e-Kafkas Journal of Educational Research e-KJER Research Article

Construction of a Science Teacher's Topic-Specific Pedagogical Content Knowledge in the Gifted Class[1]

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To cite this article:
Çaylak, B., & Çakıroğlu, J. (2024). Construction of a science teacher's topic-specific pedagogical content knowledge in the gifted class. *e-Kafkas Journal of Educational Research*, *11*, 378-401. doi:10.30900/kafkasegt.1491730

Research article **Received:** 29.05.2024 **Accepted:**27.08.2024

Abstract

This study examines a science teacher's pedagogical content knowledge during instruction on the topics work and energy, simple machines, and friction force in a gifted class. The research adopts a single case study approach, employing qualitative methods. The participant is a middle school science teacher, and data collection tools include interviews, observations, card-sorting activities, and lesson plans. The study's data were analyzed in an in-depth analysis of explicit PCK. The main findings of the study are: (1) gifted students required additional science practice beyond the scope of the traditional curriculum, (2) the participating teacher encountered challenges when designing and implementing enrichment activities, (3) the characteristics of gifted students positively influenced the development of the teacher's pedagogical content knowledge, and (4) the presence of gifted students prompted a shift in the teacher's science teaching orientation from traditional methods to reform-based practices. Teachers need to have additional knowledge bases or pedagogical content knowledge components. Notably, the research underscores the relevance of the knowledge of enrichment curriculum and knowledge of characteristics of gifted students in the training of science teachers, along with the crucial role of STO in the education of gifted students, especially in the context of teaching physics. These findings offer significant implications for the curriculum designed for gifted students, particularly concerning the teaching and learning of physics topics.

Keywords: Characteristics of gifted students, enrichment activities in physics topics, pedagogical content knowledge, teacher preparation standards, qualitative design.

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[1] This article was produced from the thesis of the first author.

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Introduction

The realm of education for gifted learners recognizes the necessity for special learners to engage in specific instructions and opportunities tailored to their individual abilities for the purpose of meeting their unique learning needs (Heilbronner & Renzulli, 2016; Kaplan, McComas, & Manzone, 2016; Laine & Tirri, 2016; Ülger & Çepni, 2020; VanTassel-Baska, 2021). Gifted students often grasp general curriculum concepts and activities more quickly and easily than their peers (Benny & Blonder, 2018; Gilson, 2009). Because gifted students are those who perform at a high level compared to their peers in specific areas such as general intelligence (Callahan, Moon, & Oh, 2014), creativity and motivation (Renzulli & Reis, 2018), perfectionism and emotional sensitivity (Clark, 2008), rapid learning and areas of interest (Gilson, 2009). Therefore, teachers play an important role in meeting the varied learning needs of gifted students (Croft, 2003; Tirri, 2017). Moreover, gifted students regard their teachers not only as providers of information, but also as individuals who can positively influence their lives (Gómez-Arízaga, Conejeros-Solar, & Martin, 2016). In this regard, the ability to understand and effectively address these needs, encompassing cognitive, emotional, and social aspects, is a key for teachers. Those who possess the knowledge of these demands and understand how to fulfill them contribute to the comprehensive improvement of gifted students (World Council for Gifted and Talented Children, 2021).

To meet the needs of gifted learners effectively, teachers should possess certain requirements, such as knowledge of the characteristics of gifted students (KoCG) and knowledge of enrichment curriculum (KoEC). Furthermore, teachers should be equipped with the knowledge and abilities to design and implement a variety of programming options, including enrichment activities (Eilam & Vidergor, 2011; Pfeiffer & Shaughnessy, 2015), or differentiation instructions (Laine & Tirri, 2016; Ülger & Çepni, 2020). Teachers should possess an inclusive curriculum comprehension and consider the individual differences of learners when designing and applying enrichment activities. A uniform curriculum alone is insufficient for the development of gifted students as each student may be at a different level of development in achieving the academic goals and objectives. Thus, teachers need to extend these goals and objectives beyond the common curriculum (Kaplan, 2009).

When attending to the current requirements of gifted students in science education, a critical question emerges: "How can we effectively meet the educational needs of the most talented learners in science classes?" (Taber & Sumida, 2016, p. XVII). The main focus should be on the skills and expertise of teachers. Science teachers should acquire specific knowledge bases, including subject matter, general pedagogical skills, context, pedagogical content knowledge (PCK) (Loughran, Berry, & Mulhall, 2006; Shulman, 1987), assessment, students and curricular knowledge (Gess-Newsome, 2015), collective PCK, personal PCK and enacted PCK (Carlson & Daehler, 2019). More specifically, Magnusson, Krajcik, & Borko (1999) emphasize the importance of teachers' PCK as a crucial aspect of their professional development, particularly for effectively teaching science topics. In other words, PCK is the knowledge and skill of how to plan and apply specific science topics to a specific group of students (Magnusson et al., 1999). Table 1 provides an overview of the knowledge and competencies required for both teachers of gifted learners and science teachers.

Table 1
Teachers' Knowledge and Competencies

Gifted Students' Teachers*	Science Teachers**
(1) Learner development and individual learning differences	1. Subject matter knowledge
(2) Learning environments	2. General pedagogical skills
(3) Curricular content knowledge	3. Contextual knowledge
(4) Assessment	4. Pedagogical content knowledge
(5) Instructional planning and strategies	a. Science teaching orientation (STO)
(6) Professional learning and ethical practice	b. Knowledge of curriculum (KoC)
(7) Collaboration	c. Knowledge of learner (KoL)
	d. Knowledge of instructional strategies (KoIS)
	e. Knowledge of assessment (KoA)

* Seven gifted students' teachers preparation standards (NAGC & Council for Exceptional Children, 2013).
** Science teacher knowledge is adapted from Magnusson et al.'s (1999) PCK and teacher knowledge model

In general, both science teachers and gifted students' teachers share common competencies, including a strong knowledge of curriculum, instructional strategies, learners, and assessment. Nevertheless, being an effective teacher for gifted students requires additional competencies, such as understanding KoCG (Akgül, 2021), individual learning differences among gifted students (Benny & Blonder, 2018), designing enrichment activities (Benny & Blonder, 2018; Callahan et al., 2014; Sternberg, 2019), differentiation (Callahan et al., 2014; Gubbins et al., 2021; Han, 2017; Laine & Tirri, 2016), or challenging learning opportunities (Sternberg, 2019; Taber, 2016; VanTassel-Baska, 2021). However, studies indicate that, despite legal regulations in some countries, there are insufficient practices to fulfill the requirements of gifted learners (Antoun, Plunkett, & Kronborg, 2022; Reis-Jorge, Ferreira, Olcina-Sempere, & Marques, 2021). Programs that consider the characteristics of gifted children and align with a defensible curriculum model are rare (Han, 2017). In regions where regular education is provided, teachers still lack sufficient knowledge about gifted students (Şahin & Levent, 2015; Tirri & Laine, 2017), while necessary identification processes cannot be carried out in schools (Tirri & Laine, 2017). Moreover, some teachers have misconceptions about identifying gifted students (Brevik, Gunnulfsen, & Renzulli, 2018). Many teachers also lack the knowledge to plan and implement required teaching strategies (Antoun et al., 2022; Brevik et al., 2018; Tirri & Laine, 2017). Those teachers who apply general teaching strategies (differentiation, enrichment, and acceleration) do so without relying on any framework (Callahan et al., 2014). Remarkably, teachers who have gifted students in their classes advocate for these students to be taught by specialized teachers (Akgül, 2021). In this context, the aforementioned educational problems of gifted students may lead to misconceptions about how to educate them in classrooms (Stargardter, Laine, & Tirri, 2023).

