in inquiry. Shulman, however, did not integrate the four new teacher knowledge types into the idea of PCK.

Kind and Chan (2019) built a PCK model using Shulman's expanded conceptualization with such integration. Teachers progressing from novice to expert add new types of knowledge, and their knowledge grows within each of six categories:

• Knowledge of Assessment and Curriculum	These first four together comprise
• Organization of Resources and Materials	Knowledge of Pedagogy (KP)
• Classroom Management	
• Knowledge of Instructional Strategies	
• Knowledge of Students	Bridges KC and KP
• Content Knowledge: Facts and Concepts	Knowledge of Content (KC)

This model more precisely defines the elements of KP. Knowledge of goals, purposes, and contexts fit within assessment and curriculum. General pedagogical knowledge is divided into teaching organization and classroom management. Cross-disciplinary pedagogical techniques such as question asking or soliciting evidence-based explanations from students could fit into the catch-all knowledge of instructional strategies (some of

which might be subject-specific and some more general). A strength of Kind and Chan's PCK model is the emphasis on career-long growth in each category. Our first concern is that it does not strongly emphasize the recursive, cyclical experiences stressed by the NRC (2000) and Park and Chen (2012), although nothing prevents adding this feature. Second, knowledge of content remains potentially limited to the previously organized canon of current knowledge in a field (as in textbooks) and does not extend explicitly to the ways new knowledge is created within or across domains.

The important advance, however, was asserting the central mediating role of KS as a bridge between KC and KP. KS addresses characteristics of learners from specific and general abilities, interests, strengths, and areas for improvement, and an individual's facts, concepts, vocabulary, skills, and experiences within and across domains. Student-centeredness helps teachers integrate KC and KS, thereby defining and impacting PCK. KS helps teachers make appropriate judgments regarding the selection of instructional strategies for conveying specific content to an individual or group.

2.5. More Recent Integrative Models of PCK

As conceptions of inquiry and giftedness have developed, so have conceptualizations of PCK. For example, inquiry-based instruction is more than students pursuing their interests, and notions of giftedness have graduated from high IQ (even if practice sometimes lags) to the development of expert-like thinking. All three concepts have added important nuances. Our focus in this attempt to connect PCK and inquiry as important to the future of GCT instructional knowledge and practice has focused on three basic, perhaps now oversimplified but still useful, notions within PCK, namely, KC, KP, and KS. This selectiveness is intended to draw the attention of GCT educators to the fact that the PCK literature can and probably should be a useful part of their instructional thinking, dialogue, and enactment. The most general PCK models to date have integrated all the elements described above, including assessment.

3. Connecting PCK and Inquiry-Based Instruction

3.1. Inquiry-Based Instruction

There are many definitions of inquiry-based instruction. A useful one is within Keegan's (1993) comparison of different instructional models as distinguished by the nature of student and teacher interactions and responsibility (elaborated further below). In inquiry, students are responsible for the questions; students and teachers share responsibility for designing and conducting paths to the answers. Implicit in this model is the student task of asking researchable questions and for the teacher to use these curiosities as the launching pad for learning. Such shared responsibility between teachers and students, as well as students with other students, illustrates the social-constructivist (Vygotsky, 1978) roots of inquiry-based instruction.

Inquiry manifests differently across disciplines because the ways of knowing and what qualifies as valid evidence are varied. This has been recognized for nearly a century or more, and the 1930s European group led by Neurath et al. (1938/1969) especially recognized the instructional implications of these differences, notably, that in every discipline, it is important to provide guidance to learners so that they may engage in original inquiry and not merely absorb content that has been summarized and recorded. This was echoed in the possibly more familiar classic example by Bruner (1960) of a school child learning physics better "when behaving like a physicist than doing something else" (p. 14), that is, constructing new personal understanding of the material, not just memorizing what others have mastered and organized, but also being motivated and tackling extended challenges. An important commonality across disciplines is the central role of students

asking questions, not just about class management or clarifications of text, but questions that extend and deepen their understanding within and across disciplines, and in relation to their experiences and prior knowledge.

