ePCK Transfer between Math and Science

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ePCK Transfer Between Math and Science

Elise Joyner

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Arts

Ryan S. Nixon, Chair
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ABSTRACT

ePCK Transfer Between Math and Science

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Master of Arts

Generalist elementary school teachers have little time to develop enacted pedagogical content knowledge (ePCK) in all content areas. Therefore, the transfer of ePCK from one content area to another, such as between math and science, can help generalist teachers build their knowledge needed for teaching regardless of their content area strengths. This self-study examines the ePCK components and their elements present in both math and science instruction. I am a fifth-grade teacher in Utah County who has been teaching for 4 years. Math is taught daily, and science is taught approximately three times a week. The self-study includes six video observations of my instruction—three for math and three for science—as well as a journal of my thoughts on my ePCK after each lesson and a guided discussion with a colleague while reviewing the video observations. Each data source aims to identify ePCK while noting the similarities and differences in the way it presents in each content area. The data analysis reflected this goal through the coding process. Through analysis, each ePCK component—subject matter knowledge, knowledge of students, and pedagogical knowledge—was observed in both math and science instruction. For subject matter knowledge, the presence is different in math and science, implying that this component was not transferred between the two content areas. Regarding knowledge of students, the presence is similar in both math and science, implying that this component transfers between content areas. The elements of pedagogical knowledge that transfer include knowledge of the importance of and ways to establish classroom structures and knowledge of student thinking about content as a key component to learning. These findings suggest that ePCK is a development of past enacted knowledge. Therefore, the more knowledge that is enacted, the more it develops. ePCK transfers between content areas if the presence of components is both present and are similar. If ePCK is transferred from one content area to another, generalist elementary teachers can use the strengths of their ePCK in one content area to improve that of another. With so few studies conducted on this topic, more research needs to be done to further understand ePCK transfer, especially at an elementary level and in the action of teaching.

Keywords: enacted pedagogical content knowledge, knowledge transfer, generalist elementary teacher
ACKNOWLEDGMENTS

My first and greatest token of gratitude goes to my chair, Dr. Ryan S. Nixon. I would not have made it through this process without his endless patience, optimism, and grace. He recognized how new the educational research writing process was to me and taught me step-by-step, holding my hand the whole way through, and explaining the same things over and over again until I finally understood. Dr. Nixon took the time to learn how I learn and catered the thesis experience to what I needed. I will forever be grateful for his mentorship through this journey.

I am also so very grateful to my family. To Mom and Dad who believed in my educational aspirations and encouraged me every step of the way—thank you for your unwavering faith in my abilities. To Dayne who sent me encouragement through the long nights of writing—thanks for the Swig pick-me-ups, little treat drop offs, quick Disneyland getaways, and funny videos. To Alex and Emma who checked in on me at least once a week for 2 years—thanks for the Sunday dinners, fun outings, and for being my taste testers after I stress baked. To Cole who provided company and fun through the process—thanks for driving all the way to my house to hang out so I had more time to write. To Grandma and Papa who asked how the paper was going each time I saw you—thanks for the freezer meals and mostly for your constant love. To the Langstons who have been my Utah home for 10 years—thank you for all the Sunday dinners, fun laughs, piñatas and nachos on the beach, game nights, movie nights, and immeasurable love.

It takes a village, and I am so grateful for mine!
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CHAPTER 1

Introduction

How do teachers know what to teach and what to do in the classroom? While there are many answers to this question, the model of Pedagogical Content Knowledge (PCK) is one way to better understand the nuances of this question. The idea of PCK helps researchers and teachers alike understand the intersection of three components of teacher knowledge: what teachers are teaching (subject matter knowledge), who and where they are teaching (knowledge of students), and their own knowledge of the actions that they do when in the classroom (pedagogical knowledge) (Abell, 2007; Ball et al., 2008; Bullough, 2001; Carlson et al., 2019; Cochran et al., 1993; Shulman, 1986). There are also more nuanced elements that comprise each component.

In order to better understand, the most interesting aspect is found in how the three components of PCK come together in the actual classroom. This is known in science education research as enacted PCK (ePCK). Documenting moments of ePCK can lend insight into what a teacher knows and how they approach instruction (Carlson et al., 2019). If the research community can learn what a teacher needs to know, teacher preparation courses can identify areas of focus to prepare the next group of teachers and fill in the gaps of teacher knowledge. Through knowing what they themselves do and do not know, teachers can improve their practice by focusing on learning more in areas where their knowledge may not be as strong. This practice, in turn, may affect the learning of the students as their teacher uses improved teaching practices.

ePCK is specific to the content area that is being taught. Each content area is different and requires different subject matter knowledge from a teacher as topics taught vary by content area (Abell, 2007; Ball et al., 2008; Carlson et al., 2019; Chan & Hume, 2019; Shulman, 1986; van Driel et al., 2014). Because of this, there is a preexisting difference in the subject matter
knowledge component of a teacher’s ePCK. With one component of ePCK being different, it begs the question, is a teacher’s overall ePCK different for different content areas? If so, are there ePCK components in each content area that could transfer to other content areas? Specifically, are there components in a teacher’s ePCK that transfer between math and science? Existing literature has already investigated science ePCK and math ePCK independently, but to identify the transfer of a teacher’s ePCK between science and math we need to study the two content areas simultaneously (Adler et al., 2014; Amador et al., 2022; Ball et al., 2008; Coetzee et al., 2020; Hume et al., 2019). This will provide a closer look into the state of ePCK for each.

**Statement of the Problem**

Generalist elementary school teachers face pressure to focus on tested content areas, specifically literacy and math. Teachers, schools, and communities are judged on how well the students perform on high stakes testing, so teachers naturally spend more time with the content area of those tests. The No Child Left Behind Act added pressure onto teachers to prepare for mandated high stakes testing by spending more time teaching the tested content areas (Jennings & Rentner, 2006). While that act has been replaced with the Every Student Succeeds Act, the requirement to test students in literacy and math is still in place (Brown et al., 2016). As teachers spend more time with literacy and math, it can be assumed that they will naturally have a greater potential to develop ePCK in those content areas (Smith et al., 2022). Other content areas, such as science, are not taught as often and, therefore, may result in poorer ePCK (Haverly & Davis, 2023; Mulholland & Wallace, 2005).

In my personal teaching practice as an elementary school fifth grade teacher, I have been given specific amounts of time by administrators that need to be spent on math and literacy instruction. From there, I am able to fill the remaining time of my school day with science, social
studies, and other content areas. My knowledge of how and what to teach with the mandated content areas of math and literacy is naturally more developed because I spend more time with those content areas each day. Math and literacy become a focus of learning for my students and my own teaching. The other content areas of science and social studies do not receive as much instructional time in my classroom, and therefore my personal knowledge in those areas suffers. This, in turn, causes student learning in those content areas to be lower due to a lack of time they are given.

As a teacher who has limited time each day to devote to all content areas, I wondered how the knowledge I develop for teaching one content area transfers to teaching another content area. For example, could the instructional moves such as using small groups, checking for understanding or questioning, and the knowledge of my students that I use in math be the same in the content area of science? Knowing the answer to this question can improve my teaching practice as I look to improve all areas of my teaching. More specifically, transfer is applying learning from one area to another, so could I apply my learning from one content area to another (National Academies of Sciences Engineering and Medicine [NASEM], 2018). Teaching would be meaningless to me without students present, so identifying ePCK and how it presents in a classroom full of students can help me be a better teacher. It can also be applied on a broader scope to inform teacher preparation programs as an understanding of what is already known by teachers can inform necessary future improvements.

**Statement of the Purpose**

This study explores my math and science ePCK as a fifth grade teacher. Specifically, this study will seek to identify ePCK components and their elements of components that are present and transferring between math and science content areas.


**Research Questions**

The research questions are as follows:

1. How are ePCK components evidenced in this classroom context?
2. What ePCK components transfer between my math and science instruction?
3. What elements of the ePCK components transfer between my math and science instruction?
CHAPTER 2

Review of Literature

History of Pedagogical Content Knowledge

PCK is a specific form of teacher knowledge that teachers develop through their careers. Simply stated, it is knowing how to teach the content you are teaching (Abell, 2007; Bullough, 2001; Cochran et al., 1993; Shulman, 1986). The idea of PCK was brought to the fore by Lee Shulman (1986) who defined PCK as “the particular form of content knowledge that embodies the aspects of content most germane to its teachability [as well as] the ways of representing and formulating the subject that make it comprehensible to others” (p. 9).

After Shulman’s original article conceptualized the idea of PCK, other researchers began exploring the framework further (Hume et al., 2019). Books were published, such as Gess-Newsome and Lederman (1999), and further articles began to apply the ideas to various disciplines (Ball et al., 2001). Branches of thinking emerged with additional researchers, and contradictions filled the literature related to PCK (Hume et al., 2019). This created issues within the PCK research community. The problems reached a point where researchers were calling for clarity and more definition of PCK (Abell, 2007).

In response to the confusion surrounding PCK, researchers convened in 2012 at the PCK Summit in order to unify the conceptualization of the framework (Hume et al., 2019). From that conference, the Consensus Model of PCK was developed, and work was published to consolidate the researchers’ consensus (Hume et al., 2019). Even with the work to bring a unified understanding to PCK, researchers and practitioners continued to take their own interpretations on the concept. As each researcher interpreted the framework differently, confusion arose in the research community as to what PCK really was.
A second PCK Summit was called in 2016 in an effort to once again synthesize and organize international researchers’ expertise on the topic (Hume et al., 2019). The focus of the second summit was to solidify the conceptualization from the first summit and apply the PCK framework more specifically to the domain of science. Researchers also wanted to make sure that PCK measures were aligned with the other researchers in the field (Carlson et al., 2019). The major development that emerged from this conference was the Refined Consensus Model of PCK (Hume et al., 2019). While the summit further standardized the concept of PCK, researchers and practitioners have continued to apply the model in various ways that diverge from a streamlined vision of the concept (Gray et al., 2022; Mazibe et al., 2020). However, the Refined Consensus Model created during the summit has allowed researchers to visualize and conceptualize the PCK framework more than simply defining it, as had been done previously (Carlson et al., 2019).