The overall status regarding developments in the education of gifted students remains unclear (Hernández-Torrano & Kuzhabekova, 2020). Moreover, there is a lack of evidence-based study on gifted learners' education that could illustrate the specific knowledge bases (Coleman, 2014; Gilbert & Newberry, 2007) or pedagogies (Kidman, 2016), which is required for teachers in gifted classes and how gifted students influence their teachers' knowledge. Existing research on teachers of gifted education often focuses on their competencies, attitudes, or applications of general pedagogy (Bangel, Moon, & Capobianco, 2010; Chan, 2001; 2011; Kaplan, 2012; Newman & Hubner, 2012). In addition to these studies, when more recent research is examined, it is observed that researchers continue to investigate teacher perspectives on gifted students (Akgül, 2021; Godor, 2019). Among the research topics are teacher competencies (Akar, 2020; Shaughnessy & Senior, 2022) and teachers' practices (Laine & Tirri, 2016; Reis-Jorge et al., 2021). Studies have explored how different approaches contribute to students such as differentiation (Brevik et al., 2018; Stollman, Meirink, Westenberg, & van Driel, 2021; Ülger & Çepni, 2020; VanTassel-Baska, Hubbard, & Robbins, 2020), Science, Technology, Engineering, and Mathematics (STEM) (Ayvacı & Bebek, 2023; Sternberg, 2019), or Inquiry, Problem-Based Learning (Han, 2017; Sternberg, Ehsan, & Ghahremani, 2022; Ülger & Çepni, 2020). Finally, professional development programs were organized (Benny & Blonder, 2016; Edinger, 2017, 2020), and these programs aimed to improve teachers' specific knowledge and skills.

Since the research trend in the literature focuses on the practices used by teachers, classroom practices that determine the quality of education are ignored (Laine & Tirri, 2016). Therefore, many researchers recommend examining the activities implemented by teachers within the classroom (Gubbins et al., 2021; Laine & Tirri, 2016; Reis-Jorge et al., 2021; VanTassel-Baska et al., 2020). Teacher and student interaction should also be comprehensively investigated (Benny & Blonder, 2016). Therefore, it is essential to conduct topic-specific studies involving teachers of gifted students, rather than studies that only consider common characteristics of gifted individuals and general instructional strategies (Park & Oliver, 2009). The execution of classroom activities like differentiation, which are viewed as pedagogical actions (Stollman et al., 2021), can differ based on factors such as the student, the subject being taught, and the individual teacher's approach. Hence, teachers may require different skills and competencies at various educational stages (elementary school, middle school, high school) and in different subjects (Akar, 2020). Additionally, it's important to analyze the kinds of information teachers utilize when determining who requires differentiation and when it's necessary (Laine & Tirri, 2016).

The present study aims to investigate a science teacher's topic-specific PCK and how gifted students influence the teacher's PCK while introducing physics topics in the gifted classroom. The research questions for this study are: (1) what specialized knowledge and teaching strategies does a science teacher use when teaching gifted students on the topics of work/energy, friction force, and simple machines? (2) How do the attributes of gifted students influence the PCK of the teacher when teaching the three physics subjects—work/energy, friction force, and simple machines?

To answer these questions, we employ the PCK framework (Magnusson et al., 1999) to enhance understanding of the science teacher's decision-making and practice in these specific topics. Because, when seeking an answer to the question "How good is good enough," content knowledge and PCK play a dominant role (Gómez-Arízaga et al., 2016). The PCK framework enables us to explore the intersection of competencies between science teachers and teachers of gifted students during the participant teacher's instruction on these topics. While many studies have explored science teachers' PCK, research on teachers' PCK specific to gifted individuals is scarce (Kidman, 2016; Rosemarin, 2014). Therefore, the findings of this research offer valuable insights for teachers, detailing how teachers' skills manifest in their teaching, how the traits of gifted students impact teachers' approaches, and strategies for improving the quality of gifted teacher education.

Theoretical Background and Framework

Teacher Preparation Standards

When it comes to teaching and learning, teachers have a pivotal role in education. To provide guidance to educators, the National Association for Gifted Children (NAGC) and the Council for Exceptional Children (CEC) have established seven standards for teacher preparation (NAGC & CEC, 2013): *"(1) Learner development and individual learning differences, (2) Learning environments, (3) Curricular content knowledge, (4) Assessment, (5) Instructional planning and strategies, (6) Professional learning and ethical practice, and (7) Collaboration"*. These principles provide educators with clearer guidance on their procedures and application (Kaplan, 2012), and it seems they contribute positively to teacher competence (Johnsen, 2012). Successful teachers embrace and exemplify these standards in their abilities, which play significant roles in designing, implementing, and assessing content.

For science teachers, Magnusson et al.'s (1999) model of PCK appears to be particularly relevant to address these standards. Moreover, this model has been widely used in research on science teachers as a conceptual and analytical framework (Abell, 2007; Gess-Newsome, 2015). PCK is an essential construct to comprehend when teaching science topics, and PCK research provides detailed insights into the interactions between science teachers and students.

Pedagogical Content Knowledge

Shulman (1986) initially introduced the term Pedagogical Content Knowledge (PCK), defining it as "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" (p.9). This definition emphasizes the teacher's applications and performance in the classroom context while effectively conveying subject matter knowledge to learners. Shulman (1987, p. 8) further elaborates PCK as "a special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional knowledge". Moreover, Magnusson et al. (1999) adapted PCK for science teachers, defining it as:

> Pedagogical content knowledge is a teacher understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction (96).

More specifically, science teachers' PCK was also considered in the five components, "*Science Teaching Orientation (STO), Knowledge of Curriculum (KoC), Knowledge of Learner (KoL), Knowledge of Instructional Strategies (KoIS), and Knowledge of Assessment (KoA)"*, to teach any science topics effectively.

STO refers to teachers' goals and purposes when teaching and planning specific science concepts. It includes teachers' broader outlook on teaching science, thus playing a pivotal role in both the planning and teaching phases of science instruction. The STO framework serves as a guide for teachers in making decisions regarding the formulation of suitable curriculum objectives and materials, the adoption of instructional strategies, and the choice of assessment tools (Magnusson et al., 1999).

Additionally, teachers' general teaching view, as reflected in their classroom practices, can be categorized into various approaches, such as "academic rigor, didactic methods, conceptual change strategies, discovery-based learning, or inquiry-based instruction" (Magnusson et al., 1999, p.100). These approaches can be further grouped into student-centered or teacher-centered instruction, depending on the emphasis on either the learner's autonomy or the teacher's guidance in the learning process. By understanding and utilizing the STO framework, teachers can effectively plan and execute science lessons, taking into account their goals, the needs of their students, and identifying the most suitable instructional strategies.

KoC is generally categorized into two main areas. The first aspect of KoC involves selecting goals and objectives for specific curriculum topics in subjects such as physics, chemistry, biology, or geology, with the aim of fostering conceptual understanding among students throughout a school year. The second aspect of KoC pertains to the development or modification of specific curriculum programs. By possessing knowledge of curriculum in these two areas, educators can effectively shape and deliver instructional content that aligns with their teaching objectives and meets the needs of their students (Magnusson et al., 1999).

In addition to KoC, KoL is another crucial component that significantly influences teachers' instructional approaches. Just as the curriculum plays a vital role in shaping educational content, understanding students' learning needs and challenges is essential for effective teaching. KoL can be categorized into two main areas: (1) knowledge of the learning needs and requirements of students (2) knowledge of areas where students may face challenges or difficulties. The former category encompasses understanding students' prior knowledge, individual differences, learning approaches, and abilities. The latter category involves being aware of abstract concepts, alternative conceptions or misconceptions that students may have, problem-solving capabilities, common mistakes, or areas where students may lack prior knowledge. It is essential for teachers to be aware of these factors because they can result in learning obstacles for students and present teaching hurdles for educators (Magnusson et al., 1999).