3.2. Inquiry in GCT

Instructional models that advocate enacting GCT in ways that are identifiable as inquiry-based are not new. The best-known example is probably Renzulli's Type III enrichment activities first published in 1977 and updated several times with colleagues since then (Renzulli & Reis, 2014). Type III activities are interest-based, individual and small-group student investigations, with results shared with others, preceded by exploration of resource material and in-depth study of the topic for potential deeper study. These fit well into Keegan's (1993) framework and Bruner's (1960) characterization, and their emphasis on student–teacher and especially student–student interactions reflects the social-constructivist pedagogy.

GCT students experiencing inquiry opportunities reported high enjoyment, reversed underachievement, and generated exceptional products (Baum et al., 1995). The concept of PCK helps focus and operationalize what is meant by both teacher expertise and learners' development of expertise, a conception of giftedness that has been promoted for decades (Pelletier & Shore, 2003; Sternberg, 1998), but one that still faces hurdles in identification and content-focused achievement. Also, it might be hard even for gifted learners initially to fully emulate the thinking processes of adult experts. The related fields of gifted-and-talented or GCT education and talent development also benefit from more closely connecting to mainstream theory and models applied to education (Shore, 2021/2022). PCK is one such connection. Giftedness becomes less subject to perceptions of elitism when it is framed as the development of expertise, and promoting inquiry-based instruction in that context ties it directly to social-constructivist learning theory that drives mainstream educational initiatives, for example, in science (EC, 2007; NRC, 2000), mathematics (NCTM, 2000), social studies (NCSS, 1994), and across the curriculum (UNESCO, 2008).

Skills such as problem solving, communication, collaboration, experimentation, critical thinking, and creative expression become curricular goals in themselves, and these are the objects of new assessment methods. Perhaps the most significant goal is for students to be able to determine their own learning goals and plan—the ability to establish what they already know, assess their strengths and weaknesses, design a learning plan, stay on task, track their own progress, and build on successes and adjust to failures—skills that can be used throughout a lifetime to participate in a learning society (UNESCO, 2008, p. 8).

4. How Inquiry-Based Instruction Informs PCK

Inquiry-based instruction (Aulls & Shore, 2008; Keegan, 1993) adds several layers to a teacher's understanding of the actions of planning, teaching, and assessment, as well as to KC, KP, and KS. Researchers such as Suh and Park (2017) used a PCK framework in a triple case study that explored elementary school teachers' implementation of inquiry-based science instruction. Similarly, Lee and Kriewaldt (2025) reported a survey of 44 Australian secondary geography teachers and the intersection of their teaching knowledge and beliefs with inquiry methodology. The following are some main general points about how inquiry and PCK intersect, each illustrated by a teaching example.

4.1. Knowledge of Content

The most critical part of a teacher's KC impacted by an inquiry approach to instruction is that the subject matter content extends beyond the organized canon of knowledge to the processes of how knowledge is created and what constitutes evidence and appropriate

argument in that field, as highlighted, for example, by Neurath et al. (1938/1969) and Bruner (1960). KC, in inquiry, includes being a creator of, at least, new personal understandings of the material taught, if not actually creating new knowledge in the domain. There are at least two ways to achieve this new knowledge: Engage in knowledge creation in the subject (e.g., as part of a scholarly group, completing a graduate, undergraduate, or earlier investigation), or formally study research methods of a discipline (Aulls et al., 2016). Knowing a subject, even to the level of conducting a research project, does not assure knowledge of how to create a situation in which it can be learned by others (Syer et al., 2013). Linking KC to KP requires intentional learning opportunities.

Expert teachers have more elaborate and extensive subject matter knowledge than novice teachers and better knowledge of how new knowledge is created in the domains under consideration. The structuring of their subject matter is also more highly connected and integrated (Berliner, 1986), containing more well-explained and accessible interconnections and overarching thematic elements (Chi et al., 1982). More successful learners' concept maps exhibit fewer unconnected concepts and better explanations of the links (Austin & Shore, 1993). Leinhardt et al. (1991) observed that novice teachers are not as aware of the lesson segments and their associated goal states because they have not yet mastered the subject matter well enough to be creative and flexible in their teaching.

KC-Centered Illustration

Barreto-Espino and Zembal-Saul (2014) asked prospective elementary science teachers to teach science as argument. They used first-hand data and worked together to interpret the data and draw defensible conclusions based on evidence-based scientific explanations and arguments. They experienced the process of inquiry as learners and teachers while meaningfully addressing the specific content (plants). Afterward, they more frequently engaged their students in similar experiences. This also illustrated how PCK is more than KC alone. It involves articulating how, as well as what, we have learned.