**Pedagogical Content Knowledge**

The use of PCK allows teachers to match the instructional moves they make in a classroom to the content-specific areas as they teach each content area. Researchers have identified components that comprise PCK including subject matter knowledge, knowledge of students, and pedagogical knowledge (Abell, 2007; Bullough, 2001; Carlson et al., 2019; Cochran et al., 1993). Teachers use each component of PCK to teach more effectively within a content area.

Within PCK, subject matter knowledge is teachers’ knowledge of the content that teachers want students to know by the end of their learning experiences. Teachers need to know the subject matter in order to clearly teach the content to their students, as it varies content area to content area (Abell, 2007; Ball et al., 2008; Carlson et al., 2019; Chan & Hume, 2019;
Shulman, 1986; van Driel et al., 2014). For example, a teacher needs to know how to divide fractions for themselves to teach it to their students. Each content area is unique, so teachers need to know each content area individually if they are going to teach various content areas. Specifically, a teacher needs to know both science and literacy if they are going to teach both of those content areas. A teacher cannot effectively teach science without the subject matter knowledge of science or teach literacy without the subject matter knowledge of literacy. The teacher must understand the content of each content area they teach.

Another key component of PCK is knowledge of students. This is “the knowledge of communities, schools, and student backgrounds that teachers use in their teaching” (Abell, 2007, p. 1108). Knowledge of students allows teachers to maneuver the educational system in order to provide the best education for their students (Ball et al., 2008; Carlson et al., 2019). This type of knowledge lets educators select moves and practices for the varying teaching situations they encounter each day (Bullough, 2001). Knowledge of students is built on a teacher’s past learning and teaching experiences to inform teacher actions with the community they currently teach (Carlson et al., 2019). Knowledge of students serves as a filter that sifts the necessary teaching knowledge needed for that moment (Chan & Hume, 2019). For example, a teacher may know that their students’ basic needs have not been met at home as the students arrive at school, so they may take more time to connect with their class before starting their instruction for the day.

The last key component of PCK is pedagogical knowledge (Abell, 2007; Ball et al., 2008; Carlson et al., 2019; Chan & Hume, 2019; Shulman, 1986; van Driel et al., 2014). This is “the general, not subject-specific, aspects of teacher knowledge about teaching, such as learning theory, instructional principles, and classroom discipline” (Abell, 2007, p. 1108). Pedagogical knowledge informs the pedagogical moves and practices teachers use in the classroom as they
approach the learning environment. This knowledge helps educators know what to do to encourage collaboration and deeper thinking, while maintaining the structure and order of their class. Examples of pedagogical knowledge could look like a teacher utilizing wait time before eliciting student response, asking open-ended questions, and class discussions, to name a few (Center For Education Policy Research, 2023). Pedagogical knowledge is a foundational component of PCK on which most generalist elementary teachers rely while the other components develop (Hanuscin et al., 2018; Mulholland & Wallace, 2005; Nixon et al., 2016; Sanders et al., 1993). These basic instructional strategies have been instrumental for teachers in changing contexts, such as content area to content area or grade level to grade level (Hanuscin et al., 2018).

When the components of PCK blend together, they create various types of knowledge. All three components together create PCK. Blending subject matter knowledge and pedagogical knowledge create a knowledge of instructional strategies (Abell, 2007). This looks like knowing the content—subject matter knowledge—in order to appropriately select the proper teaching strategies—pedagogical knowledge. Another blend of the components is knowledge of students with subject matter knowledge to create a knowledge of student ideas (Abell, 2007). This looks like knowing the particular students in a class and their ideas—knowledge of students—and knowing the subject matter well enough to gauge the accuracy of those ideas—subject matter knowledge.

While the components blend together to form PCK, each is specific to the content area being taught (Abell, 2007; Bullough, 2001; Hume et al., 2019). Because of this content-area specificity it is unclear if the PCK components for one content area could be transferred to another content area. Transfer is “the capacity to apply learning in a new context.” This “most
likely occurs when the learner knows and understands the underlying general principles that can be applied to problems in different contexts” (NASEM, 2018, p. 14). Relating to PCK, transfer would mean applying the learning of each component to a different context as in another content area.

Levels of Pedagogical Content Knowledge in Science Education

An important contribution of the Refined Consensus Model is the articulation of three levels of PCK (see Figure 1), illustrated by a model of three concentric circles layered on top of one another with the area they fill growing more narrow as the model extends inward (Carlson et al., 2019). These levels are collective PCK (what is known by the teaching community at large), personal PCK (what is known by the teacher themselves), and ePCK (what the teacher does in the classroom with the knowledge they possess) (Carlson et al., 2019). Each level focuses on the cognitive view of knowledge as its epistemology, which is common in science education. The model maintains that as one level of PCK improves, the other levels of PCK will also improve as there is a “two-way knowledge exchange [that] takes place between the various concentric circles in the model” (Carlson et al., 2019, p. 82). As one level of PCK develops, it contributes to the other two levels. In regards to PCK transfer, discussions are usually focused on transferring knowledge from one level of PCK to another and not within a level itself (Carlson et al., 2019).
Figure 1

Refined Consensus Model of Pedagogical Content Knowledge

Collective PCK is “the knowledge held by a group of people and considered
generalizable to some degree” (Carlson et al., 2019, p. 89). This type of knowledge is an agreed,
shared, public knowledge that can be created by multiple groups of people, including
nonpractitioners. It is not specific to an individual teacher. This type of knowledge is an agreed
knowledge documented through research, articles, conferences, and the like. For example,
knowledge of the effectiveness of inquiry-based instruction for student learning (e.g., Minner et
al., 2010) is a part of collective PCK because it is knowledge shared among the educational
community, created by researchers and published in research journals.

A level of PCK that is specific to an individual teacher and is closer to the knowledge
needed to teach is personal PCK. This is “a teacher’s personal knowledge and unique expertise
about teaching a given subject area, resulting from the cumulative experiences with and
contributions from students, peers, and others” (Carlson et al., 2019, p. 86). It is what a specific
teacher knows about the various contexts of teaching that informs their practice. Personal PCK is
closer to what a teacher knows to do in the classroom but does not necessarily take into account
exact learning situations (Mavhunga & Van der Merwe, 2020). It is not context specific with the
learning situations at the time of instruction. For example, this type of knowledge can inform
how a teacher teaches the content area of math overall through their past and current interactions
with colleagues, students, and educational material without narrowing to specific lessons.

The level of PCK that informs exact teaching situations in the moment is ePCK. This is
“the specific knowledge and skills utilized by a teacher in a particular setting to achieve
particular student outcomes” (Carlson et al., 2019). This is the most specific level of PCK:
personal PCK is a general knowledge of teaching, while ePCK is about teaching this lesson, in
this specific context (Mavhunga & Van der Merwe, 2020). It involves the various interactions
teachers have in the learning context and how they respond to those situations in order for their students to reach the desired learning goal (Carlson et al., 2019). ePCK can be drawn upon in each stage of the instructional cycle: planning, teaching, and reflecting on a lesson. The actions and knowledge of the teacher during each of those instructional stages exhibits a teacher’s ePCK. Examples of ePCK can look like fluent and precise use of mathematical language, use of different mathematical representations to present or solve a problem, and clarity in launching a mathematical task (Center For Education Policy Research, 2023).

Enacted Pedagogical Content Knowledge in Science Education

ePCK is specific to each teaching context, matching knowledge of students with a teacher’s subject matter knowledge and pedagogical knowledge. If students, content areas, or contexts of any kind alter, the ePCK is different as well (Carlson et al., 2019). As Carlson et al. (2019) stated, “ePCK is the way a teacher’s actions draw on his/her knowledge to meet the unique needs of students in the classroom during a given instructional period” (p. 84). Teachers proceeding through the planning, teaching, and reflecting cycle for each of their individual students demonstrates the importance of teachers and researchers studying ePCK. By studying ePCK, teachers can improve their own teaching practice and effectiveness in the classroom, thus impacting more students (Carlson et al., 2019; Coetzee et al., 2020).

Studying ePCK allows researchers to approach teacher knowledge from a variety of viewpoints. Researchers can study each stage of teaching from a different vantage point, depending on their focus (Carlson et al., 2019). Within the planning stage, researchers can look at the resources a teacher accesses when planning for instruction. Within the teaching stage, researchers can study how a teacher approaches and adapts the material and lesson through the instructional period with the students present. Within the reflecting stage, researchers can view
how teachers adjust their future lessons based on the knowledge they gained about students and the current classroom contexts during the previously taught lessons (Carlson et al., 2019).

Because ePCK refers to knowledge that teachers use in specific contexts in their instruction, studying this level of PCK allows researchers to see what is actually happening in the classroom. Improved study of teacher practice can increase what a teacher knows about their own instruction and how to improve it for future application. This, in turn, impacts the students who are in the teacher’s class. The students benefit from a teacher who improves their own teaching practice (Carlson et al., 2019).