Building on the foundational understanding of students' needs and challenges, KoIS refers to teachers' ability to apply and present specific strategies in their teaching. It is categorized into two sub-knowledges. The initial knowledge base includes subject-specific strategies like inquiry-based learning, conceptual change approaches, or instructional models such as the learning cycle (e.g., the 5E model). The second knowledge base involves topic-specific instructional strategies, such as activities, experiments, presentations, examples, or models (Magnusson et al., 1999).

Finally, complementing these instructional strategies, the first component of KoA pertains to the dimensions of science learning that teachers utilize for assessment purposes. This includes assessing students' conceptual understanding, science process skills, and their perspective on the nature of science as part of the teaching process. The second knowledge base pertains to the methods of assessment, which may include activity reports, homework, multiple-choice tests, or unit evaluation exams (Magnusson et al., 1999).

It appears that the framework of the PCK model in this study and NAGC and CEC's (2013) standards have some similarities. For instance, both Learner Development and Individual Learning Differences and KoL address similar competencies. Other similarities can be observed between Curricular Content Knowledge and KoC, between Assessment and KoA, and between Instructional Planning-Strategies and KoIS. However, there are some differences when it comes to teachers of gifted students. For teachers of gifted students, ensuring high-quality education requires designing relevant enrichment activities, using appropriate teaching methods, understanding the characteristics of gifted students, and implementing these strategies effectively in the classroom.

In a nutshell, Shulman’s (1987) concept of PCK has been utilized by numerous researchers, leading to the emergence of various models (Carlson & Daehler, 2019; Gess-Newsome, 2015; Loughran et al., 2006; Magnusson et al., 1999). Despite the differences in models, a general definition of PCK can be put forward as follows: “PCK is both an external and internal construct, as it is constituted by what a teacher knows, what a teacher does, and the reasons for the teacher’s actions” (Baxter & Lederman 1999, p. 158). The latest PCK model, Refine Consensus Model (Carlson & Daehler, 2019) is divided into several components: enacted PCK, personal PCK, collective PCK, and other knowledge bases (pedagogical, student, curricula, assessment, and content knowledge). Among these components, enacted PCK (ePCK) examines a teacher's knowledge and skills in planning, implementing, and reflecting on any subject. Exactly, ePCK focuses on how a teacher plans, teaches, and reflects on delivering a science topic within the classroom setting.

> This ePCK is the specific knowledge and skills utilized by an individual teacher in a particular setting, with a particular student, or group of students, with a goal for those students to learn a particular concept, collection of concepts, or a particular aspect of the discipline (Carlson & Daehler, 2019, 83).

This study aims to examine the knowledge and skills utilized by a science teacher when planning and implementing physics topics. Given the limited research on teachers' PCK specifically to gifted individuals, this study focuses on two primary objectives: to investigate a science teacher's topic-specific PCK and to examine how gifted students influence the teacher's PCK while introducing physics topics in the gifted classroom. In line with these objectives, utilizing the ePCK component of the Refine Consensus Model as a guide is the most suitable approach. However, alternative methods and techniques are still needed to uncover PCK in teachers' classroom practices (Park & Suh, 2019). In other words, different models are required to reveal what a teacher does and thinks during practice (Carlson & Daehler, 2019). Specifically, there are no components in the ePCK to examine and describe the teacher’s ePCK (Park & Suh, 2019). In addressing this issue, Magnusson et al.'s PCK model serves as the theoretical framework in this study, as its components offer insights into the actions and thought processes of teachers in the classroom. Moreover, Magnusson et al.'s (1999) PCK model and its variations are commonly employed in PCK research (Chan & Hume, 2019).

Method

Research Design

The study employs a single case study approach within a qualitative research design. With a single case study, researchers can gather in-depth and comprehensive information about social phenomena (Marshall & Rossman, 1989). Hence, a science teacher who specialized in teaching gifted students physics topics was chosen as the case to investigate the teacher's PCK. The selection was purposefully based on specific criteria. The main criterion was having experience in teaching gifted and non-gifted learners, which would allow for easy and accurate comparison of students' performance. However, due to the limited number of gifted learners (Bélanger & Gagné, 2006; Callahan et al., 2014; Gubbins et al., 2021) and their science teachers, finding suitable participant teachers for PCK research has become a challenging task. The ideal context for PCK research entails the involvement of two or more teachers and students within comparable age groups, engaging in the simultaneous teaching and learning of similar subjects and topics. Despite these limitations and challenges, one science teacher volunteered to participate in this study, making the participant teacher a unique and hard-to-reach choice.

The Participant of the Study

For participant teacher selection, a private school catering to primary and middle school gifted students (ages ranging from 6 to 15) was chosen in one of Türkiye's metropolitan cities. The teacher participating in the study holds a master's degree in solid-state physics, having completed her undergraduate studies in the physics department of the faculty of science. The teacher also had a pedagogical formation certificate to become a teacher. With three years of teaching experience, she taught non-gifted middle school students for one year and has been working with gifted students for the past two years. The participant volunteered to participate in our study.

Description of Research Context

This study was conducted in a private school that exclusively educates gifted students, and the educational programs implemented in the school were the curricula mandated by the Ministry of National Education (MNE, 2006). These programs were applied nationwide in all primary schools (both public and private) as part of compulsory education. As well as science curriculum, educators and experts enhance or redesign each scientific subject or activity to address the specific requirements of gifted students. Twelve seventh-grade gifted middle school students, whose ages ranged from 12 to 14, were observed and analyzed in the study. These gifted students were admitted to the school after passing specific tests, including assessments of general aptitude, competence, and intelligence. The school administration defines giftedness based on Gagné's (2004) criteria, which includes students who fall within the top 10% of the population, with an IQ score of ≥120 based on the WISC-III (The Wechsler Intelligence Scale for Children, 1991). Consequently, the study's context comprised seventh-grade middle school students with gifted status, possessing IQ scores greater than 120.

Subject and Topic Selection

In this inquiry, physics topics; work and energy (WE), simple machines (SM), and friction force (FF) were assigned since the participant teacher had a bachelor's degree from the physics department. In this respect, it is assumed that the participant possessed strong subject matter knowledge and reflected stronger PCK because solid subject matter knowledge provides more PCK development (Abdul Razak, Mat Yusoff, Hai Leng, & Mohammadd Marzaini, 2023; Abell, 2007; Magnusson et al., 1999). Moreover, three topics were selected because they include abstract and complex concepts (Hammer, 1996) and misconceptions about WE (Erduran Avcı, 2019), SM (Marulcu & Barnett, 2013), and FF (Öztuna Kaplan, 2019). While teaching those concepts, the teacher experienced a large number of teaching and learning difficulties (Ahtee & Johnston, 2006) which were pedagogical challenges for the teacher. Each challenge provided enriched pedagogical situations and a way of making the teacher's PCK understandable. Finally, we observed three physics topics, which enabled and ensured long-term pedagogical engagement among students and the teacher. Thus, we obtained a better understanding of the teacher's PCK during long-term teaching and learning activities.

Data Collection

Multiple data tools were employed in the current study, including content representation, card-sorting activities, classroom observations, semi-structured interviews, and field notes. This multiple approach was chosen in line with the purposes of the research because relying on a single data collection instrument can make it challenging to grasp a teacher's PCK (Baxter & Lederman, 1999). Figure 1 illustrates the data collection process. The purpose of each data collection tool is linked to the research questions. The primary research question pertains to the PCK of science teachers and its constituent elements. Card-sorting activities, content representation as lesson plans, and interviews were employed to gather insights and answer this question. The second research question, on the other hand, focuses on how the instructional approach of teachers can be influenced by the characteristics of gifted students. Classroom observations and interviews will reveal the answer to this question. It should be noted that each data collection tool will play a supportive role during the analysis of the data and will contribute to supporting the interpretations made in the findings section.