4.2. Knowledge of Pedagogy

Windschitl et al. (2008) viewed teaching itself as an act of inquiry with two key related pedagogical qualities. First, the curriculum is co-constructed with learners; not necessarily every element of every lesson, but student interests, prior experiences, learning preferences, strengths, and weaknesses, should impact planning, enactment, and assessment. This defines PCK as student-focused and teachers' knowledge of pedagogy interacting with knowledge about students. Second, the teacher is not the only source of content, nor the only catalyst for learning, although critically engaged in both. Inquiry-based instruction is a part of a social-constructivist approach to learning and teaching (Vygotsky, 1978); therefore, student progress involves interactions not only between learner and teacher but among learners, especially as dialogue within those interactions, and playing diverse (sometimes regarded as each other's) roles in the process (Walker et al., 2022). Although inquiry is the most widely applied label to this approach to teaching and learning, somewhat of a schism has emerged between science education and other disciplines. The United States NRC (2012) chose instead to use the term methods of science rather than inquiry. The close coupling with what scientists do as science might mislead some to understand it as what used to be called scientific method, a simplified, and possibly inaccurate, sequential representation that potentially underplays the creativity, collaboration, deliberate long-term focus, and serendipity encountered in real-life scientific knowledge creation. Tang et al. (2010) warned that focusing on scientific methodology as a discrete set of independent steps may draw teachers' attention away from instances of productive inquiry in their classrooms. Focus on processes of science might be suitably reserved for later school years

when specialist teachers can invoke more sophisticated discipline-specific and general curricular objectives.

KP-Centered Illustration

Specific pedagogical or instructional strategies invoked in PCK include engaging students in structured or guided inquiry, scaffolding them through questioning toward the desired response, usually a theoretical concept, asking students to share and explain what they already know about a topic in dialogue with each other, the teacher, or in writing, and changing the pace among different instructional strategies. Rehearsing prior and new knowledge in different ways, then linking prior and new knowledge, are important parts of more expert thinking. Other KP can include Socratic questioning, asking questions ranging in challenge to ascertain the students' zone of proximal development (Vygotsky, 1978), providing explanations, eliciting explanations and questions from students, linking theory and knowledge so students can defend their assertions, and providing demonstrations.

Pedagogical knowledge and skills need to be shared in age-appropriate ways with students and include, for example, structuring and managing student groups (e.g., who chooses workmates? who assigns roles? how does one ensure fair work distribution and participation?), and teaching the learners, and sometimes themselves, if these experiences are new, to engage in classroom dialogue to promote learning (e.g., asking high-level questions, offering and evaluating evidence for claims, explaining ideas to other learners, navigating and possibly resolving disagreements, and giving feedback) (Shore et al., 2020). These skills exceed parsing and ordering content into portions that learners can master.

4.3. Knowledge of Students

In an inquiry context, the main KS that is potentially unique is to know about students' prior inquiry-related experiences, collaboration and research skills, question asking, and more-or-less independent projects that extended beyond one or a few lessons. This teacher knowledge is attained through formal and informal assessments and can be documented in a student's cumulative record or portfolio.

Some KS exists independently of new assessments, such as general understanding of child development, children's thinking, and common misconceptions. There are also risks inherent in some kinds of KS, for example, assumptions teachers might inadvertently make—positive or negative—about children's interests, abilities, or experiences based on sex, language, neighborhood economic status, ethnicity, or social group. We sometimes need to intentionally set aside some knowledge brought into a teaching situation. KS actively impacts planning, teaching, and assessment, thereby being a component of PCK.

KS-Centered Illustration

An expert secondary science teacher we observed had assumed that students in his honors biology class would be better prepared for an independent laboratory exercise than students in his regular class. To his surprise, the honors students asked more low-level factual and procedural questions. He had to take time to explain the procedures in more depth. His entering assumptions about the students' initial readiness to undertake laboratory experiments, their levels of cognitive functioning, and the sophistication of questions they would pose were challenged. He needed to ask them about their prior laboratory experiences. This new student information required a change in instructional planning and enactment, illustrating their link to KS in PCK.

