Assessing Elementary Teachers' PCK for Magnetism: Challenges and Insights[1]

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Introduction

Since its introduction by Shulman (1986), pedagogical content knowledge (PCK), or the specialized amalgam of content and pedagogical knowledge that underlies teaching expertise, has received a great deal of attention in the literature. A multitude of perspectives on PCK abound, and it remains an elusive construct in terms of its assessment. Researchers are challenged with selecting and/or designing assessments that 1) align with their specific conception of PCK, 2) provide a valid and robust assessment of teachers' PCK, and 3) address contextual and local constraints. Accordingly, in approaching the assessment of elementary teachers' PCK as part of a larger study of a teacher professional development program, we took these challenges into consideration. In this paper, we describe our approach to assessing PCK and consider the extent to which we were successful in addressing these challenges.

Theoretical Perspective

Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) was introduced by Shulman (1986) as a fundamental component of the knowledge base for teaching. According to Shulman, PCK is what makes possible the transformation of disciplinary content into forms that are accessible and attainable by students. PCK can be defined as a teacher's understanding and enactment of how to help students understand specific subject matter content by using multiple instructional strategies, representations, and assessments while working within the contextual, and social limitations in the learning environment (Park & Suh 2014). Other definitions of PCK view it as an internal and tacit form of teachers' professional knowledge that is topic, person and situation specific (Berry, Cooper, & Loughran, 2014).

In science education research, the conceptualization of PCK by Magnusson, Krajcik, and Borko (1999) is that of a *transformation* of multiple types of teacher knowledge. In order for effective teaching to occur, the integration of knowledge from various domains must take

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place. Magnusson et al. call this an “integrated and differentiated knowledge” of teachers that leads to a “deep and integrated understanding” by students. Their framework for assessing teacher PCK consists of five components.

The first component of Magnusson et al.’s (1999) model, orientations towards science teaching, speaks to the general way in which a teacher views the teaching of science and the objectives of instruction. The second, knowledge and beliefs about science curriculum, is divided into two sections: a) mandated goals and objectives, including knowledge of and the ability to articulate goals and guidelines, and b) specific curricular programs and materials, which includes the knowledge of programs and materials for teaching that are domain specific. The third component, knowledge of student understanding of science, is broken into two subdomains: a) knowledge of requirements for learning, which includes teachers’ knowledge of prerequisite ideas and skills that students need to learn, and b) knowledge of areas of student difficulty, which includes teachers’ content knowledge of content areas that students will find difficult to learn. The fourth component, knowledge of assessment in science, is also broken into two subdomains: a) knowledge of dimensions of science learning to assess, which includes teachers’ knowledge of which parts of student learning are the most important to assess, and b) knowledge of methods of assessment, which refers to the way in which a teacher will assess certain aspects of student learning specific to a topic area. The last component, knowledge of instructional strategies, is broken into four subdomains: a) knowledge of subject specific strategies that includes strategies for teaching the subject of science, b) knowledge of topic specific strategies which include activities and representations, c) topic specific representations which refers to illustrations, models etc. that can be used to represent specific content and the knowledge of student strengths and weaknesses and d) topic specific activities that include teacher’s knowledge of problems and simulations and how these activities will impact student learning. We have utilized this model to frame our work in teacher professional development, and to assess the impact of our efforts.

Assessing Pedagogical Content Knowledge

PCK is a highly complex construct (Baxter & Lederman, 1999), and there are several challenges in assessing teacher PCK, as highlighted by researchers attending the recent PCK Summit sponsored by BSCS (http://pcksummit.bscs.org/). These include developing valid and reliable instruments to assess PCK as well as practical tools for conducting large-scale assessment of teachers’ PCK. Researchers have utilized several approaches, each with its own advantages and disadvantages. These have included paper-and-pencil surveys, observation rubrics, teachers’ responses to teaching scenarios, and interviews (Table 1).

Table 1. Approaches to Assessing PCK

Researcher	Method(s) of Assessing PCK	Advantages	Disadvantages
Park & Oliver (2008)	1. Classroom observations 2. Semi-structured interviews 3. Lesson plans 4. Teachers' Written reflections 5. Work samples 6. Researcher's field notes	Multiple methods of assessing provide a better overall picture of teacher PCK.	Researchers cannot observe everything they want to know; Researchers may focus on different things during observations; Lesson plans may not be completely created by teacher.
[2]Kirshner, Borowski & Fischer (2011)	1. PCK tests using vignettes of critical teaching situations in the form of a script.	Results show the test is able to measure knowledge that is not pedagogical knowledge, general knowledge or abstract thinking.	It is difficult to reliably code the answers on this test in order to determine if the tested teachers focused on the "right" problem.
[2]Carlson & Gess-Newsome (2011)	1. Two-year intensive professional development. Participants implement high quality curriculum materials during this time.	Results showed an increase in Student Achievement when there was an increase in Academic Content Knowledge.	Results showed no relationship between Academic Content Knowledge to teaching practice.
[2]Henze and van Driel (2011)	1. Semi-structured interviews held in three subsequent years following the teaching of designated chapter.	Identifies some possible patterns across the knowledge development of a variety of teachers.	Does not describe individual PCK development.
Berry, Cooper & Loughran (2014)	1. Content Representation Tool (CoRe) 2. Pedagogical and Professional Experience Repertoires (PaP-eRs)	Allows researchers to capture, portray and codify science teacher PCK in ways that are useful to science teachers.	CoRes and PaP-eRs help illustrate PCK that is well developed but cannot be used as the only aspect for defining PCK.
Smith (2014)	1. ATLAST Assessments-Multiple choice tests 2. Cognitive interviews with teachers and students 3. Teacher logs	Analysis shows the teacher assessments are valid and reliable. Assessments are tightly aligned with each other as well as certain content areas and are ideal for studies that are content-dependent.	Creation of the assessments can be time consuming. High level of teacher attrition, possibly due to the burden of keeping the teacher log.
Park & Suh (2014)	1. Teacher surveys 2. Think-aloud teacher interviews 3. PCK Rubric 4. Teacher Observation 5. Pre/Post observation interviews	Multiple methods of assessing provide a better overall picture of teacher PCK. The PCK Rubric appropriately measures knowledge of student understanding and knowledge of instructional strategies and representations.	Initial Teacher Surveys: Small number of items. Low return rate. Second round survey: Higher number of surveys returned but still not enough to test construct validity.