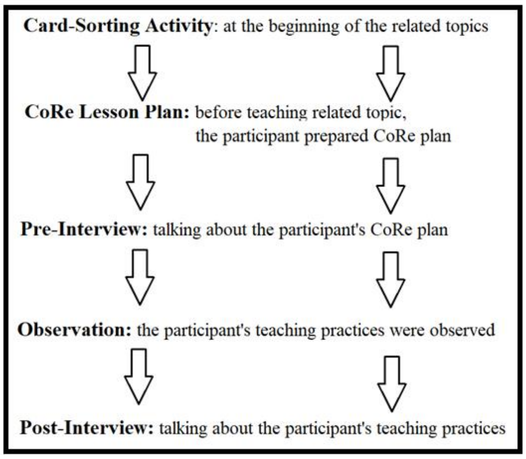

Figure 1. Data Collection Process

Card-Sorting Activities

The first utilized data collection tool was card-sorting activities, commonly employed in science teachers' PCK studies to analyze their STO. STO is defined as the teacher's overall perspective on teaching, encompassing their understanding of goals and purposes in planning, teaching, and assessing a specific science topic (Magnusson et al., 1999). Alongside interviews and observations, card-sorting activities provide researchers with more concrete evidence to determine and categorize science teachers' goals, purposes, and general views of science teaching (Friedrichsen & Dana, 2003). To facilitate this process, researchers developed three card-sorting activities for each topic. When creating card-sorting tasks, various research studies were reviewed on the topic, such as Aydın (2012), Friedrichsen and Dana (2003, 2005), Friedrichsen, van Driel, and Abell (2011), and Magnusson et al. (1999). Magnusson et al.'s (1999) model of PCK outlines nine different ways (STO types) to teach a specific subject. Nine scenarios were related to the teacher's overall perspective on teaching, assessing whether it aligns more with student-centered or teacher-centered instruction, as derived from the PCK framework. Additionally, six scenarios were associated with the teacher's goals and purposes while planning, teaching, and evaluating topics for gifted students, including curricular goals, gifted education goals, and affective domain goals based on Friedrichsen and Dana's definitions (2003, 2005). Following the completion of the card-sorting tasks, feedback was sought from three experts to ensure the validity, language, and clarity of the content.

Two examples of scenarios related to the teacher's general view of teaching included: “An effective way to describe the ‘work and energy’ concepts and their units is to transfer information from a PowerPoint presentation through lecture or discussion (Didactic),” and “An effective way to teach the factors affecting the gravitational potential energy of an object is by asking students to observe the process and discuss the results by examining the weight and height of an object in different situations, accompanied by a teacher (Guided Inquiry).” Moreover, two examples of scenarios related to the teacher's goals and purposes in gifted education were: “As a science teacher, your aim is to make gifted students aware of their abilities and to develop and use their capacities at the highest level (Gifted education goal),” and “It is to enable gifted students to carry out various projects aimed at solving problems or meeting needs by creating conditions, environments, and opportunities that allow students to acquire a scientific study discipline in subjects suitable for realizing their life projects (Gifted education goal).”

Before teaching the related topic, the teacher was asked to choose scenarios that were more or less appropriate for her teaching and planning process. To gain a better understanding of the teacher's scenario selection and a detailed explanation of her STO (Baxter & Lederman, 1999; Friedrichsen & Dana, 2005), she was invited to an interview.

Content Representation (CoRe)

CoRe was the second data tool to reveal explicitly teachers' thoughts and knowledge about the planning process for each topic. CoRe is a blank template in table format comprising key science ideas or concepts along its horizontal axis, while the vertical axis incorporates inquiries regarding factors influencing teachers' choices. These factors include reasons behind their belief in the significance of a concept for student learning, common challenges faced by students in understanding the concept, and similar considerations (Loughran, Mulhall, & Berry, 2004). CoRe table includes eight items or questions to analyze teachers’ PCK and its components. In general, CoRe is implemented as; first, the participant identifies one or a few big ideas (e.g. work/energy, simple machines, and friction force) about the topic she will teach. Then, she considers this big idea(s) and answers the following questions: “What do you intend the students to learn about this idea? What else is important for students to know this idea? What information do you have about students' thoughts that influenced your teaching of this idea? And what are teaching and assessment procedures?” To identify the teacher's PCK, we initially employed the CoRe framework as a lesson planning tool. We requested the teacher to develop CoRe plans and respond to each item before instructing the topics of work and energy, simple machines, and friction force. As a result, the teacher filled three CoRe tables to ensure an understanding of her PCK components in the planning phase.

Interviews and Classroom Observations

The CoRe plans were insufficient for capturing her PCK as the teacher did not articulate the required knowledge within the CoRe plans. For such situations, interviews enable researchers to obtain missing information about teachers' thoughts and knowledge (Baxter & Lederman, 1999). In this regard, we conducted semi-structured pre-interviews and post-interviews. The former were conducted to better understand the teacher's CoRe plans. Moreover, post-interviews were carried out after the teacher's teaching for each topic in order to match the teacher's pedagogy between CoRe plan and her teaching. Post-interviews also provided us with the teacher's knowledge and behaviors not directly observed in her teachings (Merriam, 2009). Figure 2 shows the interview questions and the data collection process.

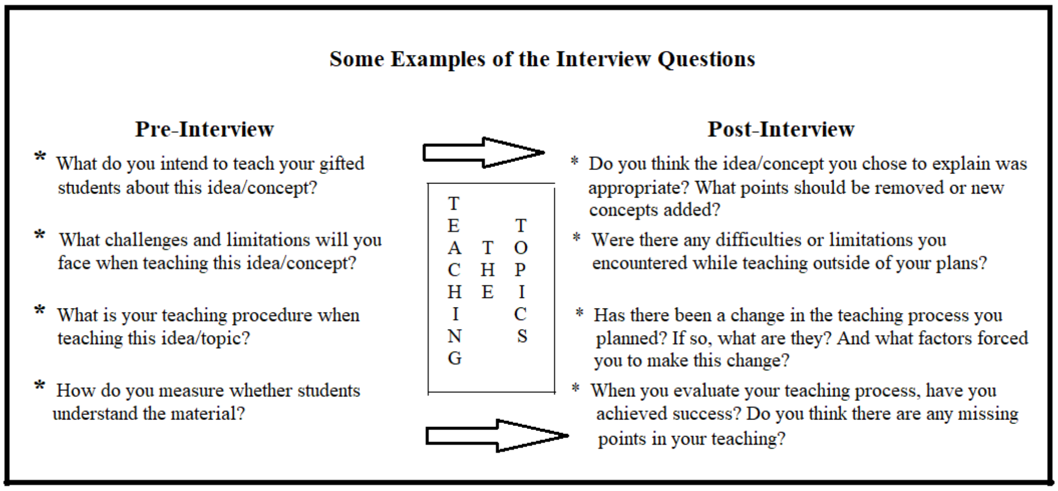

Figure 2. Some Examples of the Interview Questions

Another data collection tool was observation, which is an appropriate technique and primary source to describe social events in the school context (Merriam, 2009; Yin, 2009). We supported the interviews with classroom observations to gain a deeper understanding of the teacher's behaviors and practices, which may not have been fully addressed during the interviews. Therefore, in this study classroom observations were conducted for three topics; work/energy, simple machines, and friction force during twenty lessons, with each lesson spanning 40 minutes. An observation protocol was used when collecting observation data, no video recording was taken during the lesson.

Data Analysis

The study utilized an in-depth analysis of explicit PCK for data analysis. For this purpose, we employed Magnusson et al.'s (1999) PCK model as an analytical and theoretical framework. Initially, the data was coded in a deductive manner, using predefined theoretical categories and codes. This deductive coding approach, which follows a generic method, is frequently utilized for the initial coding and identification of themes. (Creswell, 2007). The deductive open coding technique was employed to identify general patterns in the data set concerning PCK components, such as STO, KoC, KoL, KoIS, and KoA. Additionally, during the data analysis process, new codes were noticed that deviated from the theoretical framework. To incorporate these new themes, such as knowledge of enrichment curriculum (KoEC) and knowledge of the characteristics of gifted students (KoCG), we utilized the inductive coding technique. Detailed information about the codes, sub-codes, and their explanations are illustrated in Table 2. After completing the coding process, an attempt was made to form themes that represented common patterns of the teacher's knowledge.