**Pedagogical Content Knowledge in Math Education**

The literature reviewed to this point has been primarily from science education. However, science is not the only subject to which ePCK applies. Knowing how to teach and what to teach for specific contexts has been addressed in mathematics education (Adler et al., 2014; Ball et al., 2001, 2005, 2008; Mitchell et al., 2014). While the Refined Consensus Model, which is based in science education, refers to this as ePCK, mathematics education uses the model of Mathematical Knowledge for Teaching to describe a similar knowledge base (Adler et al., 2014; Ball et al., 2008). A key difference between Refined Consensus Model and Mathematical Knowledge for Teaching is the situating of the teacher’s knowledge in the classroom. Mathematical Knowledge for Teaching refers to knowledge in action, a sociocultural epistemology, that teachers use in the classroom, while ePCK in science is knowledge teachers draw upon to teach in their context, a cognitive epistemology. In the Mathematical Knowledge for Teaching model, there is no separate section specifically for the context the knowledge is held in, whereas one of the ePCK components talks specifically to the who and where the teaching occurs (Ball et al., 2001, 2005; Carlson & Daehler, 2019).
Mathematical Knowledge for Teaching is composed of varying knowledge types similar to those discussed in science’s PCK (Adler et al., 2014). It includes six domains of knowledge: specialized content knowledge, common content knowledge, knowledge of content and students, and knowledge of content and teaching. The four types connect to the different areas found on the Refined Consensus Model, although the labels describing the knowledge types and the direct connections may differ based on the content area (Adler et al., 2014; Ball et al., 2008). ePCK research in science and Mathematical Knowledge for Teaching research in math have been studied and discussed separately but ultimately come back to the same types of knowledge as seen through the similarities in the models. Both math Mathematical Knowledge for Teaching and science ePCK research is concerned with what teachers know, the moves they make during instruction, and how teachers attend to their students in context (Abell, 2007; Adler et al., 2014; Ball et al., 2008).

Because the models are similar for both math and science, this study draws on the Refined Consensus Model as a basis. This study is specifically looking at subject matter knowledge, pedagogical knowledge, and knowledge of students which are all present in the Refined Consensus Model compared to Mathematical Knowledge for Teaching. While not all models in math and science are easily applicable across content areas and domains, most aspects of Mathematical Knowledge for Teaching are included in the Refined Consensus Model of PCK, with the exception of horizon content knowledge (Ball et al., 2008; Carlson et al., 2019). The content area is different (math versus science), but the model for looking at teacher knowledge applies as most aspects of Refined Consensus Model of PCK have counterparts in Mathematical Knowledge for Teaching as previously stated. Due to the inclusion of horizon content knowledge in Mathematical Knowledge for Teaching, Refined Consensus Model of PCK is a better fit for
this study as the content area of science does not have clear vertical alignment across grades and domains like math.

**Differences in Enacted Pedagogical Content Knowledge of Math and Science**

Although there is similarity in the way researchers discuss teacher knowledge of math and teacher knowledge of science, it is important to study the knowledge teachers use when teaching both content areas as there are key differences in subject matter knowledge preparation and general content area confidence/attitudes of teachers for each. A report generated from The National Survey of Science and Mathematics Education surveyed teachers in regard to background, beliefs, teacher preparation programs, and instruction relating to math and science (Banilower et al., 2018). This report found that elementary teachers took more math courses than science courses in their teacher education programs, thus having more exposure to one content area over the other. Between math and science lessons, the greatest disparity in opinion found through the survey related to the knowledge of students, as elementary math teachers were more in favor of ability grouping than elementary science teachers (Banilower et al., 2018). When asked about how prepared the teachers felt in their knowledge to teach math and science, the majority of those surveyed reported that they felt very well prepared for math while most were only somewhat to fairly prepared for science instruction (Banilower et al., 2018). Breaking down that preparedness by content area, most teachers felt very well-prepared to teach all topics of math, while the science topics greatly varied by discipline showing more disparity in preparation for that content area (Banilower et al., 2018). When looking at pedagogical moves, teachers reported a greater capability to foster student thinking and use intentional strategies in math than science (Banilower et al., 2018). In regard to professional development opportunities, teachers spent more time overall and more frequent time on math than science; some teachers having
never completed any science professional development (Banilower et al., 2018). In the classroom, double the daily time is spent teaching math over science (NASEM 2018, 2022).

The Banilower et al. (2018) and NASEM (2022) reports show that teachers tend to have greater subject matter knowledge and preparation in one content area over another. This suggests that what and how much these teachers know about each content area is different; therefore, their ePCK will vary. For example, the highly tested content area of math is emphasized more than science in preparation and instructional time given (NASEM, 2022). This would lead to the result in a teacher’s subject matter knowledge and, in turn, ePCK having differing qualities in math compared to science.

**Previous Research with Enacted Pedagogical Content Knowledge**

Research on ePCK is recent and developing; it is a relatively new concept. Studies completed with a focus on ePCK in science education generally date within the past 10 years (Alonzo & Kim, 2016; Amador et al., 2022; Barendsen & Henze, 2017; Bismack et al., 2021; Coetzee et al., 2020; Hanuscin et al., 2018). Before then, ePCK was not coined as an important or specific PCK term (Hume et al., 2019). While this model has been used theoretically, it has not been explored much empirically.

Most of the studies conducted on ePCK have focused on what teachers say they know or what tests show that they know. Amador et al. (2022), Bismack et al. (2021), Coetzee et al. (2020) and Hanuscin et al. (2018) all completed studies on ePCK and its components outside of the classroom context. They looked at the planning or reflection phases of teaching but not the actual act of instruction in the classroom. Only recently have a few studies begun to bridge the missing gap of studying in the classroom, but they did not lend much to the literature due to inconclusive findings (Alonzo & Kim, 2016; Barendsen & Henze, 2017). By missing the
classroom context of ePCK, researchers cannot fully understand how the teacher’s knowledge affects actual instruction with students present. Without that classroom context, ePCK studies idealize the complexities of teaching; it is difficult to grasp a full picture of a teacher’s ePCK in actual practice. This lends to the conclusion that more research needs to be completed in the context of an actual classroom for teachers to show a complete picture of what they know.

Some researchers have explored the idea of comparing a teacher’s ePCK in one content area to their ePCK in another. One specific study grounded in the Refined Consensus Model framework was conducted by Coetzee et al. (2020). This was a case study involving three pre-service science teachers in their last year of schooling in South Africa. The pre-service teachers were observed, interviewed, and completed written responses based on content representations. The study specifically investigated “how the pre-service teachers translated the knowledge taught during training into practice” (Coetzee et al., 2020). It showed a correlation in the depth of the teachers’ ePCK with their subject matter knowledge. As the teachers’ subject matter knowledge grew, their ePCK was richer because the teachers could focus on implementing their pedagogical knowledge (Coetzee et al., 2020). This author also asserted with the findings of their study that ePCK may not transfer from science discipline to science discipline or even content area to content area. It may be specific to the topic and context at hand (Coetzee et al., 2020).

In contrast, Amador et al. (2022) compared two content areas in an effort to discover differences between a teacher’s ePCK for both with how teachers used student representations, students sharing ideas, and assessments. This study involved 11 first-year teachers and their planning and teaching math and science. The data collected included the teachers’ preparation through their lesson plans and researcher’s field notes, classroom observations, and interview
transcripts. The study found little difference in the ePCK of math and science suggesting that teachers’ ePCK transferred between the two content areas.

The limited and contradictory findings from both studies indicate the need for further research to test the transfer of ePCK among content areas. Most discussion surrounding PCK transfer to this point has been focused between the levels of PCK on the Refined Consensus Model, such as between collective and personal PCK (Carlson et al., 2019).
CHAPTER 3

Method

In this study, I seek to answer the following research questions:

1. How are ePCK components evidenced in this classroom context?
2. What ePCK components transfer between my math and science instruction?
3. What elements of the ePCK components transfer between my math and science instruction?

To answer these questions, I conducted a qualitative self-study that focused on observations, guided reflections, and journaling as a means to learn about teachers’ ePCK in a real classroom context (Pinnegar & Hamilton, 2009). Being a teacher, I regularly look for ways to improve my personal practice. Identifying elements of ePCK components that transfer from one content area to another can boost my knowledge and practice in both content areas. In order to learn more about what I know personally, a self-study methodology best fit the study needs as it is a reflective process of what I am already doing (Hamilton & Pinnegar, 2015; Pinnegar & Hamilton, 2009). I know my knowledge the best, so the most efficient and accurate way to ascertain my ePCK was to study myself (Hamilton & Pinnegar, 2015; Pinnegar & Hamilton, 2009). A self-study also fits this the research as the focus is studying knowledge. If the researcher is also the participant, the ability to infer the participant’s knowledge gets closer to that knowledge.

I expected that the three ePCK components would be readily noticed through my interactions with my students during the lesson. I assumed that my subject matter knowledge would show through my accuracy in explaining the contents of both the math and science lessons. I assumed that knowledge of students would present through the way I interacted with
the different students in my class and gave them the individual attention they needed. I also assumed that pedagogical knowledge would be evident in the mechanics of the lessons for both math and science and that pedagogical knowledge would be the teacher knowledge component observed most in a classroom. I assumed that pedagogical knowledge would be the most observed component because, as a generalist elementary school teacher, I draw on this component frequently (Hanuscin et al., 2018; Mulholland & Wallace, 2005; Nixon et al., 2016; Sanders et al., 1993). With the last research question, I expected that the most elements of the ePCK components would appear in pedagogical knowledge, as it includes so many facets of knowledge and can be presented in a variety of ways. I suspected that knowledge of students and pedagogical knowledge would transfer between math and science, and subject matter knowledge would not transfer between math and science.

**Participant**

For this study, I analyzed my own practice and knowledge. I am a fifth-grade teacher in Utah County who teaches both math and science regularly through the school year. This is my fourth year teaching and the only grade I have taught.

As is common for elementary teachers, I have more teaching experience and coursework related to math than science. I teach math every day for at least 50 minutes and science two to three times a week for 30 minutes at a time. My teacher preparation program in college required three math courses and only one science course. Because of this emphasis on math, I feel like I have more strategies related to math instruction and more subject matter knowledge for that content area. In regard to science preparation, I have personally sought out science professional development to improve my own knowledge of the content area, both instructional practices and subject matter knowledge.
My math instruction follows my district’s chosen curriculum with supplemental materials that increase practice with our learning targets. My grade level team uses the curriculum to develop our own scope and sequence according to our students’ learning needs. As a team, we give common assessments but teach each lesson according to our own teaching styles based in the district curriculum program.