4.4. Planning as a PCK Element Within Inquiry

Planning inquiry-based lessons is challenging because "teachers must include conjectures about student thinking" (Windschitl, 2002, p. 144) regarding the subject matter or

students' assumptions and preferences about group work, how their work will be evaluated, and roles. Students bring diverse experiences and backgrounds to every topic, and often incomplete understandings or misconceptions about the content (Llewellyn, 2002) or the learning process. In curricular and lesson planning in an inquiry context, students should be offered opportunities to actively participate by selecting the topic or the means of investigation or exploration (Windschitl et al., 2008).

Active student roles are core to inquiry-based learning and teaching. Instructors whose observed teaching includes such roles (e.g., questioner, explainer, participant in student–student dialogue and collaboration) have explicitly planned for this to happen lesson-by-lesson and across curricular units (Aulls et al., 2026). The most complex, comprehensive student roles particular to inquiry are individual or small-group investigations over extended periods of time, culminating in sharing results with classmates, at knowledge fairs, or beyond.

Planning-Centered Illustration

Instructional planning occurs at multiple levels: across a whole semester or year, a unit extending beyond a single class, or a particular lesson or class. Aulls et al. (2015, 2026) reported that, unless ongoing overall and class-by-class planning both occurred, inquiry-based or active learning was not observed in class. Lesson planning must specify more than content to be "covered" but also times in every class for students to engage in dialogue, especially explaining and linking key ideas. General planning needs to specify spaced or distributed and varied assessment of student learning. In addition to promoting deeper learning, in an age of artificial intelligence tools that students might use inappropriately, such instructional and assessment approaches help ensure student integrity.

4.5. Teaching Enactment as a PCK Element Within Inquiry

Teaching and learning—hence, the PCK a teacher uses to make these happen—differ in teacher and learner roles, with less teacher talk and more student talk in a lesson, and in other respects summarized by Keegan (1993). He compared didactic, Socratic, inquiry, and discovery models. These differ in patterns of discourse and roles promoting learning; for example, teacher talk dominating entire lessons, some of that talk being reframed as questions with varying combinations of who provides the answers, and more prominent and student-directed student dialogue. Responsibility for setting the agenda and choosing content, for designing and selecting the learning activities, and for ongoing and even summative evaluation shift toward students and toward student–teacher collaboration across this progression. Examples of students' instructional activities, in the broadest terms, shift from lecture, texts, and videos in didactic instruction, to recitation and discussion in Socratic, to laboratory exercises, fieldwork, and surveys in inquiry, and in discovery learning to library research and increasingly independent guided projects and reports.

Each type of instruction accomplishes different goals. Inquiry adds to, and does not displace, the teacher's instructional repertoire. For example, didactic instruction can efficiently introduce vocabulary and new abstract concepts and motivate learners to explore others. Discovery and guided inquiry are effective ways to introduce learners to asking clear, high-level questions, planning ways to search for answers, and to communicate process and product. Discovery places the most burden on the learner and is appropriate for complex ways of knowing in different disciplines, but might not be the optimal instructional strategy, even for highly able students.

PCK is most directly observed as these different models are matched to different goals and student characteristics during planning, classroom enactment and roles, and types of assessment of the outcomes. Numerous detailed examples were provided by Aulls and

Shore (2008), Park and Chen (2012), and Shore et al. (2008), including barriers to creating such classroom experiences and ways to overcome them. Barriers ranged from cheating to disagreements and dominant behavior in group work, hidden social curricula, and uses of internet-based technology.

Teaching Enactment-Centered Illustration

Leinhardt et al. (1991) described a mathematics lesson in which an expert teacher represented three ways to regroup elements. Each highlighted the integrity of the whole and provided different ways for students to connect their initial understanding to their prior knowledge. The teacher focused on the most unique, relevant, subtle aspects of each representation and de-emphasized, at least initially, what is not absolutely necessary to begin to construct understanding, thereby avoiding confusion, distraction, frustration, and possibly avoidance. Expert teachers explicitly state the conditions under which a concept is relevant or a procedure needs to be used. Principles need to be explained and illustrated in a way that legitimizes the new concept (e.g., cross-checking with other knowledge).