Hence, to ensure the credibility of the research, we implemented analyst triangulation and triangulation of multiple data sources (Patton, 2002), long-term observation (Merriam, 2009; Patton, 2002; Yin, 2009), and member checks (Merriam, 2009). The first triangulation was to engage other researchers during collecting and analyzing the data. For that reason, interrater reliability was tested by using Miles and Huberman's (1994) formula to increase the validity of the coding.

$$\frac{\text{Number of agreements}}{(\text{Total number of agreements } + \text{ disagreements}) \text{ X100}}$$

Table 2.
Detailed Information about PCK Components and Coding Process

Codes	Sub-codes	Explanations
STO	teachers' knowledge about the purposes and goals for teaching science (school and curriculum goals)	Conceptual understanding, the reality of the Turkish education system, gifted education goals, history of development of concepts, effective domain, science technology sociality, and environmental goals.
	a general way of viewing or conceptualizing science teaching	
	1. process:	Provide students to enhance science process skills.
	2. didactic:	Transfer conceptual understanding of science from teacher to students.
	3. academic rigor:	Present different and difficult example or problems.
	4. conceptual change:	Change scientific knowledge with naïve or alternative concepts.
	5. activity-driven:	Engage students in active learning with hands-on activity.
	6. discovery:	Discovered science concepts by students on their own.
	7. project-based science:	Engage students in examining solution to real problems.
	8. Inquiry:	Engage students in defining and investigating problems, attaining conclusions, and evaluate the validity of results.
	9. guided inquiry:	Engage teacher and students in defining and investigating problems, attaining conclusions, and evaluate the validity of results.
KoC	Knowledge of horizontal relation:	Teaching curriculum concepts in a relation to order in the same grade.
	Knowledge of vertical curriculum:	Teaching curriculum concepts in a relation to order in the previous grade or next grade.
*KoEC	Knowledge of upper grade concepts:	Designing enrichment activities and teaching by using upper grade concepts, materials, problems, or mathematical calculations.
KoL	Knowledge about pre-requisite knowledge:	Considering students' prior knowledge and skills to provide meaningful learning.
	Knowledge of areas of student difficulty:	Considering students' difficulties in specific topics.
	Knowledge of areas of student's alternative conceptions:	Considering students' alternative conceptions or misconceptions in specific topics.
KoIS	Knowledge of subject-specific strategies:	Using inquiry, learning cycle 5E, or conceptual change
	Knowledge of topic-specific strategies:	Using questioning, analogies, models, examples, demonstration, problems, experiments

* KoEC is emerged with the inductive method during the data analysis process.

Table 2
(continued)

Codes	Sub-codes	Explanations
*KoCG	Not easily persuaded:	Students did not easily accept the work or concept explained by the teacher.
	Being curious and making inquiry:	Students ask difficult and interesting questions.
	Need enrichment activities:	Students can extend general science teaching.
	Learning quickly and easily:	Students can learn quickly and easily.
KoA	Dimension of science assessment:	Student's prior knowledge, content assessment, and grading students' performance
	Methods of science assessment:	a. Informal assessment technique (questioning) with diagnostic assessment technique b. Formative assessment was served to evaluate students' conceptual understanding with handout test including multiple choose, and short answer questions. c. Summative assessment was performed in order to grade students' performance

* KoCG is emerged with the inductive method during the data analysis process.

By taking into account this formula, card-sorting activities, and CoRe plans interviews reached the level of interrater reliability of 89%. Moreover, the reliability of observations including the teacher's teaching was 85%. The second triangulation was using multiple data sources. In doing so, card-sorting activities, CoRe, interviews, and observations served to provide an alternative explanation about the related phenomena. Another credibility strategy was member checks which enabled us to increase the internal validity of the study. The participant read the results of our interpretation and understanding in order to edit the misunderstanding and misinterpretations about the data, and missing information. The last strategy to ensure the credibility of this study was long-term observation which meets the reliability of the study and constructs trust among researchers and participants (Creswell, 2007). The data collection process started after getting approval of the Institutional Review Board to ensure ethical standards to protect the participant's rights and confidentiality.

In this study, the researcher took on the role of a full observer, seated at a desk at the back of the classroom, simply watching the teaching environment. The researcher did not engage in any teaching activities or join in any discussions. Once the teacher consented to participate, a schedule was arranged for both the participant and the researcher for the study. To familiarize the researcher with the school setting and the students, the researcher began visiting the school two weeks before the actual observations. During this period, no data was collected. To avoid causing any disruption and to ensure that students behaved naturally, the researcher was introduced to them as a pre-service science teacher.

Findings

After further data analysis, the findings of the science teacher's knowledge revealed the following four salient headings: (1) the teacher's teaching pattern, PCK components of knowledge of instructional strategies (KoIS), and knowledge of assessment (KoA), (2) teacher's knowledge of science teaching orientation (STO), (3) teacher's knowledge of enrichment curriculum (KoEC), and (4) teacher's knowledge of characteristics of gifted student (KoCG).

The Teacher's Teaching Pattern and PCK components of KoIS and KoA

As for KoIS, it revealed that the teacher used different individual topic-specific strategies. The teacher's approach to instructing the topics of "work/energy (WE), simple machines (SM), and friction force (FF)" in the middle school science curriculum follows a structured pattern, as outlined in Table 3, providing detailed insights into her teaching methods for each topic.

Table 3.
Teacher's Teaching Pattern

Topics and concepts	Beginning of the lesson	Introduction of a new concept /engagement	Presentation and elaboration of the target concepts	Evaluation
Work and energy	Reactivates the previous concepts (e.g., springs)	Asks warm-up questions to determine alternative concepts	Lectures using examples and visual materials, Gives the formula of work, and dictates the concepts for students to take notes	Monitors class, asks questions, and gives handouts including multiple choice test
Simple machines	No pedagogical action	Asks warm-up questions to determine alternative concepts	Gives daily life examples	Monitors class, and asks questions
Friction force	Asks questions to help students to recall friction force	Engages students in an experiment to discover the relationships between weight and force, and surface area and force, respectively	Guides a discussion of the experiment results, and dictates the concepts for students to take notes	Monitors class, asks questions, gives handouts including multiple choice test, and gives an achievement test end of the unit

Throughout the class session, her teaching typically comprised four segments: the lesson's outset, the introduction of the new concept, elaboration on the concept, and evaluation. In the initial phase, she reviewed previously covered concepts using questioning or lecture techniques to refresh students' understanding. Following this, in the second segment, she introduced new concepts by questioning students to assess their knowledge and explore alternative ideas. The third part of her lesson involved revealing the new concept, employing real-life examples, analogies, and various visual aids within a PowerPoint presentation. She reinforced understanding by providing formulas, ensuring a more concrete grasp of the concepts, and encouraging students to take notes on essential definitions and factors. The final part of her lesson focused on assessing students' comprehension. Using both informal methods (observing students and questioning during teaching) and formal approaches (administering handouts containing multiple-choice or open-ended tests), she assessed students' understanding at the conclusion of the teaching session.

The findings of the teacher's KoA suggest that she was capable of discerning differences among her students, given the class size of 12. Throughout the classes, the teacher demonstrated keen observation skills and conducted individual assessments effectively. The assessment of conceptual learning was generally prioritized, and the teacher's in-class assessment goals were categorized into three main areas: determining students' prior knowledge, observing content assessment, and grading students' performance.

Teacher's Knowledge of Science Teaching Orientation (STO)

This component was defined in the PCK model under two sub-components; (1) "teachers' knowledge and beliefs about the goals and purposes for teaching science at a particular grade level and (2) a general way of viewing or conceptualizing science teaching" (Magnusson et al., 1999, p. 97). To find out the teacher's STO in this study, card-sorting activities, semi-structured interviews, and class observations were utilized.