Science instruction is left to my discretion. The district provides access to a website that has videos and activities for each core topic, but there is no set curriculum. Through my teacher preparation science course and other science professional development opportunities, I have learned that the 5E instructional model is an effective teaching practice (Duran et al., 2011) and I try to utilize this model, and related inquiry-focused strategies, to encourage thinking and exploration of science topics. I cannot always follow an inquiry-based model of teaching science, however. With the school schedule focused on literacy and math, science becomes a content area that I can only teach two to three times a week, time permitting. The separation of instructional days within the content area creates a disconnect that limits potential investigations I could feasibly conduct with my class. I tend to fall back on the prepared videos and activities provided by the district’s resource.

**Data Sources and Procedures**

After IRB approval was obtained, three data sources were used for this study: video observations, guided discussions, and journals (see Appendix A). The first data source was six 30-minute video-recorded observations of my math and science instruction (Roth et al., 2011). I selected 3 days within one math unit and 3 days within one science unit for these 30-minute observations to take place; having all lessons for one content area within a single unit ensured that a change within content areas content did not affect the outcome. In order to compare my
ePCK in math and science, I also chose lessons in similar stages of the units. Both the math and science units were nearing the end so my instructional purposes were to solidify concepts previously introduced. By using a Swivl set up, the video and audio recordings were focused on me as the teacher. Videos were transcribed for analysis through a transcription service.

The second data source was three guided discussions that followed an inquiry protocol corresponding with the video observations. Before beginning the discussions, I selected a trusted colleague who watched and talked about the video observations with me. The trusted colleague is a member of my grade-level team with whom I already have a relationship around mutual professional development. We frequently discuss our own teaching practices, which allowed greater vulnerability and open discussions about the six video observations. To ensure the trusted colleague was informed about ePCK, I provided information and training about each ePCK component as that was the focus of our discussion. The trusted colleague and I watched the six video observations together and identified moments where ePCK components were present. We had guiding questions that elicited my reasoning for various actions within the classroom (see Appendix B). These questions were developed from other studies that employed interviews to study PCK (Alonzo & Kim, 2016; Chan & Yung, 2015; Coetzee et al., 2020; Hanuscin et al., 2018). I used the questions from their protocols to create my own guiding questions in addition to my own questions that encouraged focus on ePCK components. This helped me be more aware of my own enacted knowledge. Recordings of the guided discussion were transcribed for analysis through a transcription service.

The third data source was a research journal I kept during the course of the study. After each of the recorded observations, I wrote my own thoughts about my ePCK as I reflected on the
lesson. I journaled specific things I did and my thoughts about what happened and why. The journal helped me reflect on my own enacted knowledge in the classroom.

**Data Analysis**

All three data sources were coded in an iterative process. I led the coding process, with input from my chair. The analysis began with a priori coding (Creswell & Creswell, 2018). Because I was looking for evidence of the ePCK components, I created a priori codes related to knowledge of students, pedagogical knowledge, and subject matter knowledge. Within each of these categories were more specific a priori codes related to various facets of the ePCK components. I began coding each data source with my chair and completed the coding process independently.

After this initial phase of coding, I noticed that pedagogical knowledge had more occurrences than the other components. The high occurrences of pedagogical knowledge prompted further investigation of the data coded as “Classroom Management” and “Teaching Strategies.” We began a second stage of inductive coding to identify patterns within these codes (Creswell & Creswell, 2018). In this stage, we identified emergent codes (see Appendix C).

Once coding was completed, I compared the data coded for math and the data coded for science in each of the Classroom Management and Teaching Strategies categories. To do this, I displayed the math data for a single code side-by-side with the science data for that same code. From there, I looked for similarities, differences, and evidence of my knowledge. Specially, I was looking for common phrases, phrasing, and routines. Next, common themes in the codes were identified (Creswell & Creswell, 2018). Presence of similarities in both math and science suggested that that the ePCK components and elements of ePCK components had transferred.
Limitations

One limitation of this study is the number of lessons observed for each content area—three lessons for math and three lesson for science. Three lessons in each content areas may only provide a snapshot of my ePCK and may not be representative of a full teaching repertoire.

Another limitation is inherent of self-studies. As I was analyzing my own knowledge, I found it hard to recognize what I do not know. This makes the research only focus on what I do know and skews the findings to see only what elements of ePCK components are present in the findings and not what could be missing. To attend to this limitation, the inclusion of a trusted colleague helped mitigate some of that skewed focus. Additionally, the insertion of personal dispositions that emerged as I looked at the data may have biased my interpretations. Although there are limitations to a self-study, there are still advantages that outweigh the disadvantages. For example, it is easier to write about a knowledge that a teacher has if the teacher is the researcher as they know what their knowledge is.

A last limitation found in this field of study is the nature of looking at enacted knowledge. One cannot make a straightforward judgement about knowledge from action because of the reliance on inferences (Alonzo & Kim, 2016; Cochran et al., 1993; Hume et al., 2019; Mitchell et al., 2014). Those inferences can inform a study’s conclusions, but there is a margin of error between actual knowledge and inferred, researched knowledge. Therefore, studying ePCK, as a theory, does not concretely capture all the nuances of teacher knowledge.
CHAPTER 4

Findings

In this section, the findings are described according to the research question with which they correspond. The data is labeled according to the source and the day out of three. For example, if the data is from the recorded math lesson on Day 1, the data would be labeled “Math Video Day 1.” If the data is from the conversation with my trusted colleague in which we watched both the math and science lessons from Day 2, the data would be labeled “Conversation Day 2.” If the data is from the journal after my science lesson on Day 3, the data would be labeled “Science Journal Day 3.”

Research Question 1

The first research question is as follows: How are ePCK components evidenced in this classroom context? Through the data, ePCK was evident in my classroom through the presence of the three components: subject matter knowledge, pedagogical knowledge, and knowledge of students. Below, I will describe ePCK evident in the math lessons followed by ePCK evident in the science lessons.

Math

The math lessons studied occurred at the end of the unit about dividing decimals. We had been through a variety of strategies to solve decimal division problems—partial quotients, repeated addition, long division, area models, the box method—and were at the point of solidifying their chosen method through discussion and practice. We also were relating the decimal division problems to visual representations through models. The first lesson observed for this study was discussion based. I gave the students a few problems to work in whatever method they wanted and then had a few selected students present their method to the class.
talked about the similarities and differences of the methods before working in partners for more practice. The second lesson was more direct instruction with students following along with their own assignments. We were drawing and labeling models of decimal division by coloring groups on a hundred grid. The students then had time to practice in partners while I worked with a small group. The last lesson consisted of center rotations. I split the class into three groups, each with an individual task. I took one of the groups as a small group to provide more explicit instruction to students who were struggling with the concept. We worked a problem together in two ways and talked about advantages of using one method over another. The other two groups were continuing their practice from the previous days and working on online modules for decimal division.

Subject matter knowledge is present through the lessons as I taught students how to divide decimals accurately. My competency allowed me to guide them through the process by either telling them directly how to divide or asking them questions that led them to the process for themselves. Subject matter knowledge was evidenced as I taught students about the conceptual understanding behind division.

This problem shows us two ways we can look at division. The first way we can look at putting things into equal groups. The second way is taking the raisin and we’re putting the same amount per box. We don’t know how many boxes we’re gonna need. So those are two ways to look at our division problems. (Math Video Day 1)

Pedagogical knowledge is present in the math lessons through the instructional practices I employed each day. This knowledge is displayed through the teaching strategies and classroom management I used. One specific example comes from my use of questions as a teaching strategy to prompt student thinking: “What other similarities or differences do you see between those
two?” (Math Video Day 1). This strategy could be used in any content area and, as such, would be considered pedagogical knowledge instead of PCK.

Knowledge of students is present in the math lessons through interactions with my students as well as what I know will help them focus on learning. One example of this is noted in the guided discussion: “Some of my kids, I usually either scatter through the class or keep closer to the front with me” (Conversation Day 1). This shows that I know that individual students need to be in different areas of the room in order to pay attention to the instruction.

**Science**

The science lessons occurred at the end of our ecosystems unit, so we were solidifying the ideas of creating food chains. The first day, I gave each table a set of cards that consisted of a unique ecosystem different than the rest of the class’s cards. I instructed each table to categorize the cards any way they wanted. As they worked, I went from table to table asking them guiding questions that highlighted their reasoning and led them to think of the vocabulary we had learned in the unit—producer, consumer, decomposer, and food chain. Some groups made the connections faster than others, but each table had their own unique grouping. We then compared and contrasted how each grouping was similar/different than the rest. The second day, I gave each table a different set of cards than the day before and instructed them to use the cards to make connections with the cards, leading them to create a food chain as we had discussed the day before. We then did a gallery walk through the classroom for each table to see the other connections throughout the class. The last lesson was project-based learning. I introduced an assignment to students that they could do with a group or on their own and then assisted them as they worked on it. Their task was to select any ecosystem they wanted, research animals and
plants that live in that ecosystem, and create a food chain based on their research. They could choose from a variety of modes to present their food chain.

Subject matter knowledge is present in science as I had activities that focused on the learning targets. It is also present as I asked students questions that directed their thinking to the vocabulary and food chain concepts. As stated in the notes after the first science lesson, “My focus was talking through how food chains/webs connect and the flow of energy and the sun” (Science Journal Day 1). This shows I know what my students need to learn for this unit.