[2] Cited in Borowski et al. (2011)

Banilower & Smith (2014)	1. Multiple choice item tests 2. Cognitive teacher interviews	Items do not measure teacher PCK but do help measure disciplinary content knowledge.	Items seemed to assess teachers' beliefs and/or orientations more than their knowledge.

Because PCK "is constituted by what a teacher knows, what a teacher does, and the reasons for the teacher's actions" (Baxter & Lederman, 1999, p. 158), no single instrument may be able to fully assess PCK. Researchers are challenged with selecting and/or designing assessments that 1) align with their specific conception of PCK, 2) provide a valid and robust assessment of teachers' PCK, and 3) address contextual and local constraints. Accordingly, in approaching the assessment of elementary teachers' PCK as part of a larger study of a teacher professional development program, we took these challenges into consideration. In this paper, we describe our approach to assessing PCK and consider the extent to which we were successful in addressing these challenges.

Purpose of the Study

Our purpose in this study is to answer the broader question, *In what ways does our approach help us understand elementary teachers' PCK for magnetism?* In examining our answers to this broader question, we further consider *To what extent does our approach yield useful insights into elementary teachers' PCK that can inform research and professional development?* In this paper, we share our data collection tools, discuss the pros and cons of our approach, and what we were able to learn about elementary teachers' PCK. That is, we explore both the methodological trade-offs and practical considerations inherent in assessing PCK.

Context of Our Work

The current study is part of the Quality Elementary Science Teaching (QuEST) project, funded by the National Science Foundation DRK12 grants. QuEST is a longitudinal research program examining the impact of elementary teachers' (grades 3-5) participation in a practicum-based professional development experience. The professional development experience consists of an intensive two-week summer institute and academic year follow-up activities. During the first week of the summer institute, all teachers participate as learners in content and pedagogy focused sessions. During the second week, teachers work collaboratively to plan and enact instruction with students, applying what they learned in week one. Our research program examines the contribution of this embedded teaching experience to teachers' PCK.

Assessing the impact of the program on teachers' PCK requires that there to be some baseline assessment of teachers' PCK prior to their attending the program. Since the topical focus of the summer institute was magnetism, we needed to take into account the topic-specific nature of PCK in our assessment, as well as a number of practical constraints. For example, some teachers who were recruited to participate in the professional development program, due to changes in grade level and/or curricula, had never taught magnetism. Additionally, due to the timing of recruitment (spring), some teachers' teaching of magnetism preceded our data collection window of opportunity. With this in mind, we combined two existing data collection techniques to create a three-part data collection process to help us capture robust information about elementary teachers' PCK.

Participants

In the current study, conducted in year one of the program, 33 third grade teachers were recruited to participate. Participating teachers came from a cross-section of urban, rural, and suburban school districts in a Midwestern state. Tables 2 and 3 provide an overview of teachers' experiences and comfort level teaching science.

Table 2. Characteristics of Teacher Participants

	Average
Number of years teaching	9.4
Number of years teaching third grade	5.3
Number of science-related PD hours completed in the past 3 years	17.5

Table 3. Teachers' Comfort Level Teaching Science

	Well-Qualified	Adequately Qualified	Not Well Qualified
Teaching Science	3(9%)	24(73%)	6(18%)
Teaching physical science	2(6%)	19(58%)	12(36%)
Teaching about magnetism	2(6%)	15(45%)	16(49%)

Data Collection

To gather data related to teachers' pedagogical content knowledge prior to their participation in the program, we combined two existing data collection methods. These included the Lesson Preparation Method (Valk & Broekman, 1999) and the Content Representation tool (CoRe) (Loughran et al., 2004).

The Lesson Preparation Method (Valk & Broekman, 1999) was developed to probe the PCK of preservice teachers. These researchers emphasized that even if preservice teachers didn't have teaching experience, they had prior knowledge about teaching and learning springing from their experience as learners. In their study, participants were given one hour to design a lesson (sans textbook) on a predetermined topic, given information about the classroom environment and preceding curriculum. This was followed by an interview. All participants were able to complete the task, despite not having taught a lesson prior. Because of the open-ended nature of the task, the researchers were able to gather rich information about preservice teachers' knowledge base; this richness, however, made it difficult to analyze and describe results concisely.

The CoRe is a methodological tool that is used to help uncover teacher PCK, as well as a way of representing it (Loughran et al., 2004). The CoRe itself is a matrix that outlines the important aspects of teaching and learning of specific science content. Questions in the CoRe address what teachers intend students to learn and why it is important, limitations and difficulties connected with teaching the content, knowledge of student thinking and specific ways in which to gauge student understanding, and the teaching reasons and procedures for using them. The CoRe allowed researchers to capture and explore a holistic, multifaceted picture of a teachers' PCK.

In our study, we combined these two methods in a three-part data collection process consisting of a lesson plan task, CoRe questionnaire, and follow-up interview. Prior to participating in the PD, teachers were instructed to submit a magnetism lesson plan through our program website (Figure 1). At the same time, teachers responded to an online questionnaire, in which questions from the CoRe were modified to refer specifically to the lesson plan they submitted. Once teachers submitted their lesson plan and responded to the CoRe, the research team conducted a follow up interview using a semi-structured protocol. The sequential nature of the task allowed the researchers time to review teachers' lesson plan and questionnaire data prior to the interviews, so they could more deeply probe specific aspects of their PCK during the follow-up interview.