The analysis results for the first sub-component of STO indicated that conceptual learning derived from the national science curriculum served as the foundation for her teaching approach. In addition to conceptual learning, the teacher had gifted education goals related to enabling gifted students to notice their special abilities and enhance those abilities with appropriate activities. Furthermore, because of the school's mission (recognizing and developing the special abilities of the gifted) the school administration asked the teacher to design and practice some activities to enhance the students' knowledge and abilities; the teacher explained that:

> … In addition to the science curriculum, we use an enriched curriculum where we design and plan different activities, including watching video or documentaries, playing games, and doing a field study. In school, there are also workshops or application classes for each subject. For seventh-grade science class, the students can participate in an application course which is planned and designed by the other science teacher. In this course, the students can obtain theoretical knowledge and practice related topics.
>
> ... In order to enhance the students' technological ability in education, tablet computers are used by each student in the science class. The students generally use tablets to play games, but I encourage the students to use their tablets for educational purposes. (card-sorting activity, individual interview)

The second sub-component of STO revealed the teacher's general way of viewing or conceptualizing science teaching for the topics of WE, SM, and FF from the teachers' card sorting activities for each topic. During activities, she chose similar teaching orientation cards, and reflected a similar teaching pattern for planning and practicing of three topics. The teacher held the belief that gifted students should actively engage in classroom activities. Consequently, she chose cards featuring student-centered approaches that aligned with her teaching orientation. These included emphasizing science process skills such as observation, prediction, data collection, and experimentation, promoting conceptual change, facilitating hands-on activities, encouraging discovery learning, and fostering inquiry-based learning. Furthermore, she thought that these activities were more appropriate for enhancing gifted students' skills. This situation can be exemplified through her statement below:

> …in these activities, the students are active, and teachers are passive. Our purpose is to make students learn by experience in order to obtain meaningful learning. We know that they don't enjoy the lecturing… Thus, hands-on activities are more appropriate for these students (card-sorting activity of SM, individual interview).

Moreover, the teacher rejected the cards including academic rigor and didactic science teaching orientation, owing to the fact that the gifted students were bored while teaching in a lecturing nature. She expressed her reason as the following:

> If I always lecture the topics and they are asked to listen to me for a long time, they don't listen to me…They become bored and you can even understand their boredom from their eyes. They need to engage in an active learning environment (card-sorting activity of SM, individual interview).

In a nutshell, the findings of the card sorting activities revealed that the teacher had a student-centered teaching orientation and rejected the didactic orientations. However, the findings of class observations showed different teaching practices from the teacher's ideal views. In other words, her belief about STO did not often match with her classroom practices. Generally, the teacher started the lesson by posing questions to create a discussion environment, and then she continued the lecturing to explain related science concepts. After that, she offered more examples and problem-solving. This teaching pattern, which arose from three topics of WE, SM, and FF, actually reflected teacher-centered orientation. Thus, this means the teacher was not able to present student-centered activities. Some factors that emerged during lesson observations, such as limited class time, unforeseen course cancellations, and never-ending student questions and requests, hindered the teacher's student-centered practices. On the other hand, two student-centered activities supported the assumption that the teacher had competencies to plan and practice laboratory works while teaching lever and friction force topics. The teacher allowed two laboratory activities in which the students were able to observe and predict related phenomena, collect the data, and design an experiment. The students could discover related concepts and their relations in the laboratory activities. As a result, it was difficult to label the teacher's

STO. The teacher believed that student-centered activities are more appropriate for gifted students, and was able to offer two of such activities.

Teacher's Knowledge of Enrichment Curriculum (KoEC)

According to the findings on KoEC, it is evident that gifted students possess special abilities, such as rapid comprehension of scientific concepts, curiosity, and profound critical thinking. Due to these unique characteristics, these students can quickly grasp science topics within the middle school curriculum, necessitating more intellectually stimulating and challenging activities to meet their needs. To address these requirements, the teacher introduced topics and applications that encompass advanced-grade concepts and materials. The middle school curriculum has an upper limit defined by advanced concepts and materials, and non-gifted students are not required to cover these contents. The subsequent statements elaborate on the teacher's perspective regarding alternative activities for these students.

> ...I use the limitations in the middle school curriculum as enrichment activities. I am looking for, if there is a limitation for seventh-grade students, and if the limitation is appropriate for the students, I can design the limitation as an enrichment activity (pre-interview of WE, individual interview).

KoEC was evident since the gifted students required supplementary explanations, activities, or demonstrations that were not covered in the seventh-grade curriculum. This necessitated the teacher to draw on her curriculum knowledge to design and implement enrichment activities. The distinctions between the standard curriculum and the enrichment curriculum applied by the teacher are further explained in Table 4.

Table 4
Differences between General Science Curriculum and Enrichment Curriculum Contents

Topics	KoC (curriculum objectives)	KoEc
Work and energy	To investigate the relationship between force, work and energy. To define work and to specify units of work. To express that the force which acts perpendicular to an object does not mean a work. To identify that energy is the ability of work.	To investigate work done by the resultant force (the effects of sinα and cosα values). To use a formula to calculate the amount of work.
Kinetic and potential energy	To recognize that moving objects have kinetic energy. To discover relationship between kinetic energy and speed/mass. To indicate objects have gravitational potential energy according to their location. To discover relationship between potential energy and height/mass.	To use the formulas to calculate kinetic and potential energy. To specify the units and to identify symbols of the kinetic and potential energy.
Simple machines	To determine how changes the direction of the force. To identify simple machines. To recognize getting greater output force than input force by using simple machines. To identify that simple machines provide only ease of doing work, and not energy savings.	To identify hoists, spinning wheel, gears and hoop as example of simple machines. To consider pulley weight while calculating force. To calculate force and load by using a formula.
Friction force	To show the heat of the friction surface. To recognize that friction force leads to decrease in the kinetic energy. To explain energy transformation in terms of kinetic energy.	To show what factors affect friction force by doing an experiment.

Based on the findings regarding the topic of WE, the teacher introduced enrichment activities that included the concept of resultant force and mathematical calculation formulas typically found in high school science curriculum. The teacher elaborated on her enrichment approaches for the WE topic as follows:

> ...in this semester, I did not have enough class time, and I only planned to apply the problems including mathematical calculation and formulas about work and energy. If I have more class time, I will engage the students in high school curriculum objectives. (post-interview of WE, individual interview).

The study revealed similar findings for the topic SM, where the teacher incorporated high school concepts, mathematical examples, and problems. In addition to the middle school science curriculum, the teacher provided more examples of simple machines, which included hoists, spinning wheels, gears, and hoops. To further enhance the students' understanding, the teacher also introduced mathematical formulas related to these simple machines, allowing them to calculate force and load. The teacher's opinion about SM as enrichment curriculum is given below:

> … The middle school science curriculum does not consider hoists in detail, we did. Mathematical formulas and difficult problems were practiced by the students. We will add these applications next year as enrichment activities. These applications are appropriate for gifted students, and the students had a favorable reaction from the applications and problems... I will add something about the incline plane. The more difficult questions about the incline plane may be represented... (post-interview of SM, individual interview).

Based on the findings related to FF, an experiment was conducted to explore the relationships among "force acting on an object," "weight of the object," and "surfaces on which the object moves." The students designed this experiment with the aim of discovering the factors influencing friction force. This inquiry effectively integrated science process skills, aligning with the objectives outlined in the high school science curriculum. Consequently, the experiment was considered an enrichment activity for the friction force topic.

Overall, the gifted students required involvement in enrichment activities. The teacher demonstrated effective utilization of both the middle school and high school science curriculum when planning and teaching related topics. This reflects the teacher's commendable grasp of curriculum knowledge and skills. Consequently, planning and implementing enrichment curriculum likely requires a level of teacher proficiency in high school science curriculum and materials. As such, KoEC should be considered a crucial component within the PCK model in the context of gifted students.