Pedagogical knowledge is present through science in the teaching strategies and classroom management techniques I use through my science teaching. One demonstration of this knowledge comes from a comment I made to a student when asked why we work in small groups so often: “Because you learn more when you talk and you can’t just talk to yourself. You gotta talk to the people around you” (Science Video Day 2).

The last component, knowledge of students, is evident through my knowledge of what students need throughout a lesson to stay engaged in learning. In the second lesson, my students were starting to lose focus after working on connecting their cards for so long, so I had them do a gallery walk as a result—“I think this was good as it got them out of their seat and engaged with what other people in the class were doing” (Science Journal Day 2).

**Research Question 2**

The second research question is as follows: What ePCK components transfer between my math and science instruction? Related findings will be reported by ePCK component: knowledge of students then subject matter knowledge.

As evidenced by the number of occurrences in the data, knowledge of students transferred (127 occurrences) and subject matter knowledge did not transfer (40 occurrences).
between math and science instruction. Due to the high number of occurrences for knowledge of students and the similarities in which the occurrences appeared in both math and science, knowledge of students transfer is implied. Due to the low number of occurrences for subject matter knowledge and the differences in the occurrences for both content areas, lack of subject matter knowledge transfer is suggested.

*My Knowledge of Students Transfers Between Math and Science*

As an elementary school teacher, I have my same 31 students all day long, for all content areas. Because of this, the knowledge I have about them—their backgrounds, their specific circumstances, their needs, their accommodations, their personalities, etc.—was seen to transfer across content areas. While their needs may be different from math to science, they are still the same students, and what I know about them does not change.

My knowledge of the students in my class does affect how I teach and approach different content areas. A specific example occurs in math instruction as observed through the discussion with my colleague after watching the video observations together.

And like going with like [student] … if you don’t give him that validation of understanding, he’s gonna lose it. He’s gonna get upset, which is gonna not just derail his learning, it’s gonna derail everybody’s learning. So knowing that, ‘Okay, I can either get mad at him being out of a seat to come talk to me without giving permission. Or I can just validate his learning, have him return.’ (Conversation Day 2)

This shows that I know how to approach situations based on what I know about my students and the content area I am teaching. I know I need to handle situations like the example a certain way in math, while my knowledge of this student in science is that they do not need the extra attention to focus their learning. This is evidenced in the discussion when my colleague asked
about the same student needing validation in science. My response was, “It’s mostly just math. I feel like math is, it’s more like, this is the final answer. And so he’s more focused on the answer, not the process to get there” (Conversation Day 2).

My Subject Matter Knowledge Does Not Transfer Between Math and Science

My knowledge of content was not seen to transfer between math and science. No codes in the area of content were found in both content areas. In math, subject matter knowledge is focused on decimal division. This did not appear in the science lessons. Likewise, science subject matter knowledge, focused on food chains, did not appear in math lessons.

Research Question 3

The third research question is as follows: What elements of the ePCK components transfer between my math and science instruction? These findings focus on the component of pedagogical knowledge, as this was the most observed ePCK component in the data. Findings will be reported by themes arising from the analysis. Due to the high occurrence of the pedagogical knowledge component—385 occurrences—the identified elements of the pedagogical knowledge component that transferred between math and science included knowledge of classroom structure and student content thinking.

My Knowledge of the Importance of and Ways to Establish Classroom Structures Transfers Between Math and Science

From this analysis we see evidence of my knowledge of the importance of classroom structures, and how to establish them, in both math and science. These data demonstrate my knowledge that students need a consistent class routine and order in the classroom. I observe this in the data in three ways. First, I set up lesson expectations in a variety of similar ways for both content areas. Second, I use the same routines and patterns for calls for class attention in both
math and science. Lastly, I use knowledge of managing a large class size similarly between both content areas.

One way I observed my knowledge that classroom structures provide consistency and order for my students is in the way I set up lesson expectations. That knowledge was observed in the findings in the way I set up directions for students both at the beginning and during a task as described in the following data.

My knowledge of structure in the classroom is highlighted through examples of starting class instruction by previewing student tasks in both math and science instruction. Before beginning a new task, I give an overview of that task in both math and science. In math, I say, “Here’s what we’re going to do. I’m going to give you some practice where I’m going to give you your own page with ones like this” (Math Video Day 2). In science, I say, “As we look at the pictures, I want you just to look with your voices off. Okay? So we’re not gonna make any observations out loud yet” (Science Video Day 3). The instructions at the beginning of the task shows my knowledge of classroom structure through using established routines as I start each activity the same way.

My knowledge of classroom structure through routine and order is also evident through the way I give specific directions to students and have them repeat the directions throughout the lesson. This is present in both math and science instruction. I specify how I want students to answer questions with the same phrase in math and science—“by the raise of hand” (Math Video Day 2, Science Video Day 1). Using the same phrase in both content areas gives students the expectation that I am looking for a specific way they need to answer, thus showing that I know students need a consistent routine from content area to content area as a way of furthering their learning readiness. Another way I do this is by having students repeat the instructions to a
neighbor or the class. For example, in math I say, “Tell the person sitting next to you, what group are you in?” (Math Video Day 3). In science, I have students repeat the instructions and then repeat other students who rephrased the instructions—“Who can tell me what [student] just said?” (Science Video Day 3.). This shows my knowledge of students repeating instructions to ensure understanding as part of our structure and highlights my knowledge of using consistent routines from content area to content area.

Another way my knowledge of the importance of classroom structure is visible is through the use of classroom calls for attention, such as counting down. Counting down is a frequent strategy I use as a call for class attention. In both math and science, I use the exact same phrasing, “All right. And back to me in three, back to me in two. Back to me in one” (Math Video Day 2; Science Video Day 1). Because I use this phrasing consistently through both math and science, my students know the structure of the call as they should have their voices off and be ready for instructions by the time I reach zero. The structure stays consistent so that the students know what to expect. My knowledge of using the same routine from content area to content area to prepare student learning is highlighted through this example.

The last way my knowledge of the importance of classroom structure is evidenced is through the use of student groupings. Smaller groups give students more accountability and personal attention to increase their learning. This is seen in math as I say, “You need to be with whatever group you need to be in” (Math Video Day 3). In science, I say, “[Student], if you wanna come join [these two students] you can. [Student], come join this table right here” (Science Video Day 1). My knowledge is displayed as I made sure that each student had other people to work through their tasks. It shows that in both math and science I know that smaller group work is beneficial for learning than constant whole group instruction.
My Knowledge of Student Thinking about Content as a Key Component to Learning Transfers Between Math and Science

From this analysis, my knowledge of student thinking about content as a key component to learning is evident in both math and science instruction. More specifically, the data shows that the strategy of paying attention to student thinking in order to encourage student learning transfers; the data related to each of these points will be described below.

One way I attend to student thinking is by checking my students’ understanding of lesson content and class directions. This is used when I do quick surveys with my class to ascertain their understanding of concepts we are learning, confidence levels in skills, or understanding of directions. Through checking for understanding of concepts in math and directions in science, I am paying attention to what the student is thinking as I gauge if they are understanding what we are learning, if they need extra support, what they need to fully grasp the learning, or if I need to clarify lesson expectations. In math, I use a quick assessment that allows the students to communicate on a one to five scale with their fingers which lets me know their understanding of the concept we are learning. I ask them to hold up their number as I do a scan of the room to see who still needs help and who feels like they understand. An example of this checking for understanding looks like the following:

Give me a one through five with decimal division. How you feeling? A five. You could teach a college course on this. You can explain it to anyone. Help them through the process. A four is, you can do it yourself, but maybe can’t explain it quite yet. Four. A three is, it’s starting to make sense. Maybe you need some more practice, some more help with it, but you can kind of do it. A two is, you know that we’re doing math right now. A
one is, you think this is the best PE lesson we’ve done all year long. Gimme one through five. (Math Video Day 1)

In science, I do these same one to five finger scale checks but they are focused on students’ understanding of directions, such as “How’s it going over here? Do you have any questions? Need any help?” (Science Video Day 3). Both of these instances demonstrate my knowledge that being mindful of student thinking is a key aspect of learning, although the focus of the checks is different in math versus science. This may imply that checking for understanding may not transfer directly from one content area to another due to the difference in purpose for each.

Another way my knowledge of attending to student thinking appears is in efforts I make to help students make connections across lesson content. This occurs when I allude to previous concepts/lessons or when I preview upcoming material. The connections are either made to remind students to use previously learned skills or to build upon concepts from the lesson before.

For example, in math, I say, “Okay, think back to the problem that we did last week with the yarn we stretched out” (Math Video Day 1). Similarly in science, I use phrasing that calls students to think about concepts we have already learned to complete the new task at hand: “We talked a little bit about [the definitions] yesterday, as well as before when we were doing science in here. See if you can remember what they mean” (Science Video Day 2). In math, I do this at least once in every lesson, while in science, there is evidence of connecting across lessons in two out of the three instructional observations. Connecting across lessons shows my knowledge that it is important to build student thinking upon itself by referencing concepts students have already mastered in order to build new, deeper knowledge on that topic. This demonstrates my knowledge of student thinking as a key component to learning.
My knowledge of student thinking about content as a key component to learning is evidenced through being open to multiple ideas. One way I show this is through taking cues from the students through the lessons. As I notice different work produced by individuals, I highlight their strategies in both math and science as ways to prompt other students’ thinking. In math, I have students write different methods for solving a problem on the board:

[Student], will you do that on the board? What method do you use? Box method. [to next student] Will you do it on the board? All right. [to class] We’re gonna take about 30 more seconds to finish up and then we’ll look at some strategies that we’ve done on the board.

[Student], will you do this on the board? (Math Video Day 1)

In science, I notice a group using a work strategy that I have not told them to use and mention it to the class as a way to organize their thoughts:

Alright, everybody pause. Hands up. Freeze. We’re gonna keep going, but one thing that I’m seeing some people do, um, is this table is using their markers to write down the different categories as they come up with them. So there might be an idea to help you keep track of what your categories are. (Science Video Day 1)

Both of these examples are unplanned reactions to things I notice about my students’ thinking. Because I know it is a key part of learning to pull out student thinking, I take their lead and highlight excellent examples of thinking I see in each lesson.