The expert teacher distinguished herself from novices through extensive knowledge of the content, its clarity and connectedness, and how to keep the lesson flowing toward its goal. She anticipated when, where, and why confusion and misconceptions were likely to occur and avoided these. Expert teachers' explanations consistently orbited between the goals and desired outcomes; novices' did not. The lesson reflected planning to ensure every new concept in a unit was explicitly connected to the whole unit, as when zooming in and out to locate a place on a map. It also enjoined assessment: How will I recognize at every stage of the lesson that students are creating valid understanding for themselves? PCK helps guide a teacher to such ends.

In contrast, a novice teacher's lesson on multiplication by nine was disjointed, although the concepts were mathematically correct. Explanations did not clarify for students how the information connected to a whole. Novice teachers were less explicit about how each lesson segment fit within the overall lesson and unit.

4.6. Assessment as a PCK Element Within Inquiry

Inquiry-based curricula, in whole or part, add several elements to assessment in the form of questioning, logged observations of noteworthy incidents, activity portfolios, self-reflections, student-teacher conferences, group-work products, as well as more content-focused individual tests, work samples, or testing-out quizzes. Student understanding and application of the process are as central as content. Talanquer et al. (2013) found that science student–teachers focused assessment on processes related to designing investigations rather than the quality of the analysis and interpretation of evidence. There is a need in inquiry (perhaps generally) to help teachers assess the discipline-relevant (and sometimes cross-discipline-relevant) plausibility of students' ideas and conclusions. This might be related to the depth and breadth of teachers' own KC.

Windschitl et al. (2008) recounted that, within inquiry, students are invited to participate in assessment by co-constructing some assessment criteria and reflecting on related personal and peers' learning. Chappuis and Stiggins (2020) emphasized the dual functions of assessment for (to support) learning and assessment of learning. The former includes, for example, developing and using rubrics with students, providing timely individual and group feedback, planning opportunities for self- or peer assessment within lessons and units (assessment as learning, according to Chappuis and Stiggins (2020)), open discourse in the classroom about targets and goals, and sharing unattributed examples of exemplary work. This includes the processes of being an inquirer.

Assessment-Centered Illustration

Assessment was an adjunct in the inquiry-based examples provided above. Assessment can also be the prime focus. Students can comment in groups on others' posters, writing, or displays, and write short essays about what impressed them, citing evidence for why. Constructively evaluating one's own and others' work is a valuable and empowering life skill that needs practice supported by feedback. Assessment is a demanding cognitive task that requires accurately foreseeing the outcome of instruction, designing meaningful instruction and valid measures aligned with the outcomes, and a back-and-forth between enactment and planning. Rubrics need updating. Students should be explicitly taught about the criteria and the process of evaluation of their learning and know in detail what an evaluation means. Students practicing assessing their own and peers' work with rubrics have the added benefit of generating formative evaluation not immediately dependent on the teacher's or other evaluator's input. However, as lead learners in classrooms, teachers must explicitly model for students how to effectively engage in these assessment practices. Rubrics can emphasize each section and connectivity with processes and other knowledge, writing quality, and interactions with others in group activities.

Assessment feedback informs student learning, future planning and teaching, which, in turn, inform assessment. Assessment aligns with planning and teaching and is integrated in instruction through reflection and formative assessment which, in turn, further guide teaching plans and the enactment of these plans. Teachers develop assessment expertise by repeatedly aligning old and new understandings and practices.

5. Conclusions

PCK can be portrayed by three conceptions of teacher knowledge expanded to enable their relevance to an inquiry approach to teaching that has a privileged place in gifted and talented education, and applied to three parts of the instructional process, also embracing inquiry (Table 1). PCK combines these three knowledge types (KC, KP, and KS) into a whole whose integration can be viewed through the three instructional components (planning, teaching enactment, and assessment). The cells of this three-by-three grid contain abbreviated examples illustrating how inquiry adds original emphases to understanding PCK. The content of the cells highlights teacher actions (enaction) with strong inquiry-based pedagogy. The cells are also reminders to attend to the combinations and interactions among these considerations in fostering or developing PCK, and that these cells overlap. One can start anywhere in the grid and make connections elsewhere.

