ACQUISITION OF KNOWLEDGE FOR TEACHING IN SITE-BASED SECONDARY TEACHER EDUCATION COURSES

by

LU WANG

(Under the Direction of J. Steve Oliver)

ABSTRACT

This dissertation was designed to investigate how a group of prospective teachers built their knowledge for science teaching and learning as they enrolled in a block of site-based courses leading to secondary science certification. Three manuscripts composed this dissertation. The first manuscript investigated what and how prospective science teachers noticed as they participated in classroom activities associated with their site-based teacher education courses. Results show that prospective teachers' noticing is idiosyncratic and not related to the context and that their development of noticing is a slow process. The second manuscript characterized prospective teachers' knowledge development as described by the PCK framework. Findings suggest that although the prospective teachers were placed in the same learning context, the outcomes and experiences of their learning are different. A qualitative data analysis of prospective teachers' PCK and noticing indicate that their knowledge development is dependent on what and how they notice when they were in their mentor teachers' classes. The third manuscript employed the framework of distinctiveness to understand the processes of prospective teachers' noticing and knowledge development. This study demonstrated that

the distinctiveness framework is a viable way of understanding how teachers identify the stimuli to start their learning process. Through this framework, teachers' processing of the differences and similarities among events and incidents is made visible. This dissertation adds to the literature of teacher knowledge acquisition process, connects teacher noticing with teacher knowledge, and indicates the feasibility of using the distinctiveness framework to understanding teacher knowledge development.

INDEX WORDS: Teacher knowledge, noticing, PCK, stimuli

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DEDICATION

To my husband, Lei Zhang, for your love, support, and being the adult when I acted like a five-year old kid.

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TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS v

LIST OF TABLES x

LIST OF FIGURES xi

CHAPTER

1 INTRODUCTION 1

Purpose of the Study 1

Rational 2

Overview of Chapters 6

References 9

2 WHAT DO THEY SEE? CHARACTERIZING PROSPECTIVE SCIENCE TEACHERS' NOTICING DURING A BLOCK OF SCIENCE TEACHER EDUCATION COURSES 12

Abstract 13

Introduction 13

Theoretical Framework and Literature Review 14

Method 19

Results and Discussion 24

Conclusion 36

References 39

3 EXPLORING PROSPECTIVE TEACHERS' DEVELOPMENT OF KNOWLEDGE FOR TEACHING DURING A BLOCK OF SECONDARY SCIENCE TEACHER EDUCATION COURSES: THE IMPACT OF NOTICING 50

Abstract 51

Introduction 51

Literature Review 53

Method 57

Findings 59

Conclusion 68

References 70

4 EXPLORING THE CONCEPT OF DISTINCTIVENESS TO UNDERSTAND PROSPECTIVE TEACHER NOTICING AND ACQUISITION OF KNOWLEDGE: A CASE STUDY 81

Abstract 82

Introduction 82

Conceptual Framework 83

Research Questions 92

Methodology 92

Results 94

Conclusion 106

References 108

5 CONCLUSION 114

Summaries of Manuscripts 118

Conclusion of the Dissertation 122

References 124

APPENDICES

A PSTs Observation Form 126

B Guided Questions for Weekly Journal 127

C PSTS Noticing Analysis with Five Dimensions Code Book 128

D Examples of Noticing Units at Each Score 133

E An Example of PCK Segments 135

LIST OF TABLES

Page

Table 2.1: Participants Information 44

Table 2.2: Noticing Score Rubric 45

Table 2.3: Sophistication of PSTs Noticing.....46

Table 2.4: PSTs Noticing Scores 47

Table 2.5: PSTs Noticing Scores across Weeks 48

Table 3.1: PCK Components Based on Magnusson et al. (1999).....74

Table 3.2: PCK Components and Learning Sources 75

Table 3.3: PSTs PCK Table.....77

Table 3.4: PSTs PCK map 80

Table 4.1: Distinctiveness Analysis Framework 112

Table 4.2: Gabby's Changes of Distinctiveness Processing.....113

LIST OF FIGURES

Page

Figure 2.1: PSTs Noticing Scores 49

Figure 3.1: An Example of PCK Components Interplay 76

Figure 3.2: PSTs PCK Components 79

CHAPTER 1

INTRODUCTION

Research of teacher education has been prevalent since 1960s (Abell, 2007). Different theoretical foundations and methodological strategies have been developed to understand teacher learning (Abell, 2007). The goals of this research have been to provide input to teacher learning and how teachers build their knowledge. This chapter contains information of the purpose of the study, the rational of the research and an overview of the following chapters.