Another way I show how being open to multiple ideas as evidence of knowing about student thinking about content is through phrases I use in both math and science to not constrain student work strategies. In math, I say,

Again, the strategy that you use is whatever is making the most sense to you. You can use a picture, you can use a long division, you can use partial quotient, you can use the box
method. If there’s another method that makes more sense to you, use that. (Math Video Day 1)

In science, I say, “You’re gonna get some cards. I want you to categorize them. I’m not gonna tell you a category to use. You can use whatever is going to make sense for your table” (Science Video Day 1). In each lesson, the premise of my comments is not to constrain student thinking to one way of solving the tasks. The variety of strategies I use in each instructional period opens the class’s thinking to different avenues of thought that would not have resulted otherwise. This shows that I know being open to multiple ideas produced by students allows them to deepen their thinking more than being told one correct way to complete a task. My knowledge of student thinking is highlighted as I am focused on student produced ideas over my own teacher ideas.

The use of questions is another demonstration of my knowledge of student thinking about content as a key part of learning. Through both math and science instruction, I rely on questions to advance the lessons and prompt student thinking. One way I use questions is through comparing various class strategies. By looking at different ways to approach tasks, I am opening the students’ thinking to the idea that there are multiple ways to approach a problem, with no one way being the only correct solution. I use similar questions in both math and science instruction to help me prompt this student thinking. In math, I say, “What other similarities or differences do you see between those two?” (Math Video Day 1). In science, I say, “What do you notice? What are some similarities? Some differences. What, um, were the different categories they used? Did you think the same thing? Did they have something different?” (Science Video Day 1). Both question examples have similar phrasing and are aimed at the same idea—find the commonalities and differences in example tasks. Questions like this showcase my knowledge that students talking and answering questions furthers their thinking more than being told an
explicit answer. My knowledge that student thinking is key to learning is brought forward as questions focus on student thought over teacher thought.

The way I group students to encourage student talk is also evidence of my knowledge of student thinking as important to learning. This strategy shows that I know how different sized groups can affect how actively students are thinking about tasks and how to approach student thinking based on the group size. At least once in both math and science instruction, I have students participate in a small group discussion by turning to the people at their tables. In math, an example of this is “Tell the people at your table, what did you do to solve this problem?” (Math Video Day 2). In science, an example of this is “Tell the people sitting at your table, what does every food web or food chain begin with?” (Science Video Day 3). Because I know my students are more willing to participate if it’s a smaller audience, the smaller sized table group allows them to share more of their thinking and engage in the tasks rather than be passive learners. By using the smaller group settings frequently through instruction, I show my knowledge of how student thinking is influenced by the size of the instructional group.

The last way that I demonstrate my knowledge of how student thinking about content is a key component of learning is the use of student talk through instruction. Student talk refers to when students share their thinking out loud through explanations, questions, and discussions. My knowledge of this aspect is especially demonstrated in this statement I make to a student when asked why we kept working in groups: “Because you learn more when you talk and you can’t just talk to yourself. You gotta talk to the people around you” (Science Video Day 2). An example of this in math instruction occurs as I give students time to think and then talk to their table groups before sharing with the whole class: “By the raise of hand, who can tell me what they talked about with their table?” (Math Video Day 1). An example of this in science
instruction allows students to synthesize their own thinking with that of a partner’s: “Who can tell me something really cool that their partner said?” (Science Video Day 2). This shows how I know that learning is enriched through discussion with other people as we learn from each other’s ideas. The quotes also show that I know that student thinking is better processed when talked about out loud.
CHAPTER 5

Discussion

This study adds to the few that have been conducted in the teaching phase of ePCK in an effort to explore teacher knowledge in action (Alonzo & Kim, 2016; Barendsen & Henze, 2017). It aims to better understand the transfer of ePCK between math and science instruction for an elementary teacher. Most discussion surrounding PCK transfer to this point has been focused between the levels of PCK on the Refined Consensus Model, such as between collective and personal PCK (Carlson et al., 2019). In contrast, this study focuses on transfer between content areas (math and science) within one level, ePCK. Few studies have been conducted on ePCK, and even fewer studies have looked at comparing ePCK between content areas (Alonzo & Kim, 2016; Amador et al., 2022; Barendsen & Henze, 2017; Bismack et al., 2021; Coetzee et al., 2020; Hanuscin et al., 2018). Specifically for elementary school teachers who teach multiple content areas, this study is important as ePCK transfer between content areas can enrich the instruction and teacher knowledge of each area.

The findings suggest that there are elements of ePCK components that did transfer from one content area to another. This corroborates research from Amador et al. (2022) who found there was little difference between the ePCK of science and math, indicating transfer between content areas. In contrast, however, the findings of this study contradict another study that found no transfer of elements of ePCK components between content areas (Coetzee et al., 2020). As ePCK is dependent on the context, I speculate that the differences found in this study compared to Amador et al. (2022) and Coetzee et al. (2020) may be due to the context of each teaching situation—country, grade level, self-study versus outside researcher, and the focus of each study specifically. ePCK refers to the enacted knowledge that is evident in a specific moment of
teaching (Carlson et al., 2019). As details of the context change, the enacted knowledge also changes. Therefore, studies in different contexts show different enacted knowledge. Nevertheless, the contradiction of findings between the three studies calls for more research to be done.

As seen through the previously stated studies, varying contexts may have an effect on the findings of ePCK research (Amador et al., 2022; Coetzee et al., 2020). Within the same classroom, there could be varying contexts affecting ePCK transfer. The time within the school year, for example, could affect a teacher’s knowledge of students. Earlier in the year, their knowledge of students for that group of students may not be as developed as towards the end of the year. The stage of the units being taught could affect the pedagogical knowledge a teacher enacts, because lessons earlier in a unit may engage different pedagogical knowledge than lessons later in a unit. The topics being taught in two content areas may lend themselves to subject matter knowledge transfer better than other topics in the same content areas. Overall, the findings of this study in conjunction with Amador et al. (2022) and Coetzee et al. (2020) suggest that context is key when studying ePCK transfer.

As these findings suggest, some ePCK components did transfer from one content area to another and others did not transfer. My knowledge that classrooms need structure as a way for students to prepare for learning is an element that speaks to pedagogical knowledge. My knowledge that student thinking is a key component of learning is an element that speaks to PCK. My knowledge of the students in my class is an ePCK component that corresponds with knowledge of students. Finally, knowledge of content is an ePCK component that corresponds to subject matter knowledge.
My knowledge of structure connects to classroom systems that I have implemented the current school year and years past. The findings show that the routines I use through both math and science lessons are consistent across content areas and across the different instructional days observed. My enacted knowledge in those moments is drawing on what established behaviors I already have in place in my classroom with structure. These routines show that I know that students need consistency as it helps them focus on learning and builds our classroom culture.

My knowledge of student thinking relies on past teaching experiences and my knowledge of what encourages student thought about content. The enacted knowledge present in the findings is not knowledge that I gained from books or professional development; it is knowledge that I have enacted in the past and know works with students to encourage thinking. Therefore, my present ePCK is a result of past ePCK. As I have gained enacted knowledge, the knowledge that I developed through my teacher preparation program, teacher self-reflection, and studying on my own was transformed; I saw how different knowledge enacted is from knowledge studied. You do not know how to handle different teaching situations until you have experienced them and developed the enacted knowledge to know how to handle them.

When I am teaching in the moment, the knowledge I enact is based on my past experience compared to knowledge that I have planned and reflected. Enacted knowledge draws on different knowledge bases than the planning or reflective knowledge. Anyone can state what they know from study, but putting that knowledge into action calls for a different source of knowledge—experiential knowledge. Coetzee et al. (2020) found this to be true with preservice teachers who could not access their ePCK as they did not have experience in the teaching contexts yet.
Knowledge of Students

As I expected, knowledge of students was present in my classroom and did transfer between math and science. The findings show that my knowledge of students transfers from content area to content area as I had the same students for both content areas. The nuances of the knowledge may be different based on the content area, but the students are the same. For example, what I know about a student’s home life is the same knowledge no matter if I am teaching math or science. My knowledge of that student and how it affects their learning is the same (Abell, 2007; Bullough, 2001). As that knowledge is the same, that suggests knowledge of students transfers.

An implication of knowing that knowledge of students can transfer from one content area to another provides an increased importance for a teacher to get to know their students. A teacher knowing how a student is physically, mentally, and emotionally coming to school is better able to address the student’s learning needs that day. They can adjust the lesson for any content area based on student need to increase the student’s learning (Carlson et al., 2019; Chan & Hume, 2019). This is a particular strength for generalist elementary teachers. Having the same students all day long, for all content areas allows them to use their knowledge of students in the various content areas they teach. If a teacher knows them in math, they will also know them in science. The consistency of students also helps elementary teachers build routines and improve their pedagogical knowledge as the students know the expectations since they do not typically change content area to content area.

Subject Matter Knowledge

As I expected before beginning this study, subject matter knowledge was present in both content areas but did not transfer between math and science. Content areas are different in
content matter one from another making a teacher’s subject matter knowledge inherently different from math to science. Similar to the findings of Coetzee et al. (2020), I found that this ePCK component did not transfer because subject matter knowledge is too specific to each content area. This implies that a teacher has to spend time in each content area to learn for themselves the material they are teaching in order to increase their subject matter knowledge. Typically, they do not learn the content in one area and then transfer it to another. For myself as a teacher, I need more time to strengthen my science subject matter knowledge specifically, as that ePCK component does not transfer over from my math ePCK. Likewise, teachers in general do not transfer their subject matter knowledge of a specific content area to any given other content area; they also need time to strengthen that ePCK component individually by content area as suggested by Banilower et al. (2018).