Instructions

Our goal with the QuEST professional development program is to support your ability to meet students' science learning needs. To do this, we need to learn about your current understanding of science teaching and learning so we can best support your growth. To help us better prepare for the summer workshop, we ask that you please complete the following task.

Prepare and upload one ***detailed*** *lesson plan on magnetism that you would teach to your 3rd graders. This could be a lesson you have already taught or one that you might teach, but it should reflect a* ***typical science lesson*** *in your current 3rd grade classroom. If your school or district requires a specific template or format, you may use that, or you may choose one of your own.*

Figure 1. Instruction for the Lesson Plan Task

Each of the data collection techniques was aligned with the four domains of PCK (knowledge of learners, knowledge of curriculum, knowledge of instructional strategies, and knowledge of assessment) in Magnusson, et al.'s model (1999). We excluded orientations, as within the model these are considered to shape the other four domains. Friedrichsen et al. (2011) define orientations as a "set of beliefs following dimensions: goals and purposes of science teaching, views of science, and beliefs about science teaching and learning" (p. 358-

359). As emphasized by Magnusson and colleagues, a particular teaching strategy might be characteristic of more than one orientation, making such inferences difficult to make based on a single lesson. Thus, teachers' orientations were not determined based on this approach, but will be as part of the larger research program. Table 4 illustrates how we connected one of the PCK domains (Knowledge of Learners) to the CoRe survey questions and the interview protocol questions.

Table 4. Alignment of Data Collection Tools with PCK Domains

PCK Domain	CoRe Questionnaire	Interview Questions
Knowledge of Learners *Requirements for learning*	What ideas do you expect students to bring to this lesson? (i.e., prior knowledge or misconceptions)	You indicated students have prior knowledge such as ______. Can you talk about any strategies that you may include, if any, to assess students' prior knowledge in this lesson? How did you become aware of your students' prior knowledge about this concept? In what ways, if any, did you take these into account in designing the lesson? Can you talk about any misconceptions you think students might bring to the lesson? Talk about any experiences or reasons why you think this.
Areas of student difficulty	What difficulties and challenges do students have participating in this lesson and/or learning this concept?	You mentioned students have difficulty with ___. Can you talk about why do you think that might be? Talk about whether you think all students might face these difficulties? Why or why not? Can you talk about how you came to anticipate this student difficulty/challenges? How did this influence your planning of the lesson, if at all?

Findings

In this section, we share full data collected for two case teachers to illustrate both the richness of our data and the degree to which our data sources highlight contrast in teachers' PCK. These cases were selected for the purpose of highlighting differences in the robustness of their PCK evident from our data, as well as the way in which the assessments helped us identify their specific professional development needs. We then discuss patterns across the data set as a whole.

Teacher One: Dan

Dan has taught for ten years and indicated he feels well-qualified to teach science, and well-qualified to teach about magnetism, specifically. He submitted a lesson plan (see Appendix A) on magnetism that utilized the 5E Learning Cycle and included both formative and summative assessments. When asked about his lesson and past experiences with magnets during his interview, Dan stated that his own understanding of magnetism was "concrete" and he considered himself “well-versed” on the topic. In his lesson, Dan addressed how magnets work and how the atoms align in a nonmagnetic metal to make a magnet. He aligned his lesson with two state standards, but included additional learning objectives that went into greater depth about the causes of magnetism at an atomic level. To accomplish this, he utilized a visual representation of magnetic domains within an iron nail to show their alignment in magnetic materials. While his lesson addresses the standards he identified, it goes into greater depth in terms of addressing an explanatory model for the causes of magnetic interactions. Dan included a variety of strategies to assess his students, both formative and summative, in his lesson.

In Dan’s CoRe (see Appendix B), he stated that the best way he has found to teach this topic is through “hands on, student directed learning”. He wanted students to “see beyond the surface of things in order to see how things work and for students to understand the processes that lead to it”. For this reason, he selected to represent the domains within the iron nail using a graphic, indicating this teaching tool was “something [he] saw years ago”. Dan was aware of potential student difficulties in grasping magnetic domains and thought “it’s a pretty abstract concept”. This was not the primary influence on his choice of instructional strategies, however. Dan justified his decisions on what strategies to use with his students based upon how he was taught and what worked for him. He talked about how he teaches in this way (hands on, student directed) because that was how he learned. Dan connects his teaching style of teaching with his experience learning as a student in the 70s where he was successful in learning by “doing and seeing.” Dan indicated he struggled with learning anything when reading was involved, and tries to keep that in mind when developing his lessons, in order to accommodate the needs of his students.

Teacher Two: Sally

Sally was a new teacher, and indicated she feels adequately prepared to teach science, and adequately prepared in terms of teaching magnetism, specifically. She submitted a lesson plan (see Appendix C) on magnetism that includes a class KWL chart, two YouTube videos, and independent practice with magnets of varying sizes and shapes, and iron shavings. When asked about her lesson during her interview, Sally stated that she felt “fairly comfortable” or at a “pretty good spot whenever it comes to understanding magnets”, but developed her understanding through what she was taught in elementary and high school and through her own research on the internet. She also mentioned using the videos included in her lesson plan to make sure she was “very familiar with them” before teaching the lesson. While she indicated her lesson plan addressed standards related to inquiry, specifically making observations using simple tools and equipment, her specific objective involves describing magnetism as a force that can push or pull other objects without touching them and being able to identify that magnets attract and repel each other and certain materials. Overall, there is not strong alignment between the standards/objectives she indicates and her lesson plan.