Purpose of the Study

The purpose of this study is to learn how a group of prospective teachers (PSTs) acquired knowledge for science teaching and learning as they enrolled in a block of site-based courses designed to teach secondary science instructional methods, secondary science curriculum, as well as provide practical classroom experience. This study was informed by the scholarship of teacher noticing (van Es & sherin, 2012), critical incidents creation (Tripp, 1993), the psychological construct of distinctiveness (Hunt, 2006), and pedagogical content knowledge (PCK) (Park & Oliver, 2008). Using a frame of reference most nearly described by symbolic interactionism (SI), I investigated how prospective teachers, as they interacted with university instructors, mentor teachers, peers and students in the authentic context of this block of courses, noticed and built their knowledge about teaching and learning as described by the PCK framework. The question of how

distinctiveness could be used as a lens to unpack noticing and knowledge acquisition processes was also examined.

Rational

The concept of noticing was first introduced by researchers from mathematics education and has been making inroads in science education during the past two decades (Rodriguez, 2013). For this study, noticing was operationally defined as the act of teachers selectively directing their attention to some events and incidents happening in the midst of instruction (Jacobs, Lamb & Philipp, 2010). Empirical studies have shown that noticing is both a knowledge-based process, where it serves an indicator of the quantity and quality of teachers' knowledge, as well as a means through which teachers improve their knowledge for teaching and learning (Steffensky, Gold, Holdynski & Möller, 2015; Russ, 2018). Russ & Sherin's (2011) study with mathematics teachers as participants indicated that teachers' expectations and their knowledge about teaching and learning influenced their identification of unique events during instruction. This idea was confirmed by Meschede, Fiebranz, Möller & Steffensky's (2017) study in science education which investigated the relationship between teacher noticing and PCK, with preservice and in-service teachers as participants. Through quantitative analysis, their results revealed a moderate positive association between teachers' noticing and their PCK. Noticing research in mathematics education also showed that engaging in noticing practices improved teachers' knowledge described in terms of mathematics knowledge for teaching (MKT) and pedagogical content knowledge (PCK) frameworks (Kersting, Givvin, Sotelo, & Stigler, 2010; Moscardini, 2014). However, few scholars described science teachers' development of knowledge as a result of noticing.

Noticing studies in science education have focused on documenting teachers' development of noticing (Gotwals, Philhower, Cisterna & Bennett, 2015), described teachers' noticing in relation to different aspects of classroom activities, e.g. student thinking (Levin, Hammer, & Coffey, 2009), and investigated the impact of different interventions on improvement of teacher noticing (Bottoms, Ciechanowski, & Hartman, 2015; Seidel, Stürmer, Blomberg, Kobarg, & Schwindt, 2011). Researchers approached the concept of noticing as a skill that teachers needed to learn, and their objective was to teach teachers to direct their attention to specific aspects as encouraged by reform documents (Philipp, Fredenberg & Hawthorne, 2017; Weiland, Hudson & Amador, 2014). However, few papers examined science teacher knowledge associated with noticing or teacher knowledge development as a result of noticing practices. Questions of what teachers would notice if no specific directions were given, how outcomes of noticing indicate what knowledge for science teaching is possessed, and how knowledge for teaching and learning changes as teachers engage in learning to notice, remain unanswered.

As discussed above, the noticing literature focuses on equipping teachers with the skill to handle conflicting demands that require immediate attention and action during instruction. It is commonly seen in the literature that researchers employed different methods, such as lesson study, video clubs, and structured self-reflection and feedback, to improve teachers noticing in relation to specific aspects (Carter, Rogers, Amador, Akerson, & Pongsanon, 2016; Rosaen, Lundeberg, Cooper, Fritzen, & Terpstra, 2008; Weber, Gold, Prilop, & Kleinknecht, 2018). However, the psychological processes underpinning teachers' identification of, interpretation of, and/or responding to the events have received little consideration in our field. Similarly, in the mathematics education field, researchers have

also realized the lack of investigation of the psychological processes behind noticing and suggested to collaborate with educational psychologists in order to explore how teachers made in-the-moment decisions to support student learning (Criswell & Krall, 2017). Mathematics education scholars have described Gestalt psychology and research on perception and inattentional blindness may hold potential insights for understanding noticing (Criswell & Krall, 2017; Schnudrch, Kreitz, Gibbons, & Memmert, 2016). Although some of these theories have been applied in other fields, none of them has been used to unpack the mechanisms that underline teachers' practices of noticing (Wu & Zhang, 2013).