One factor that may account for subject matter knowledge not transferring between math and science could be the context of the lessons. The focus of my math lessons was solidifying strategies for dividing decimals. The focus of my science lessons was creating food chains in various ecosystems. Due to the difference in content, transfer was more difficult. If content focuses are more closely related, such as calculating a physics problem and solving math equations, transfer may be possible. The differences in contexts may account for the findings of this study as well as the contradictory results of previous studies done (Amador et al., 2022; Coetzee et al., 2020).

**Pedagogical Knowledge**

As assumed, I found pedagogical knowledge to be the component that occurred the most frequently. I did not, however, expect that pedagogical knowledge would present in the nuanced elements that initiated additional investigation. Through emergent coding of pedagogical
knowledge, my knowledge of structure and my knowledge of student thinking surfaced as unpredicted elements. This ePCK component provided the most interest to me as a researcher as these findings suggested that some elements of pedagogical knowledge transfer between math and science, while others do not. Like Amador et al. (2022), there were not many differences found between the presence of elements of pedagogical knowledge for math and science—the overall component was present in both content areas. However, I found that the way pedagogical knowledge presented varied slightly depending on the content area.

Like previous research, I relied heavily on my pedagogical knowledge throughout my teaching, no matter the content area (Hanuscin et al., 2018; Mulholland & Wallace, 2005; Nixon et al., 2016; Sanders et al., 1993). Reliance on pedagogical knowledge is a particular strength of generalist elementary school teachers. While content changes from area to area, the findings show that pedagogical knowledge was transferred from one content area to another and therefore suggests elementary school teachers who are generalist for content are specialists in pedagogical knowledge. This section details how my pedagogical knowledge in one content area is similar in the other content area, suggesting that this element of ePCK transfers. The findings also highlight how my knowledge of classroom structures helps me enact the same knowledge as I build consistent routines all day, no matter the content area.

The transfer of my knowledge of classroom structure between math and science provides consistency and puts learning first in both of those content areas. My students do not have to guess what to do in response to my actions because my actions are the same all day, with the same expected student behavior. When I finish giving students an expectation for what their physical space should look like, they have their physical space ready. Giving an overview of the lesson before jumping into instruction lets students know what to expect and what their job needs
to be during said instruction. When I use the same attention call of counting down or giving physical directions to follow, my students know that they need to be listening with all attention on me by the time I finish the call. Grouping students in different sized groups to better structure a large class of 31 allows each student to actively participate in the learning. Each of these examples of my knowledge were evident in both math and science in some form. The content area did not affect the use of this knowledge as it is a consistent structure throughout the entire day. This implies that knowledge transfers between math and science, which is helpful to both me as the teacher and students who thrive on routine.

**Pedagogical Content Knowledge**

The element of PCK that transfers from content area to content area is my knowledge of student thinking related to content as an important part of learning. I found that this element of an ePCK component transfers between math and science as it was both present and similar in the video observations, journals, and discussion with my trusted colleague. As seen through the evidence of my enacted knowledge in both content areas, teachers need to be able to teach the content through their knowledge of teaching strategies so that the students understand the concepts or skills being presented (Abell, 2007; Bullough, 2001; Cochran et al., 1993; Shulman, 1986). It only makes sense that student thinking is an important part of that process as it indicates whether or not students are learning. Amador et al. (2022) also found the value of students sharing their thinking as an important part of learning. The evidence of knowledge of student thinking suggests that this element does transfer between math and science. The specific evidences demonstrated through the teaching strategies I use allow me as a teacher to hone skills that may not be specific to one content area and therefore can benefit my ePCK in all content.
areas (Hanuscin et al., 2018; Mulholland & Wallace, 2005; Nixon et al., 2016; Sanders et al., 1993).

Checking for student understanding of concepts and instructions allows me to be more aware of what my students are thinking and therefore adjust as needed. As it was present in both math and science, checking for understanding is not limited to one content area. I can use my knowledge of that strategy in both content areas to ascertain student thought, which benefits both teacher and student.

Connecting lesson content, both past and future, allows students to make connections throughout units. As there was evidence of this in both math and science, the findings suggest that this element of my knowledge also transfers between content areas. The more I can connect student thinking about the content, the stronger their learning will be, making this element a useful transfer.

In both math and science, there was evidence of acknowledging student thinking through being open to multiple ideas, using questions in instruction, and allowing students the time to talk through ideas. The approach I used for each of those knowledge bases was the same for both math and science, implying transfer. These things transfer from one content area to another because they are basic good practice teaching strategies and improve student learning. As discussed in the Banilower et al. (2018), teachers reported more capability in knowing student thinking and using intentional teaching strategies in math than science, so this evidence of transfer can strengthen the weaker content area (Amador et al., 2022; van Driel et al., 2023).

**Future Research**

As previously stated, ePCK is a relatively new field of research with only a handful of studies focused on this aspect of PCK (Alonzo & Kim, 2016; Amador et al., 2022; Barendsen &
Most of these studies have also focused mostly on the planning or reflecting stages of ePCK and not on the classroom context. As there are so few studies on this topic, a call for future research to be conducted in the classroom teaching context is needed for continued ePCK development. As van Driel et al. (2023) stated, “We recommend more research in these areas, in particular, studies with a classroom teaching component that investigate how teachers enact and develop their knowledge in interactions with students, and how these practices impact on student learning … of science” (van Driel et al., 2023).

As more studies are needed on ePCK in the context of teaching in the classroom, I found that a self-study was an effective way to capture this knowledge. When studying knowledge, there is a margin of inference that has to be made by the researcher as to what a participant knows based on their actions (Cochran et al., 1993; Hume et al., 2019; Mitchell et al., 2014). If the participant is part of the research team, they can narrow the margin so that the inference is closer to the knowledge by providing context and justification for the reasoning and knowledge behind their actions (Alonzo et al., 2012). Another useful step in this study’s methodology was the journal and guided discussion with my colleague. While the final analysis did not draw heavily on those two data sources, they were helpful in synthesizing my own knowledge when I watched the video observations. I was able to relate back to the reasoning behind the actions during instruction which led to my knowledge.

More research is needed in the area of ePCK transfer as there is so little done. This study aims to help fill that gap by comparing ePCK transfer between content areas (Amador et al., 2022; Coetzee et al., 2020). As the existing findings from previous studies are contradictory, the studies on ePCK in the classroom also need to take into account the contexts in which the
knowledge is being studied. The variation of content area content, secondary versus elementary, and other changes in context could affect the outcomes. However, to fully understand how ePCK transfers or does not transfer across content areas, more research needs to be conducted.

Another area of research that requires more attention is ePCK related to generalist elementary school teachers. Most of the ePCK research at this point has been done on secondary teachers—especially secondary science teachers (Alonzo & Kim, 2016; Amador et al., 2022; Barendsen & Henze, 2017; Bismack et al., 2021; Coetzee et al., 2020). Elementary school teachers are in a unique context as most teach all subject areas. Researching this population could yield interesting findings related to each ePCK component.

Conclusions

Identifying elements of ePCK that can transfer is beneficial because it allows me as a teacher to concentrate on enhancing knowledge that benefits multiple subjects, rather than needing to learn specific details for each subject individually. While there are still elements of ePCK, such as subject matter knowledge, that are not able to transfer, my knowledge of teaching strategies as found in pedagogical knowledge and my knowledge of students transfers in a way that can strengthen my overall ePCK for subjects I may not spend as much time teaching.
REFERENCES


Chan, K. K. H., & Hume, A. (2019). Towards a consensus model: Literature review of how science teachers’ pedagogical content knowledge is investigated in empirical studies. In A. Hume, R. Cooper, & A. Borowski (Eds.), Repositioning pedagogical content knowledge in teachers’ knowledge for teaching science (pp. 3–76). Springer. https://doi.org/10.1007/978-981-13-5898-2_1


Coetzee, C., Rollnick, M., & Gaigher, E. (2020). Teaching electromagnetism for the first time: A case study of pre-service science teachers’ enacted pedagogical content knowledge.


APPENDIX A

Institutional Review Board Approval Letter

Memorandum

To: Ryan Nixon
Department: BYU - EDUC - Teacher Education
From: Sandee Aina, MPA, HRPP Associate Director
Wayne Larsen, MAcc, IRB Administrator
Bob Ridge, Ph.D., IRB Chair
Date: January 18, 2024
IRB#: IRB2023-352
Title: Enacted pedagogical content knowledge differences in science and math

Brigham Young University’s IRB has approved the research study referenced in the subject heading as expedited level, categories 6 and 7. This study does not require an annual continuing review. Each year, near the anniversary of the approval date, you will receive an email reminding you of your obligations as a researcher. The email will also request the status of the study. You will receive this email each year until you close the study.

The IRB may re-evaluate its continuing review decision for this decision depending on the type of change(s) proposed in an amendment (e.g., protocol change that increases subject risk) or as an outcome of the IRB’s review of adverse events or problems.

The study is approved as of 01/18/2024. Please reference your assigned IRB identification number in any correspondence with the IRB.

Continued approval is conditional upon your compliance with the following requirements:

1. A copy of the approved informed consent statement and associated recruiting documents (if applicable) can be accessed in iRIS. No other consent statement should be used. Each research subject must be provided with a copy or a way to access the consent statement.
2. Any modifications to the approved protocol must be submitted, reviewed, and approved by the IRB before modifications are incorporated into the study.
3. All recruiting tools must be submitted and approved by the IRB before use.
4. All data and the investigator's copies of the signed consent forms must be retained for at least three years following the termination of the study.
5. In addition, serious adverse events must be reported to the IRB immediately, with a written report by the PI within 24 hours of the PI’s becoming aware of the event. Serious adverse events are (1) the death of a research participant or (2) serious injury to a research participant.
6. All other non-serious unanticipated problems should be reported to the IRB within two weeks of the PI's first awareness of the problem. Prompt reporting is important, as unanticipated problems often require some modification of study procedures, protocols, and/or informed consent processes. Such modifications require the review and approval of the IRB.
Guided Discussion Protocol

❖ Research Questions:

1. How are ePCK components evidenced in this classroom context?
2. What ePCK components transfer between my math and science instruction?
3. What elements of the ePCK components transfer between my math and science instruction?