In Sally's CoRe (see Appendix D), she stated having students explore with magnets using a hands on approach is best and that students learn more when they are actively involved in their learning. However, in her lesson plan she explains how students will use a worksheet to learn the vocabulary while watching two Youtube videos following completion of the first two parts of a KWL chart. While Sally states that "kids learn best by doing" a strategy she learned through personal experience and her coursework, she uses the videos to introduce the information about the poles and the Earth's magnetic fields because the students respond better to the video rather than her lecturing "even if it's a video saying the exact same information that I would be saying." In this lesson explanation precedes exploration, as Sally later states that students will "explore on their own with magnets and iron shavings." Although students are now exploring with different sized and shaped magnets, iron shavings, and a piece of paper, she does not provide other materials that might address her second objective: *Students will be able to identify magnets attract and repel each other and certain materials.* In Sally's CoRe and during her interview, Sally stated that some students might have the misconception that all metals are magnetic. While Sally mentioned testing certain objects as a groups and discussing these misconceptions during her interview, her lesson plan does not provide the opportunity for students to explore this concept/objective. At the end of her lesson, students will come back to the carpet to share what they learned and finish the KWL chart. When asked during her interview to talk about her assessments, Sally mentioned using a pretest but "other than that, it would probably just be informal type of observation."

Comparison of Dan & Sally's PCK

As a research tool, our measures should be useful in detecting differences in teachers' PCK. In this section, we consider the extent to which our instruments help us detect meaningful differences between the PCK of Dan and Sally, in terms of both the sources and nature of their PCK.

Overall, our assessment revealed that the primary source of Dan's PCK was his own prior experiences as a learner. His ideas about how students learn the topic best were related to what he found successful in developing his own understanding of magnetism, an understanding about which he was confident. In contrast, Sally was less confident in her preparedness to teach and relied on external sources, such as web resources, to both update her content knowledge and find videos and lesson ideas.

From our combined use of the Lesson Plan Task, CoRe and Interview, we were able to detect differences within and between Dan and Sally's PCK in terms of the component knowledge bases as well. For example, Dan's had a much broader array of assessment strategies (how to assess) and specific ideas about understandings students should possess at the end of the lesson (what to assess), whereas Sally had less developed knowledge of assessment and relied primarily on informal assessment through observation to gauge student learning at the end of her lesson. Similarly, we were able to understand key differences in their overall instructional approach and choice of activities. In Dan's case, he began with hands-on activity then proceeded to abstract concepts. Sally, in contrast, provided students with explanations (via video) prior to their exploration. While Dan chose a topic-specific representation related to magnetic domains, Sally's use of videos were more generally related to magnetism and included a variety of concepts not addressed in her learning objectives.

In Dan's case, we can see consistencies between his goals and purposes, choice of instructional strategies and representations, and anticipation of student difficulties with the content he chose. Whereas in Sally's case, we saw an overall misalignment between her lesson goals and objectives, the specific activities she chose, and the assessment strategies she had in place.

Patterns across the Entire Data Set

Our data revealed a number of themes across the broader group of participants, some of which resonate with Dan and Sally's cases. First, in developing their lessons, teachers relied heavily on existing lessons and materials (either provided to them by the district or found through their own searching). Not all of these were high quality, and as such they did not effectively support teachers' PCK. For example, teachers had a limited repertoire of assessment strategies, which seemed to be drawn primarily from these materials. Additionally, from reviewing the lessons teachers submitted it became evident was that they held very different conceptions of the 'big ideas' within this topic and where instruction about magnetism should begin and how the conceptual storyline should progress. Many teachers did not have an internalized rationale for teaching the specific concepts of the lesson, citing their rationale for teaching the concepts to be because 'it was in the standards' or was 'the next lesson in the book'. This was especially true for teachers who had never taught the topic previously. However, it should be noted that even those teachers who had previously taught the topic exhibited a lack of confidence in their understanding of magnetism. Misconceptions held by teachers were evident across data sources. Additionally, the data revealed key differences in teachers' instructional approaches, many of which ran counter to the instructional approach we would introduce in the PD program.

Discussion

In combining the CoRe and the Lesson Preparation Method, we found a number of advantages and disadvantages to our approach in terms of addressing practical considerations, producing useful information to inform our professional development efforts, and providing a valid assessment of teachers' PCK. Based on our assessment of Dan and Sally, we consider the strengths and weaknesses of our approach.

Practical Considerations

As previously mentioned, a practical constraint was that we would not be able to implement direct observation of teachers' practice, given some taught the topic prior to recruitment and others not at all. In the absence of observations of their classroom instruction, we needed to find ways to capture dimensions of teachers' practice, in addition to their understanding. Centering our data collection on a particular lesson plan allowed us to do this. Similarly, as emphasized by Valk and Broekman (1999), this allowed us to probe teachers' PCK whether or not they had previously taught lessons on magnetism, which was the case for several participants (given recent changes in standards and/or teachers' grade level assignments).

Both the lesson plan task and questionnaire were administered online and the interviews were conducted in-person or via phone when in-person was not possible. This proved cost-effective and allowed greater flexibility in scheduling. The cost associated with observational methods of measuring PCK such as travel and time per observation were drastically reduced. Furthermore, this allowed us to assess all teachers at the same point in time, rather than having to adhere to a particular window of time during which teachers would be teaching this topic as would be the case with conducting direct observations of practice.

The questionnaire and follow-up interviews were structured so that each teacher was asked to provide the same information. This structure allowed for easier comparison across teachers than would be the case with classroom observational data. For example, we were able to capture an *entire lesson* from each teacher, whereas a single observation may have provided access to only a part of a teacher's implementation of a lesson.

However, there were also disadvantages to this approach from a practical standpoint—including the amount of time necessary for teachers to complete the tasks. One area of concern was the burden that was placed on the participating teachers. Because we used three different methods for assessing teacher PCK, teachers had to devote a significant amount of time to complete each task.

Information to Inform the Professional Development

The data we gathered about teachers' PCK for magnetism through our approach was useful not only for establishing baseline data for our research, but also for informing our professional development program. Reviewing teachers' lesson plans provided an indication about where we might need to begin instruction about lesson design and how we might best focus our efforts. For example, we noted that teachers relied heavily on existing lessons and materials, not all of them high quality. This is consistent with research by Appleton (2006) who described elementary teachers' reliance on 'activities that work' as a means of compensating for inadequate PCK. Additionally, we saw a limited repertoire of assessment within teachers' lessons, highlighting an opportunity to expose them to additional strategies and tools for assessments, as well as equip them with additional materials to use in their hands-on instruction.