The extent of a teacher's PCK can reflect the degree of integration and quality or coherence among the nine components of this model, aligned with inquiry-based teaching and learning, for example, in building upon students' capacity to emulate experts in a domain or across domains, ask high-level, researchable questions that draw on both their prior knowledge and curiosity, the added learning value of dialogue and sharing evidence-based conclusions and explanations of important concepts and the relations among them, and evaluating their own and others' statements. Emphasis is essential not only on the amount of knowledge in individual constituent components but also on the growth in the connectedness and complexity of PCK as a whole (Park & Chen, 2012). PCK in an inquiry context can, however, be observed through any of these constructs as an initial window. As in student learning, the strength of the understanding and ability to realize PCK in the classroom lies in consciously exploring the interconnections among the components. Because of the central role of inquiry-based pedagogy in GCT curriculum and instruction, both PCK and inquiry can be valuable parts of the repertoire of educators in GCT as well.

Table 1. PCK and instruction in an inquiry-based context.

PCK Combines PCK Occurs in	Knowledge of Content (KC)	Knowledge of Pedagogy (KP)	Knowledge of Students (KS)
Planning	- Emulate how content is created in the field. - Consider topics that can extend over time. - Plan time to incorporate student interests.	- Envision teaching as inquiry. - Be an inquirer is some domain (can be extracurricular). - Enable student dialogue and explanations in lessons. - Incorporate group collaboration.	- Consider students' experiences and expectations in collaborative inquiry learning. - Guide formation of working groups to optimize social and cognitive efficacy.
Teaching Enactment	- Promote student role as explainer. - Model being an inquirer. - Articulate general and subject-specific methods for creation and acquisition of knowledge.	- Connect experience as knowledge creator. - Increase student talk time; decrease teacher talk time. - Ask, and teach students to ask, high-level researchable questions.	- Students share their knowledge and experiences. - Help students with communication and interpersonal skills that promote positive social interactions.
Assessment	- Integrate assessment for and of learning. - Assess the process as well as the subject matter and its interconnections.	- Make teaching events formative assessment. - Provide guidance, practice, and feedback in evidence-based argument.	- Promote student role as self and peer evaluator, especially formative. - Use rubrics to assess progress toward complex and high-level learning goals.

Author Contributions: Both authors contributed equally to all parts of the preparation of this paper. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

Aulls, M. W., Kaur Magon, J., & Shore, B. M. (2015). The distinction between inquiry-based instruction and non-inquiry-based instruction in higher education: A case study of what happens as inquiry in 16 education courses in three universities. *Teaching and Teacher Education*, *51*, 147–161. [CrossRef]

Aulls, M. W., Kaur Magon, J., & Shore, B. M. (2026). *Instructor planning, distributed evaluation, and student role as explainer characterize active learning in undergraduate physics and chemistry: A triangulated multiple-case study* [Manuscript submitted for publication]. Department of Educational and Counselling Psychology, McGill University.

Aulls, M. W., & Shore, B. M. (2008). *Inquiry in education (Vol. I): The conceptual foundations for research as a curricular imperative*. Erlbaum.

Aulls, M. W., Tabatabai, D., & Shore, B. M. (2016). What makes inquiry stick? The quality of preservice teachers' understanding of inquiry. *SAGE Open*, *6*(4), 1–12. [CrossRef]

Austin, L. B., & Shore, B. M. (1993). Concept mapping of high and average achieving students, and experts. *European Journal for High Ability [Now High Ability Studies]*, *4*(2), 180–195. [CrossRef]

Aydin, S., Demirdogen, B., Akin, F. N., Uzuntiryaki-Kondakci, E., & Tarkin, A. (2015). The nature and development of interaction among components of pedagogical content knowledge in practicum. *Teaching and Teacher Education*, *46*, 37–50. [CrossRef]

Barendsen, E., & Henze, I. (2019). Relating teacher PCK and teacher practice using classroom observation. *Research in Science Education*, *49*, 1141–1175. [CrossRef]

Barreto-Espino, R., & Zembal-Saul, C. (2014). Prospective elementary teachers' knowledge of teaching science as argument: A case study. *School Science and Mathematics*, *114*(2), 53–64. [CrossRef]

Baum, S. M., Renzulli, J. S., & Hébert, T. P. (1995). Reversing underachievement: Creative productivity as a systematic intervention. *Gifted Child Quarterly*, *39*(4), 224–235. [CrossRef]

Berliner, D. C. (1986). In pursuit of the expert pedagogue. *Educational Researcher*, *15*(7), 5–13. [CrossRef]

Birlean, C., & Shore, B. M. (2018). Cognitive development of giftedness and talents: From theory to practice. In J. L. Roberts, T. F. Inman, & J. H. Robins (Eds.), *Introduction to gifted education* (pp. 95–118). Prufrock Press.