Teacher's Knowledge of Characteristics of Gifted Student (KoCG)

The gifted students showed some behaviors different from their non-gifted peers, and the teacher believed that these behaviors were unique characteristics of gifted students. In this respect, based on the class observations and post-interviews with teachers, there were generally three characteristics; (1) the students displayed science learning quickly and easily, (2) they asked interesting and difficult questions, (3) their curiosity and skills in discussions extended the teacher's applications from regular curriculum to enrichment curriculum. Table 5 also presents the characteristics of the students, along with examples and explanations of these characteristics based on specific topics.

According to the findings of the first characteristic, it was observed that the students quickly grasped the concepts covered in the related curriculum. However, they required enrichment curriculum activities, as mentioned in the teacher's KoEC section, for the remaining class time. The second remarkable ability of the students in the science class was their inclination to discuss. The teacher's initial explanation or presentation was not immediately accepted by the gifted learners. Instead, they posed additional questions, seeking further concrete examples, and demanding a more detailed explanation about the related phenomena. For instance, during the teaching of the work concept, the teacher faced challenges in explaining the scientific definition of work and its practical meaning. The students already had experience with the everyday life meaning of work, and they were hesitant to accept the new information regarding the scientific interpretation. They asked for more concrete examples and explanations. In some cases, students' discussions disrupted the flow of the lesson. For example, while the teacher physically demonstrated the task, students asked for examples that came to their mind.

Student 1: Well, teacher, if I move the pen diagonally like this, will I be doing work?
Student 2: Does the escalator work?
Student 3: For example, do elevators do work?
Student 4: Teacher, there is a lever in the elevator, isn't there?
Student 5: No, there are pulleys.
Student 6: Teacher, why do they leave spaces on the ground floors of elevators?...

Without giving the teacher a chance to talk, students brainstorm about the elevator and its working mechanism. These types of discussions cause a loss of time in class because they move the focus of the lesson to different areas.

This characteristic was also evident during the teaching of simple machines, particularly concerning the introduction of mechanical advantages of force and load in fixed pulleys and moveable pulleys. The students' inquisitive nature and their desire for a deeper understanding were consistently observed in various situations within the science class.

The last characteristic is related to enrichment activities, stemming from the students' curiosity and discussion skills, which eventually influenced the course schedule. While learning about the work topic, the students explored the concept of resultant force, which is typically covered in the high school curriculum, driven by their inquisitive questions. Similarly, during the practice of force in the inclined plane, the students independently discovered the impact of the angle factor on load and force balance. As a result, the teacher had to provide an explanation for the angle factor. Additionally, a similar gifted characteristic emerged in their exploration of the relationship between force and gravity of pulleys, aligning with the high school curriculum.

In conclusion, the characteristics of gifted students shaped the teacher's approach in teaching related concepts. It is evident that a science teacher should possess a deep understanding of their gifted students, and KoCG should be considered as an integral component of the PCK model.

Discussion

The findings of this study are discussed under three headings in line with its contributions to the field of science teacher education and the education of teachers of gifted students.

Science Teaching Orientation (STO)

The teacher's primary goal and purpose were to ensure a comprehensive conceptual understanding of science concepts. Conceptual understanding involves learning the subject matter and concepts in the science curriculum, as well as understanding the relationships and contexts among this information. It requires students to reconstruct the concepts taught, apply them in different situations, and define or explain them in their own words (Koniceck-Moran & Keeley, 2015). Prioritizing the attainment of curriculum objectives and fostering conceptual understanding are common approaches among science teachers (Ahtee & Johnston, 2006; Koniceck-Moran & Keeley, 2015). Moreover, in addition to fostering conceptual understanding, she placed significant emphasis on the affective domain and gifted education, aiming to enhance the interest and motivation of gifted students in science. Providing opportunities for her students to engage in extracurricular or enrichment activities (by offering advanced concepts, contents, and materials) was also a key aspect of her teaching approach, which aligns with the expectations of teachers working with gifted students (Renzulli, 1999, 2012; Sękowski & Łubianka, 2015). Moreover, many teachers adopt practices such as enrichment or differentiation through advanced conceptual teaching (Gómez-Arízaga et al., 2016; VanTassel-Baska et al., 2020).

Concerning the teacher's overall perspective on science teaching, she exhibited a complex set of STOs, making it challenging to categorize her teaching within any of the nine STOs outlined in the study's PCK framework. Friedrichsen and Dana (2005) explain this complexity by linking it to central and peripheral goals. Central goals are practices that occur frequently and are dominant in teachers' classroom practices. Peripheral goals are less dominant and allow the teacher to deviate from the central goals. The central goal of the participating teacher in this study is to teach science concepts to her students. Other goals of the teacher are to meet the educational needs of gifted students, to ensure that students have a positive attitude towards science, etc. These are examples of peripheral goals. The participating teacher's general teaching view is not grouped into one of nine scenarios. The teacher generally teaches science using the traditional method but includes student-centered practices at appropriate times. Friedrichsen et al. (2011) criticize the process of placing teachers' STO into a group because teachers may have different STO depending on their science subject, student group, or grade level. For example, the characteristics of the gifted students shaped the teacher's teaching orientations from teacher-centered to student-centered. As the characteristics of gifted students prompt a shift in teaching practices from traditional methods to student-centered approaches (Gómez-Arízaga et al., 2016), students seek to actively participate in the learning process with the teacher, who consequently assume the role of a guide (Subaşı, 2021). In fact, contemporary gifted education policy aims to promote student-centered, research-inquiry-based education (Renzulli, 2021). In this study, gifted learners were generally able to discuss the teacher's explanations of related concepts, because of the latter's effective use of discussion techniques, which benefits students by allowing them to be more active in their learning (Coleman, 2003). In addition, some other factors that influenced the teacher's STO, especially time constraints, lack of enough students' abilities, and loaded curriculum, led to the teacher's involvement in didactic teaching. In other words, teachers' STO is influenced by many factors (Friedrichsen et al., 2011; Friedrichsen & Dana, 2005; Ramnarain & Schuster, 2014), and the characteristics of gifted students represent one aspect of these orientations, as teachers' STO are context-specific (Abell, 2007).

Although the STO component is not explicitly mentioned in the NAGC and CEC's (2013) standards, its definition can be found within various standards, such as *"Learning Environments, Instructional Planning and Strategies, Professional Learning and Ethical Practice, and Collaboration"*. Notably, the Instructional Planning and Strategies standard prominently reflects the teachers' decision-making process in their teaching, making STO apparent. However, it is essential to explicitly highlight the STO component as a separate standard in the NAGC and CEC standards due to its significant impact on shaping and filtering teachers' PCK components (Friedrichsen et al., 2011; Magnusson et al., 1999). At the same time, teachers' beliefs about gifted students influence their classroom practices (Godor, 2019). Therefore, teachers need to establish specific goals tailored to the needs of gifted students. When teachers prioritize these goals, it leads to positive changes in students' education (Tirri, 2017). Moreover, the characteristics of gifted students influence the teacher's shift from traditional to student-centered teaching, further emphasizing the importance of explicitly acknowledging the STO component in the standards.

Knowledge of Enrichment Curriculum (KoEC)

The participant teacher effectively used knowledge of curriculum (KoC) and KoEC to design appropriate learning experiences for her students. Because of the characteristics of gifted students, they were able to easily or quickly gain a conceptual understanding of relevant topics in a short time. Therefore, for the rest of class time, there was a great need for gifted students to engage in extracurricular practices, which are called enrichment activities, including comprehensive and advanced knowledge/ability, and above grade level topics or examples (Benny & Blonder, 2018; Kim, 2016; Thomson, 2006). The concerns, including challenging content, student-centered applications, and high-quality products, time and resources, teacher competencies, and students' competencies and interests, play important roles in designing and practicing enrichment activities (Fiddyment, 2014). Moreover, engaging in the planning and implementation of enrichment activities can enhance the teacher's KoC and KoEC, as they are motivated to address the unique needs of their students (Croft, 2003). There are a variety of competencies and skills that teachers use to plan and implement enrichment activities (Chan, 2001; Croft, 2003; Fiddyment, 2014; Gómez-Arízaga et al., 2016; Park & Oliver, 2009).