In terms of our professional development goals, advanced awareness of specific ways in which teachers' instructional approaches were misaligned with the instructional approach we would introduce in the summer institute helped us anticipate possible points of resistance in working with teachers. When asked about their rationale for the concept on which they chose to focus for their lesson, teachers were unsure about why material was being taught and responded that they were teaching it because it was in the standards or it was the next lesson in their curriculum series. This emphasized a need for us to explicitly address the importance of conceptual storylines, both in our content sessions and pedagogical sessions, and how the standards could be used to develop coherent conceptual storylines.

Validity Considerations

From a research perspective, the most important question, which outweighs the two prior issues addressed, is whether our approach provided a valid assessment of teachers' PCK. Perhaps the greatest advantage to this method was the triangulation of methods around the domains of PCK, facilitated by our use of this framework in our design of the instruments. Through this, we were able to gain a richer perspective on teachers' PCK, as well as to compare responses across data sources for consistency. For example, as shown in Figure 2 below, Sally's less developed knowledge of assessment was evident across all three data sources.

Lesson Plan Task	CoRe questionnaire	Interview
<u>Closure:</u> Students will come back to the carpet. They will share with the class what they learned from experimenting with the magnets. Then, the class will finish the KWL chart and discuss it as a class. The teacher will tell the students that tomorrow they will be reviewing the vocabulary terms they learned today.	I will informally observe the students. I will walk around, ask questions, answer questions, etc. to determine where each student is at in this learning process.	…it which if I did um the day before even before this if I did a pretest that would kind of tell me where I'm at other than that it would probably just be informal type of observation um I mean and then I could look at their um worksheet that has all the vocab words but I prob I wouldn't collect it because that would be something for them to look at so most of it's going to be informal

Figure 2. Comparison of Data for Sally from Three Sources

Furthermore, in talking with teachers during interviews, we noted teachers were anxious and expressed a lack of confidence in their content knowledge; by looking across all three data sources it became evident they held misconceptions about the topic. Other data collected as part of the project (e.g., data from teachers' indications of how qualified they felt to teach science and scores on content tests) corroborated this.

One validity concern, however, is that all data collected was self-reported by the teachers. When observing practice, researchers are able to see the teachers' enactment of the lesson, using this data to evidence claims teachers report via lesson plans or survey. In this project, teachers have provided lesson plans, answered survey items, and participated in an interview in which they are discussing their knowledge and actions through their lens. Though the use of three data sources mitigates this limitation to some extent, we are aware that observations may highlight some misalignments between teachers' responses and their actual practices in the classroom.

Another limitation to our approach, the fact that teachers may not have actually taught the lesson submitted (or ever taught the topic), could simultaneously be described as a strength. In these cases, because the teachers may not have taught the submitted lesson, this task reveals little about their PCK *in practice*. Yet, classroom observations would have yielded *no data* about teachers' PCK in such cases. What is clear from our data, however, is that these teachers, at a minimum, exhibited 'PCK readiness' (Darling-Hammond et al., 2005).

Discussion & Implications

In this paper, we raised the following questions: *In what ways does our approach help us understand elementary teachers' PCK for magnetism?* and *To what extent does our approach yield useful insights into elementary teachers' PCK that can inform research and professional development?* We consider these questions in the discussion that follows.

Use of this combined task provided us with several insights into teachers' PCK for teaching magnetism. In particular, we were able to learn a great deal about the sources of teachers' PCK. We noted teachers' lessons were often gleaned from other sources (versus being of their own creation), similar to what Appleton (2006) referred to as elementary teachers' reliance on 'activities that work'. Interestingly, in cases where teachers submitted district-mandated lessons, they struggled to respond to the questionnaire and interview-- whether or not they had taught these lessons. While Appleton claims 'activities that work' can support the development of teachers' PCK, it's evident that these are, at best, an incomplete scaffolding. Having teachers design a lesson, as opposed to submitting one gleaned from another source, may provide a more valid assessment of their PCK; however, we find what this task reveals about teachers' selection of instructional materials to be important as it is representative of their teaching context and its influence on the development of their PCK. When asked why they had selected a particular concept on which to focus their lesson, some teachers indicated 'because I was told to teach this'. Teachers are very quick to share their own teaching strategies, procedures or activities but they rarely discuss the reasons behind them (Loughran 2004). Similarly, our data suggest this holds true for materials that are handed to teachers by district administration, as teacher provided little information about the rationale for teaching the specific lessons they were provided.

Additionally, our assessments shed light on the *nature* of teachers' PCK for magnetism. Specifically, we were able to compare the richness and depth of teachers' PCK across our sample of participants, as well as the extent to which there was alignment among the individual component knowledge bases of PCK (e.g., knowledge of learners and knowledge of assessment). The cases of Sally and Ben illustrate distinct differences in the depth of their PCK, which coincided with their level of confidence in their preparedness to teach the topic. Park and Oliver (2008) also emphasized teacher self-efficacy as an important aspect of teachers' PCK development. Similarly, these cases highlight that the development of teachers' PCK among component knowledge bases may be uneven, consistent with the model proposed by Magnusson et al., (1999).