Bruner, J. S. (1960). *The process of education*. Harvard University Press.

Carlson, J., Daehler, K. R., Alonzo, A. C., Barendsen, E., Berry, A., Borowski, A., Carpendale, J., Kam Ho Chan, K., Cooper, R., Friedrichsen, P., Gess-Newsome, J., Henze-Rietveld, I., Hume, A., Kirschner, S., Liepertz, S., Loughran, J., Mavhunga, E., Neumann, K., Nilsson, P., . . . Wilson, C. D. (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*. Springer. [CrossRef]

Chan, K. K. H. (2022). A critical review of studies using the pedagogical content knowledge map approach. *International Journal of Science Education*, *44*(3), 487–513. [CrossRef]

Chappuis, J., & Stiggins, R. (2020). *Classroom assessment for student learning: Doing it right–using it well* (3rd ed.). Pearson.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 1, pp. 7–76). Erlbaum.

Donald, J. G. (1983). Knowledge structures: Methods for exploring course content. *Journal of Higher Education*, *54*(1), 23–41. [CrossRef]

EC. (2007). *Science education now: A renewed pedagogy for the future of Europe*. European Commission Directorate-General for Research, Directorate L—Science, Economy and Society. Available online: https://www.eesc.europa.eu/en/documents/rocard-report-science-education-now-new-pedagogy-future-europe (accessed on 22 April 2026).

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

Gioka, O. (2009). Teacher or examiner? The tensions between formative and summative assessment in the case of science coursework. *Research in Science Education*, *39*(4), 411–428. [CrossRef]

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

Keegan, M. (1993). Optimizing the instructional moment: A guide to using Socratic, didactic, inquiry, and discovery methods. *Educational Technology*, *33*(4), 17–22.

Kind, V., & Chan, K. K. H. (2019). Resolving the amalgam: Connecting pedagogical content knowledge, content knowledge and pedagogical knowledge. *International Journal of Science Education*, *41*(7), 964–978. [CrossRef]

Krepf, M., Ploger, W., Scholl, D., & Seifert, A. (2018). Pedagogical content knowledge of experts and novices—What knowledge do they activate when analyzing science lessons? *Journal of Research in Science Teaching*, *55*(1), 44–67. [CrossRef]

Lee, S. J., & Kriewaldt, J. (2025). Where powerful knowledge and pedagogical content knowledge intersect: The case of knowledge and beliefs for teaching school geography through inquiry. *International Research in Geographical and Environmental Education*, *34*(1), 79–94. [CrossRef]

Leinhardt, G., & Putnam, R. T. (1987). The skill of learning from classroom lessons. *American Educational Research Journal*, *24*(4), 557–587. [CrossRef]

Leinhardt, G., Putnam, R. T., Stein, M. K., & Baxter, J. (1991). Where subject knowledge matters. In J. Brophy (Ed.), *Advances in research on teaching* (Vol. 2, pp. 87–113). JAI Press.

Llewellyn, D. (2002). *Inquire within: Implementing inquiry-based science standards*. Corwin Press.

Mavhunga, E., & van der Merwe, D. (2020). Bridging science education's theory-practice divide: A perspective from teacher education through topic-specific PCK. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(1), 65–80. [CrossRef]

NCSS. (1994). *Expectations of excellence: Curriculum standards for social studies*. National Council for the Social Studies.

NCTM. (2000). *Principles and standards for school mathematics*. National Council of Teachers of Mathematics.

Neumann, K., Kind, V., & Harms, U. (2019). Probing the amalgam: The relationship between science teachers' content, pedagogical and pedagogical content knowledge. *International Journal of Science Education*, *41*(7), 847–861. [CrossRef]

Neurath, O., Carnap, R., & Morris, C. W. (Eds.). (1969). *Foundations of the unity of science: Toward an international encyclopedia of unified science* (2 vols). University of Chicago Press. (Originally published in 1938).

NRC. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. USA National Research Council, National Academies Press. Available online: http://www.nap.edu/catalog/9596.html (accessed on 22 April 2026).