Regarding the teacher's KoEC, the teacher offered her students enrichment activities that emphasized content knowledge but lacked sufficient integration of science process skills, creative-productive skills, or an understanding of the nature of science. This scenario has prompted discussion on whether gifted students should be primarily engaged in acquiring more content knowledge or in developing their skills and abilities (Renzulli, 2012, 2021; Shaughnessy & Sak, 2015; Sternberg, 2019). By stating that high ability learners require detailed and compulsory knowledge (Benny & Blonder, 2018;

Çalıkoğlu & Kahveci, 2015; Newman & Hubner, 2012; Shaughnessy & Sak, 2015); however, content knowledge is not adequate to develop gifted learners' special abilities (Renzulli, 2012, 2021). In addition to acquiring advanced and challenging knowledge, gifted students' education should encompass the development of science process skills (Çalıkoğlu & Kahveci, 2015; Han, 2017), fostering motivation toward science (Çalıkoğlu & Kahveci, 2015; Newman & Hubner, 2012), understanding the nature of science (Gilbert & Newberry, 2007; Kaplan et al., 2016; Taber, 2016), self-directed learning skills (Sternberg, 2019), critical and creative thinking skills, and 21st-century skills (Ayvacı & Bebek, 2023; Kaplan, 2012). These factors play a crucial role in transforming gifted students into creative and productive individuals, emphasizing the importance of engaging them in a holistic ability development process (Renzulli, 2012, 2021).

The differences and importance of KoC and KoEC components are highlighted in NAGC and CEC standards, whereas KoEC is not explicitly mentioned in the study’s PCK framework. The findings of the present inquiry provide valuable information and evidence about the teacher's KoEC and KoC. Gifted students influenced the teacher's teaching in a way that she used both regular science curriculum and enrichment curriculum. Thus, it can be stated that KoEC should be considered as a separate component in the PCK model with gifted students' context.

Knowledge of Learner and Characteristics of Gifted Students (KoL & KoCG)

The teacher demonstrated proficiency in determining the students' prerequisite concepts to cover the targeted topics, showcasing her KoC. However, when it came to implementing enrichment activities, she faced some challenges in identifying the students' pre-existing knowledge and abilities. This highlighted the clear distinctions between her KoC and her KoEC in her pedagogical approach. As evident, designing and conducting enrichment activities demand additional competencies from teachers (Chan, 2001; Croft, 2003; Fiddyment, 2014; Park & Oliver, 2009). It became apparent that relying solely on KoC was insufficient for conducting science activities in gifted classes, as the characteristics of gifted students such as learning fast and asking lots of questions (Benny & Blonder, 2018; Reis-Jorge et al., 2021) often led to the spontaneous emergence of enrichment activities. These activities arose due to the students' penchant for posing intriguing and complex questions, as well as their curiosity and discussion skills. As a result, the teacher occasionally found herself explaining these enriched activities, which involved upper-level concepts that were not part of her initial lesson plan. This unanticipated situation sometimes put the teacher in a challenging position, as she was caught unprepared to meet her students' needs adequately. On a positive note, the distinctive characteristics of gifted students expanded the teacher's practice beyond the confines of the regular curriculum, leading to the incorporation of enrichment curriculum elements. As teachers' PCK is a construct that develops over time with increasing experience (Abell, 2008; Carlson & Daehler, 2019), this process enhanced the teacher's KoEC, enabling her to better accommodate the needs and abilities of her gifted students.

The characteristics of gifted students presented pedagogical challenges for designing and teaching topics related to WE, SM, and FF. These students' unique traits influenced the teacher's approach in two distinct ways: posing pedagogical challenges for the teacher and necessitating enrichment activities for the students. The first challenge arose from the gifted students' tendency to thoroughly probe each science concept explained by the teacher. They did not readily accept every clarification offered and frequently requested more concrete examples or detailed explanations. As a result, the teacher had to handle these pedagogical challenges skillfully. Additionally, the students' penchant for asking difficult and intriguing questions added to the complexity. It is obvious that the curious questions of gifted students lead teachers to provide long and detailed explanations (Laine, Kuusisto, & Tirri, 2016; Stott & Hobden, 2016). This situation has resulted in the loss of valuable class hours for the participating teacher's classroom practices. Moreover, these questions often demanded enriched explanations and practical demonstrations. Overall, the characteristics of gifted students introduced both challenges and opportunities for the teacher. While addressing their unique needs and inquisitive nature required additional effort and time, it also led to the implementation of enriching activities that enhanced the learning experience for these gifted learners.

The second influential factor is the necessity of enrichment activities in shaping the teacher's approach to teaching. The design and implementation of enrichment activities demand additional competencies from teachers (Chan, 2001; Croft, 2003; Fiddyment, 2014; Park & Oliver, 2009). This is because effectively teaching each concept or conducting each activity entails considering various factors, such as students' prior knowledge (Gómez-Arízaga et al., 2016), misconceptions, learning difficulties, (Magnusson et al., 1999), appropriate teaching strategies, and assessment techniques (Carlson & Daehler, 2019). Therefore, in order to ensure meaningful learning through enrichment activities, teachers must take these concerns into account. As a result, the teacher's KoCG played a vital role in effective teaching of topics such as WE, SM, and FF to gifted learners, consequently influencing her KoEC. Hence, KoCG should be acknowledged as a distinct sub-component in PCK models. Both this study and the NAGC and CEC standards (2013) underscore the significance of addressing individual learning differences when designing and implementing enrichment activities for gifted students.

Conclusion and Suggestions

This study thoroughly examined and elucidated a science teacher's PCK during teaching topics such as work and energy, simple machines, and friction force in gifted classes. Notably, we discovered that, in contrast to both the PCK model (Magnusson et al., 1999) and teacher preparation standards (NAGC & CEC, 2013), teachers should possess additional knowledge bases or PCK components. Particularly, the findings highlighted the significance of KoEC and KoCG in science teacher education, as well as the importance of STO in gifted student education when teaching physics topics. Moreover, the gifted students had a positive influence on and actively shaped the participant teacher's PCK, leading to a transition from a teacher-centered approach to a more student-centered orientation. These insights provide valuable implications for the education program of gifted students, particularly concerning the teaching and learning of physics topics. Furthermore, the findings contribute valuable evidence to the science teacher literature, enriching the quality of science teachers' PCK.

Since this study is a qualitative study in terms of research design, it has certain limitations. Examining a single teacher's teaching with gifted students provides limited information. Therefore, there is a need for research on similar topics involving more than one teacher. Additionally, this study was conducted in a homogeneous classroom, meaning the teacher's teaching was observed in an environment where all students were gifted. A research structure can be designed where gifted and non-gifted students are educated in the same classroom. This approach would allow us to observe the students' effects on the teacher's PCK with different intelligence levels from various perspectives.

Acknowledgment

Ethics statement: In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, we declare that there is no conflict of interest between the authors, which all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

Author Contributions: Conceptualization, B.Ç. and J.Ç.; methodology, B.Ç. and J.Ç.; validation, B.Ç. and J.Ç.; analysis, B. Ç. and J.Ç.; writing; B.Ç.; review and editing, J.Ç.; supervision, J.Ç.

Funding: This research received no funding.

Institutional Review Board Statement: Ethics committee decision: Middle East Technical University, Applied Ethichs Research Center Decision, Date: 10/04/2014, No: 28620816/183-347

Data Availability Statement: Data generated or analyzed during this study should be available from the authors on request.

Conflict of Interest: Authors should declare that there is no conflict of interest among authors.

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