Our second question was concerned with the degree to which our approach yielded insights useful to both our research and professional development efforts. In terms of research, we believe this approach was important to establishing a baseline assessment of teachers' PCK, particularly in cases where teachers have not yet taught a topic—thus, indicating their PCK readiness (Darling-Hammond et al., 2005). Additionally, this approach yielded new insights into contextual constraints that influence the development and enactment of teachers' PCK. Unlike Valk & Broekman (1999), we did not specify the classroom context and the availability of unlimited materials/resources-- teachers' lessons were thus constrained by their own teaching contexts, in addition to their PCK. For example, one teacher stated that her "kit" only included two magnets and a set of paperclips so she was only able to do a demonstration rather than having students work with the materials themselves. In contrast, another teacher stated she was unaware of the different types of magnets until thinking about her lesson more critically during the interview, and pondered changing that part of her lesson the next time she teaches it. In the former, the teachers' instructional approach were not limited by her own knowledge, but by her available resources, whereas in the latter, the teachers' instructional approach was a consequence of her lack of knowledge of curricular resources and materials. Both cases highlight the importance of multiple data collection methods. The analysis we have done so far indicates that our assessment approach provides a valid means of characterizing teacher PCK; however, we acknowledge that this may not fully capture teachers' enactment of their knowledge *in practice.*

Our approach further helped us understand elementary teachers PCK for magnetism by providing insight into areas where our professional development might further support their growth. We were able to review our data in order to get an idea as to where we needed to start instruction for our teachers during the summer institute that would best meet their needs. These assessments aided our ability to scaffold for teachers, just as we propose teachers should scaffold for their students. For example, we identified a need for professional development to address 1) evaluating the quality of instructional materials and resources; 2) selecting and sequencing materials to form a coherent conceptual storyline; 3) using assessment to monitor student progress in constructing understanding throughout the lesson; and 4) aligning curriculum, instruction, and assessment with student needs.

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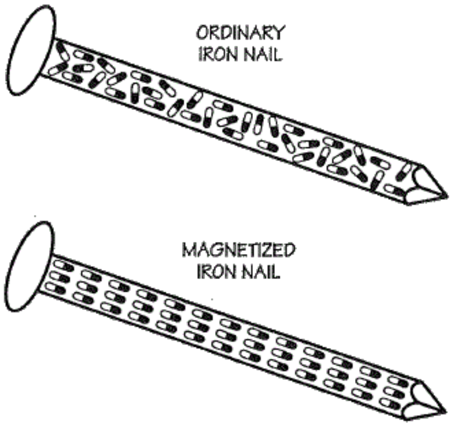
Appendix A: Dan's Lesson Plan

Lesson title	**Making magnets**
Goals and Objectives	What are your goals and learning objectives for students in this unit of instruction? What Missouri standards (GLE/CLE) will this unit of instruction focus on?
	Learning Objectives:
	• Students will learn how magnets work. • Students will learn how the align atoms in a nonmagnetic metal to make a magnet.
	Missouri G.L.E.s:
	1. Science GLE (2.2.A.a) *Identify magnets attract and repel each other and certain materials* 2. Science GLE (2.2.A.b) *Describe magnetism as a force that can push or pull other objects without touching them*.
Assessment and Evaluation	**Formative Assessments:**
	• Guiding Question- used to find a baseline for student understanding. This will be done at the beginning of the unit and then finished at the end.
	Summative Assessments:
	• Magnet Book-Students will describe what students learned about magnets.
Lesson outline	**Engage:** Guiding Question: *Think back about what you know or learned about magnet and forces the last week. What are some beliefs you can make about magnets and forces?* Students will list these ideas in their science notebook. **Explore:** *What are some of the things you listed in your Science Notebook?* List these on chart paper. • Give students an ordinary iron nail, a strong magnet, and a few paper clips. Ask them to pick up some paper clips using only the nail. Observe how students solve this question. They need to hold the magnet close to the nail, and then the nail will pick up the paper clips. What happens when the magnet is taken away? • Give students two iron nails: one already magnetized and one that has not been, and have them explore their magnetic properties using the nails and paper clips. Walk around, observe, and listen to the student as they interact. Ask probing questions to redirect students to the task at hand; why is one nail magnetic and one is not. **Explain:** • Encourage the students to explain why one was magnetic and one was not.

	• Ask students to justify their results using evidence gained by experimenting with the nails and paper clips. • After discussing the students results, formally give the students the explanations how the one iron nail is magnetic and the other one is not. Show the "Iron Nail" illustration that show how the atoms in the magnetized nail are aligned and the ordinary iron nail the atoms are not aligned. **Elaboration:** • Expect students in their Science Notebooks to use formal labels and definitions. **Extend:** • Have the student get up and physically act like the ordinary nail and then the magnetized nail. • Give each group a strong magnet and an ordinary nail and have them make their own magnetized nail. **Evaluation:** • Student will make magnet books to describe what they learned about magnets during this week long lesson. Look for evidence about the two nail experiments in these books

Figures used in Dan's Lesson *Example Notebook Entries*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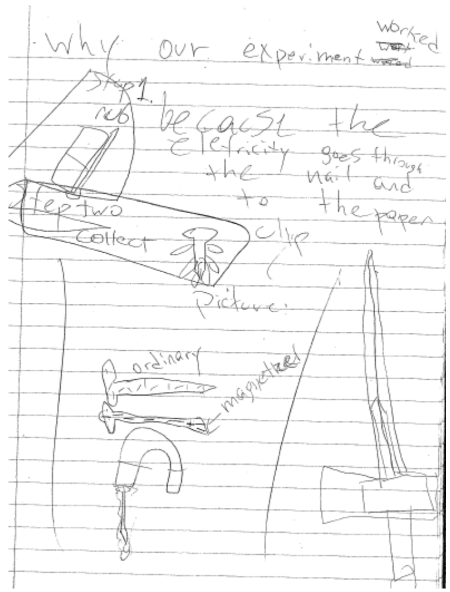
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Step two
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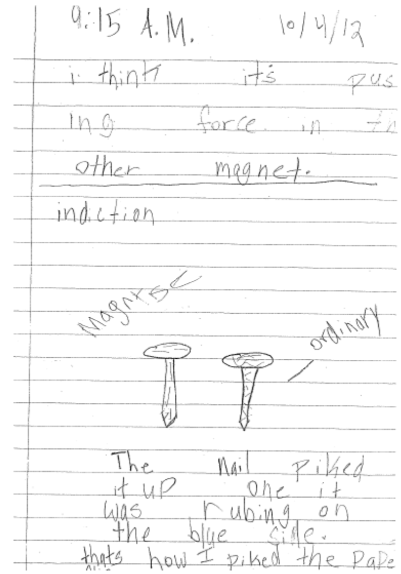
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Appendix B: Dan's CoRe Responses and Elaborative Excerpts from His Interview