NRC. (2012). *A framework for K-12 science education: Practices, cross-cutting concepts, and core ideas*. USA National Research Council, National Academies Press. Available online: https://smile.oregonstate.edu/sites/smile.oregonstate.edu/files/a_framework_for_k-12_science_education.pdf (accessed on 22 April 2026).

Otero, V. K. (2006). Moving beyond the "get it or don't" conception of formative assessment. *Journal of Teacher Education*, *57*(3), 247–255. [CrossRef]

Park, S., & Chen, Y. (2012). Mapping out the integration of the components of pedagogical content knowledge (PCK): Examples from high school biology classrooms. *Journal of Research in Science Teaching*, *49*(7), 922–941. [CrossRef]

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. [CrossRef]

Pelletier, S., & Shore, B. M. (2003). The gifted learner, the novice, and the expert: Sharpening emerging views of giftedness. In D. C. Ambrose, L. Cohen, & A. J. Tannenbaum (Eds.), *Creative intelligence: Toward theoretic integration* (pp. 237–281). Hampton Press.

Renzulli, J. S., & Reis, S. M. (2014). *The Schoolwide Enrichment Model: A how-to guide for talent development* (3rd ed.). Routledge. [CrossRef]

Shepard, L. A. (2000). The role of assessment in a learning culture. *Educational Researcher*, *29*(7), 4–14. [CrossRef]

Shore, B. M. (2022). Context matters in gifted education. In D. A. Sisk (Ed.), *Gifted education, creativity, and leadership development* (pp. 117–126). MDPI. (Reprint in 2021, *Education Sciences*, *11*, 424). Available online: https://mdpi-res.com/bookfiles/book/6393/Gifted_Education_Creativity_and_Leadership_Development.pdf?v=1695608821 (accessed on 22 April 2026).

Shore, B. M., Aulls, M. W., & Delcourt, M. A. B. (Eds.). (2008). *Inquiry in education (Vol. II): Overcoming barriers to successful implementation*. Erlbaum.

Shore, B. M., Aulls, M. W., Tabatabai, D., & Kaur Magon, J. (2020). *I is for inquiry: An ABC of inquiry instruction for elementary teachers and schools*. Prufrock Press (now Routledge).

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

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

Sternberg, R. J. (1998). Abilities are forms of developing expertise. *Educational Researcher*, *27*(3), 11–20. [CrossRef]

Suh, J. K., & 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. [CrossRef]

Syer, C. A., Chichekian, T., Shore, B. M., & Aulls, M. W. (2013). Learning "to do" and learning "about" inquiry at the same time: Different outcomes in valuing the importance of various intellectual tasks in planning, enacting, and evaluating an inquiry curriculum. *Instructional Science*, *41*(3), 521–537. [CrossRef]

Talanquer, V., Tomanek, D., & Novodvorsky, I. (2013). Assessing students' understanding of inquiry: What do prospective science teachers notice? *Journal of Research in Science Teaching*, *50*(2), 189–208. [CrossRef]

Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education*, *4*(2), 99–110. [CrossRef]

Tang, X., Coffey, J. E., Elby, A., & Levin, D. M. (2010). The scientific method and scientific inquiry: Tensions in teaching and learning. *Science Education*, *94*(1), 29–47. [CrossRef]

UNESCO. (2008). *ICT competency standards for teachers: Competency standards modules*. United Nations Educational, Scientific and Cultural Organization. Available online: http://unesdoc.unesco.org/images/0015/001562/156207e.pdf (accessed on 22 April 2026).

Vygotsky, L. S. (1978). *Mind and society: The development of higher psychological processes* (M. Cole, Trans.). Harvard University Press.

Walker, C. L., Shore, B. M., & Tabatabai, D. (2022). On the trail of authentic collaboration over extended time in inquiry classrooms: Following the footprints of role diversification as indicators that inquiry occurred. *Scandinavian Journal of Educational Research*, *66*(6), 936–959. [CrossRef]

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research*, *72*(2), 131–175. [CrossRef]

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, *92*(5), 941–967. [CrossRef]

Yung, B. H. W. (2001). Three views of fairness in a school-based assessment scheme of practical work in biology. *International Journal of Science Education*, *23*(10), 985–1005. [CrossRef]

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