• Knowledge of Students
  o Tell me about what your group of students know coming into the lesson- ie misconceptions, background knowledge, etc
    ▪ What did I expect my students to know coming into the lesson and how did that match what I found out while I were teaching?
    ▪ What did I notice about what they know?
    ▪ What did I observe about their knowing?
    ▪ Talk about what anticipated thinking you expected from the students.
    ▪ “Are those fairly typical ideas that you get when you have students talk about their initial ideas?” (Alonzo & Kim, 2016)
    ▪ “Could you talk a little bit about why those were important ideas or what kids tend to get confused about?” (Alonzo & Kim, 2016)

• Reasoning behind their pedagogical moves (pedagogical knowledge)
  o I noticed in the video I did this. This is what I was thinking about when I chose to do that.
“Can you talk a little bit about how you interpret that student’s comment” and what did you do as a consequence? (Alonzo & Kim, 2016)

“Can you talk about why you chose [this specific student response] as an example?” (Alonzo & Kim, 2016)

“I noticed that you got the right answer right away from one of the students, and then you sort of put it out to alternatives. Could you talk a little bit about why you decided to do that?” (Alonzo & Kim, 2016)

“Did any unplanned incidents/unanticipated moments happen in the lesson? If so, what did you think when that happened? Why did you react the way you did?” (Chan & Yung, 2015)

“Was this activity/instructional strategy planned? How did you come up with that idea?” (Chan & Yung, 2015)

“What is your pedagogical decision of using this activity in teaching this concept? In what way is this strategy particularly useful in helping students to learn the concept you want them to understand?” (Chan & Yung, 2015)

“What influenced your choice to use this activity/strategy?” (Hanuscin et al., 2018)

**Subject Matter Knowledge presented**

- Explain the learning target of the lesson and how you would go about the learning as a student yourself.
- What’s important for students to know about this?
- How do these ideas in this lesson connect to this lesson and future lessons?
o “Do you have any insight into why that might be difficult for students?” (Alonzo & Kim, 2016)

o “Can you talk a little about what you hope to accomplish with this demonstration?” (Alonzo & Kim, 2016)

o “Can you talk a little bit about why that is an important point to make?” (Alonzo & Kim, 2016)

o “I was wondering if you could talk a little bit about your decision to include [this part of the curriculum] as part of the discussion?” (Alonzo & Kim, 2016)

o “What are you identifying in his comment that you through you might want to come back to later?” (Alonzo & Kim, 2016)

- **CoRe Questions**

<table>
<thead>
<tr>
<th>A. Curricular saliency</th>
<th>Key idea 1</th>
<th>Key idea 2</th>
<th>Etc.</th>
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</thead>
<tbody>
<tr>
<td>A1. What do you intend the learners to know about this idea?</td>
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<td>A2. Why is it important for students to know this?</td>
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<td>A3. What concepts need to be taught before teaching this idea?</td>
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<tr>
<td>A4. What else do you know about this idea (that you do not intend learners to know yet)?</td>
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<td>B. What makes a topic easy or difficult to understand</td>
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<tr>
<td>B1. What do you consider difficult about teaching this idea?</td>
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<td>C. Learner prior knowledge</td>
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<td>C1. What are typical learners’ misconceptions when teaching this idea?</td>
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<td>D. Conceptual teaching strategies</td>
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<tr>
<td>D1. What effective teaching strategies would you use to teach this big idea?</td>
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<tr>
<td>D2. What questions would you consider important to ask in your teaching strategy?</td>
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<tr>
<td>E. Representations</td>
<td></td>
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<tr>
<td>E1. What representations would you use in your teaching strategy?</td>
<td></td>
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</tbody>
</table>

Figure 2 from Coetzee, C., Rollnick, M., & Gaigher, E. (2020). Teaching electromagnetism for the first time: A case study of pre-service science teachers’ enacted pedagogical content knowledge. *Research in Science Education, 52*, 357–378. [https://doi.org/10.1007/s11165-020-09948-4](https://doi.org/10.1007/s11165-020-09948-4)
# APPENDIX C

## Data Analysis Codes

<table>
<thead>
<tr>
<th>A Priori Code</th>
<th>Emergent code</th>
<th>Definition</th>
<th>Example</th>
<th>Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge of Students</strong></td>
<td><strong>My students</strong></td>
<td>My knowledge of my students’ personalities, backgrounds, needs, etc.</td>
<td>“When he pays attention, he’s bright. He gets it right away and he cares if he doesn’t get it.” (Guided Discussion Day 3)</td>
<td>52</td>
</tr>
<tr>
<td><strong>What my students already know</strong></td>
<td></td>
<td>My knowledge of what my students know/understand about the content we are learning</td>
<td>“They understand normal partial quotients. They both got threes on their test.” (Guided Discussion Day 3)</td>
<td>24</td>
</tr>
<tr>
<td><strong>How my students are entering the lesson</strong></td>
<td></td>
<td>My knowledge of my students’ dispositions, attitudes, moods, focus, etc. as we start each lesson</td>
<td>“It’s also valentine’s day so excitement is high in the school.” (Journal Day 2)</td>
<td>14</td>
</tr>
<tr>
<td><strong>What my students need throughout the lesson</strong></td>
<td></td>
<td>My knowledge of how to adjust my lessons based on the needs of my students</td>
<td>“If you want extra help from me on this, we’re gonna come sit up here in the front.” (Math Video Day 1)</td>
<td>37</td>
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<tr>
<td><strong>A Priori Code</strong></td>
<td><strong>Emergent code</strong></td>
<td><strong>Definition</strong></td>
<td><strong>Example</strong></td>
<td><strong>Occurrences</strong></td>
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<tr>
<td>Pedagogical Knowledge</td>
<td>Teaching strategies</td>
<td>My knowledge of pedagogical practices that are effective for increasing student learning</td>
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<tr>
<td></td>
<td>Check for Understanding</td>
<td>My knowledge of assessing student understanding through instruction</td>
<td>“How’s it going over here? Do you have any questions?” (Science Video Day 3)</td>
<td>219</td>
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<tr>
<td></td>
<td>Connecting Across Lessons</td>
<td>My knowledge of tying lesson concepts through a unit, past and future lessons with present lessons</td>
<td>“Think back to the problem that we did last week with the yarn we stretched it out.” (Math Video Day 1)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Importance of Student Talk</td>
<td>My knowledge of students sharing their thoughts to increase learning</td>
<td>“Because you learn more when you talk and you can’t just talk to yourself. You gotta talk to the people around you.” (Science Video Day 2)</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Open to Multiple Ideas</td>
<td>My knowledge of student generated thought being a powerful teaching strategy</td>
<td>“I want you to categorize them. I’m not gonna tell you a category to use. You can use whatever is going to make sense for your table.” (Science Video Day 1)</td>
<td>37</td>
</tr>
<tr>
<td>Emergent code</td>
<td>Definition</td>
<td>Example</td>
<td>Occurrences</td>
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<tr>
<td>Questions</td>
<td>My knowledge of using questions as a way to prompt student thinking for learning</td>
<td>“What other similarities or differences do you see between those two?”</td>
<td>114</td>
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<td></td>
<td></td>
<td>(Math Video Day 1)</td>
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<tr>
<td>When to Do Small Group Versus Whole Group</td>
<td>My knowledge of grouping the class in smaller groups to encourage collaboration</td>
<td>“Tell the people sitting at your table, what does every food web or food chain begin with?”</td>
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<tr>
<td></td>
<td></td>
<td>(Science Video Day 3)</td>
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<td>Classroom management</td>
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<tr>
<td>Calls for Attention</td>
<td>My knowledge of using a consistent routine to focus students before beginning instruction</td>
<td>“All right. And back to me in three, back to me in two. Back to me in one.”</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Science Video Day 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson Expectations</td>
<td>My knowledge of setting up the expectations for lessons by previewing behavioral expectations and student tasks</td>
<td>“As we look at the pictures, I want you just to look with your voices off.”</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Science Video Day 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of Large Class</td>
<td>My knowledge that grouping students into smaller numbers rather than a large class helps students have more accountability and increases individual learning</td>
<td>“You need to be with whatever group you need to be in.”</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Math Video Day 3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### A Priori Code

<table>
<thead>
<tr>
<th>A Priori Code</th>
<th>Emergent code</th>
<th>Definition</th>
<th>Example</th>
<th>Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>How to respond to</td>
<td></td>
<td>My knowledge of using my responses to students in order to students help</td>
<td>“They all move the decimals. Tell me more about that.” (Math Video Day 1)</td>
<td>27</td>
</tr>
<tr>
<td>student questioning or responses to increase learning</td>
<td></td>
<td>further their thinking</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Subject Matter Knowledge

| Subject Matter Knowledge                                                                 | 40 |

| The content itself                                                              | My knowledge of the concepts I am teaching in the lesson | “What does every food, web and chain start with? The sun.” (Science Video Day 2) | 32 |
| Priority of ideas                                                               | My knowledge of which concept should be taught/learned first | “Let’s look at two different ways. We’re gonna look at long division and partial quotients way. I’m gonna start with longer division.” (Math Video Day 2) | 8  |

*Note.* This table includes all the codes used for data analysis in the findings section. While more codes were used during the first and second pass of the data, these are the codes that support the final assert