CoRe Question	Written Response	Interview Responses
1. What is the 'big idea' or central concept of your lesson?	Understanding how magnets work, and reproducing this effect with nonmagnetic metals.	The idea for this lesson came about that I truly think that kids don't understand what a magnet is composed of and how it is different and how the magnetized metal is different than an inert metal. So, the idea was to show the kids through illustrations and through experimentation that they could just take a normal, like a…some iron and through some manipulation with a magnet they can turn that into a magnet and then we can discuss how that is now magnetized and why it doesn't last.
2. Why do you think it is important for students to know this?	I think it is important for students to see beyond the surface of things, what makes something work and for them to understand the processes that lead to it.	I guess that's how I learned. I learned from uh doing and taking things apart and seeing. When I was in school I really wasn't the kind of person who really paid attention to what the teacher said…So, it was easier for me to like, to work with my hands and figure it out. I mean certainly directions, I had to be directed toward a certain way but I just think people learn by doing. I just think that to read I mean certainly some students can learn that way but I personally was never that kind of a student.
3. What activities and/or strategies have you found work best to teach this topic/concept?	Hands on, student directed learning.	I think it's because the iron nail is a non-magnetic surface and it's uh harder it's uh I mean it's common and they hopefully have seen it and it's just easily attainable it's easy to find them. And I think that it's easy for kids to sketch those and manipulate the molecules inside or atoms actually in this case and for them to understand why it's magnetic and why it's not. It just seemed like a logical device to use… I think I saw it years ago and I don't know saw it or read it or something, it was just something that popped into my brain.
4. What ideas do you expect students to bring to this lesson? (i.e., prior knowledge or misconceptions)	What a magnet looks like and how it acts towards certain metals	I am coming to the assumption that they have never experienced this because in the lower grades they don't really discuss this so they really haven't had much exposure to it. So, how do I anticipate it? I just make an assumption that they would not have the background knowledge based on the alignment of the atom. …A lot of kids thought that they were just special metals that they um you know that the magnet was just a special metal and you know there are some natural magnets but they didn't understand what made them that way. They were really surprised when they took their iron nail that was not magnetic and made it magnetic so that was a big aha moment and then they tried it with various different metals and sometimes it worked and sometimes it didn't because it depends on the metal they are using.

5. What difficulties and challenges do you think students have participating in this lesson and/or learning this concept?	Some will have a difficult time visualizing the atoms inside the metals and how they are changed to create a magnet.	Well, it's very difficult I mean they are just third graders and something on the atomic level is a little difficult concept to understand so I mean they just look they don't understand a lot of times. The kids don't understand that this object that is made up of molecules, atoms and so the idea of aligning them so that is why to illustrate and then you know if they write it down in their notebooks and they do it many times they begin to get a better understanding. I think it's a pretty abstract concept to be able to look inside something and see how it's aligned. Or how its molecules are arranged.
6. What strategies have you found work best to address challenges or difficulties students experience during this lesson?	Hands on manipulatives work the best.	**…**I just understood that you know the kids would have to probably have it illustrated. , and maybe even do some like physical models if they had a really hard time with it? You know we could get in an alignment so the kids could manipulate each other's bodies so they could understand so they could play like they were atoms in the metal and they could pretend they were lined up and were magnetic and then they could pretend like they were scattered so they were non-magnetic.
7. What do you expect students to know and be able to do as a result of this lesson?	Why magnets are magnets, and why other magnetic metals are not magnets.	Well, during my lesson it is pretty- other than the activities we are already doing- they're making a magnet with the iron nail, but there is also the possibility for an extension. We could take an iron nail and we could surround it with tightly wound copper wire and put a battery on it and make an electric, or whatever that's called, an electric magnet. That's not the term, I know it's not. That would be fun to do because you know the electrical current is the same idea you know it aligns the atoms. So that would be a fun extension. But other than just, I guess we could take different strength magnets and different types of magnets and different stations where they could this kind of magnet and rub the nail and they saw how many paper clips they could pick up and they could go to a different station and have a stronger magnet and then say they could hypothesize why this magnet was more effective by you know this iron nail was more effective by picking up more nails based on the magnet that was with the iron nail. That would be interesting to do.
8. How will you determine whether students have been successful in the lesson?	Looking at the notebooking and see they are able to diagram and draw the models correctly.	I would like for them to have at least a successful understanding of what, why is a magnet different than a common metal that can be magnetized. For instance, what makes that magnet that iron magnet different than the iron nail? And then I would want them to have a really good understanding that it just has to do with the alignments of the atoms and the fact that they are permanently aligned instead of aligned in a temporary fashion. So, that's my, I mean to me that's the big understanding in this lesson is for them to be able to visualize the alignment of the atoms.

Appendix C: Sally's Lesson Plan

Magnetism
Third Grade

Standards (2)

Strand – Scientific Inquiry
Learning Target – Make observations using simple tools and equipment (e.g., hand lenses, magnets, thermometers, metric rulers, balances, graduated cylinders)
DOK 2

Day 1

Objective:
After learning about magnetism, students will be able to describe magnetism as a force that can push or pull other objects without touching them. Students will also be able to identify that magnets attract and repel each other and certain materials.

Introduction:
The teacher will have the students go to the carpet. The teacher will ask the students, "Have you ever played with magnets?" The teacher will call on students who raised their hands to briefly (a minute) describe their experience with magnets (ask questions like what did they do with them, where they got the magnet, etc.). After the class has discussed their experiences, the teacher will inform the students that they will be learning more information about magnetism.

Development:
Complete a KWL chart as a class. Fill out the first two parts of the KWL chart for now.

What I KNOW	What I WANT to know	What I LEARNED

After the teacher hands out the magnetism worksheet (see below), the class will then watch the following videos over magnetism:

- https://www.youtube.com/watch?v=ak8Bh9Zka50
- https://www.youtube.com/watch?v=MZtTVsIOA9c

The teacher will pause the video as necessary for certain teaching points. Example: In video one, the teacher will pause the video when Bill Nye is talking about splitting magnets apart. The teacher will make sure the students understand what is being said. In the second video, the teacher will pause the video when they are talking about Earth's magnetic field. The teacher will draw on the board the magnetic lines of a magnet and compare them to Earth's magnetic lines.

Provide a worksheet that has the vocabulary words attached (this is found after the lesson plan). The teacher will explain that students need to "look for/focus" these words/phrases as the videos are playing. After the video, the teacher will go over the worksheet with the students and answer any questions that may come up.

Independent Practice:
After the video, students will go back to their desks. Students will explore on their own with magnets and iron shavings. Students will be given different sized and shaped magnets, iron shavings, and a piece of paper. Students will be encouraged to experiment by using different magnets, moving the magnets, etc.

Closure:
Students will come back to the carpet. They will share with the class what they learned from experimenting with the magnets. Then, the class will finish the KWL chart and discuss it as a class. The teacher will tell the students that tomorrow they will be reviewing the vocabulary terms they learned today.

Magnetism Vocabulary Sheet **Name:______________________________**

North Pole –

South Pole –

Repel –

Attract –

Magnetic Field –

The Earth has a ______________________________.

What are the three metals are magnets made of?

What happens when magnets come near one of these three metals?

Magnetism acts as a _______________ for our planet.

Appendix D: Sally's CoRe Responses and Elaborative Excerpts from Her Interview

CoRe Question	Written Response	Interview Responses
1. What is the 'big idea' or central concept of your lesson?	Having the students make observations using magnets and being able to define important characteristics of magnets.	Missouri standards just pretty much states that they need to make observations using simple tools like magnets so with them playing with the magnetic—um, magnets and the iron shavings they get to see how magnets work and the magnetic field around it; so that way again, it's hands on and it's covering the standards that Missouri requires.
2. Why do you think it is important for students to know this?	Since the Earth has a magnetic field as a means to "protect" itself, I think it's important for students to know one way the Earth "defends" itself.	…the YouTube videos that they watched -one of them kind of discusses that, so then I based that off of some of the questions that might need to be answered. …in part of it that the teacher will probably have to pause the video, so that way then she can go into more detail like for example drawing on the board… using the magnet, showing the magnetic field and how Earth has a very similar magnetic field to that. … I have a worksheet while they're watching the video that they fill in… so that kind of covers the magnetic force field of the Earth.
3. What activities and/or strategies have you found work best to teach this topic/concept?	I think having them exploring with magnets using a hands on approach is best. Students tend to learn more when they are actively involved in their learning.	… from my personal experience and also from any schooling that I've had --…kids learn best by doing either by themselves in groups, partners ,whatever-- but as long collaboration with the other students …getting their hands on …doing things of that nature ,that they're more likely to remember something like that, versus you know, a lecture that you give them.
4. What ideas do you expect students to bring to this lesson? (i.e., prior knowledge or misconceptions)	I think some students might have the misconception that all metals are magnetic. I also expect that most students will have some experience with magnets.	I think the biggest one was they'd be thinking that all metals are magnetic I think that probably is the biggest misconception that students would have….I've seen different lessons and things of those natures and so I have kind of seen some misconceptions that kids have and I was I observed just briefly uh a magnetism lesson and it was the very very beginning and I couldn't stay for very long but that was one of the misconceptions the kids had was that all the metals were magnetic.
5. What difficulties and challenges do you think students have	I think a harder concept for the students might be the introduction that	…because generally whenever kids have been -if they play with magnets at home, if they've been maybe taught about magnets from parents or something along those lines, it's something that they can hold in their hand … it's generally something that they physically

participating in this lesson and/or learning this concept?	Earth has it's own magnetic field. I also think it might be hard for some students to grasp that even if a person breaks a magnet apart, that it will still have a North and South Pole.	see they can't really physically see the Earth and its magnetic field so them being able to you know know about the Earth having a magnetic field is why I said that.
6. What strategies have you found work best to address challenges or difficulties students experience during this lesson?	One-on-one time I believe is a beneficial strategy to help struggling students. By spending more time with them, you can help guide their learning. There can also be modifications made to the lesson to meet the needs of struggling students; such as helping them fill out their vocabulary sheet, giving them magnets that have opposite strengths, etc.	…that way I know where they're at, and so that way I can see exactly what's going on with their reasoning and line of thinking-- that way I can help them through it … I know where they're at it'll help me know what I might need to pull out for them, what I might need to do differently for them, what other manipulatives I might have to have for them, and so that way … gives me time to assess them to see how I can better help them.
7. What do you expect students to know and be able to do as a result of this lesson?	I expect students to be able to know that magnets have forces that can attract or repel other magnets. I also want students to be aware of what metals are magnets and that Earth has a magnetic field.	I think that's a main part of magnetism- anytime that they play around with magnets they're going to notice that one side pushes away another magnet and one side pulls it in so that's kind of on their level that's something pretty basic that they know and so it's just getting the vocabulary down to know exactly what's going on whenever they do that…
8. How will you determine whether	I will informally observe the students. I will walk	… just as long as they've had growth in their understanding as long as you know they have gained something from the lesson they have learned something from the lesson not all

students have been successful in the lesson?	around, ask questions, answer questions, etc. to determine where each student is at in this learning process.	students are going to learn as quickly or as much as other students so by just them having growth in their learning uh no matter how small it is that is success to me