Distinctiveness is a psychological concept, which describes how an event can be labeled as distinctive when the details of it are easily remembered (Hunt, 2006). Psychologists have described this concept in a variety of ways. Hunt (2006) defined the psychological distinctiveness as "the processing of difference in the context of similarity" (p. 12). His study showed that the participants recalled the representative better if he/she identified one aspect of the representative that was different from others. Schmidt's (2006) described distinctiveness as a property of stimuli that "appear to attract special attention and cognitive resources" (p.47), and this is commonly found in the novel and significant events. He argued that novel stimuli were those unlike the information already existed in the memory, whereas the recognition of significant stimuli involved an appraisal process that "matches the important memory representations" (p. 60). From Schmidt's perspective, both novel and significant aspects of stimuli engage cognitive resources and lead to physiological responses. This perspective seems directly applicable to the study of teacher noticing in that teachers tend to allocate cognitive resources and respond to events that

indicate novel and significant aspects that either they have never seen before in the class or show some important cues of teaching and learning.

This work is based on the belief that, during instruction, some events and incidents are identified by teachers as distinctive due to differences that are noted within the context of similarity and that these distinctive events and incidents attract teachers' attention and allocation of cognitive resources. For example, if a student asked a question that the teacher had not expected, it becomes distinctive as it indicates novelty of the event; Or if an event generated a teacher's concerns about misunderstanding, it is distinctive in terms of its significance. Both situations are counted as distinctiveness as defined by Schmidt (2006) and teachers are likely to direct their subsequent attention to the specific details of that event. In this regard, the psychological concept of distinctiveness has the potential of facilitating our understanding of how teachers process the differences among events and incidents of which they are confronted in the midst of teaching and why they choose to pay attention to some events instead of others. As discussed above, this process of selectively paying attention to some events is described as noticing (Sherin & Van Es, 2012).

Noticing literature has suggested that teacher noticing is based on teacher knowledge about teaching and learning, as well as previous teaching and learning experiences (Talanquer, 2015). Based on both noticing and distinctiveness research, we hypothesize that the recognition of the distinctiveness of the event serves as the stimulus for teachers to initiate spontaneous reflection and in the moment of recognition, the stimulus attracts teachers' special attention and they allocate cognitive resources to make decisions about possible strategies for responding to the related action, and that through the recognition of distinctiveness of the event and the subsequent cognitive processing/reasoning, which are

defined as noticing, teachers experience a growth of their knowledge. The examination of the mechanism of teacher noticing, with distinctiveness as lens, will shed light on teachers' knowledge development through reflection-in-action.

This study focused on prospective teachers' acquisition of knowledge as they participated in a block of site-based secondary science education courses leading toward secondary science certification. Through investigating prospective teachers' noticing, their knowledge acquisition process was discovered. The mechanism of noticing and knowledge development as a result of noticing was unpacked by employing the psychological construct of distinctiveness as a lens. This study contributes to our understanding about teaching noticing and teacher learning in science education, which could inform how we prepare science teachers.

Overview of Chapters

This dissertation is comprised of three manuscripts. The first manuscript (Chapter 2) is titled "What do they see? Characterizing prospective science teachers' noticing during a block of science teacher education courses." In this manuscript, prospective teachers' observational journals were analyzed both qualitatively and quantitatively in order to characterize their noticing, the ways prospective teachers altered their noticing across the semester, and how their noticing are different from each other. The research questions of this manuscript are: what do prospective teachers notice as the enroll in the site-based science education block of courses? In what ways do the PSTs alter their approaches to notice across the semester? What are the variations of PSTs noticing in terms of their noticing sophistication?

The research objectives of the second manuscript (Chapter 3) are to explore the prospective teachers' knowledge development as described by the PCK framework suggested by Park & Oliver (2008) as they enroll in the block of courses and to understand how prospective teachers' noticing practices support their knowledge development. The title of this manuscript is "Exploring prospective teachers' development of knowledge for teaching during a block of secondary science education courses: the impact of noticing". Research questions of this manuscript include: (1) How does noticing support prospective teachers' development of knowledge as described by PCK framework? (2) What does noticing reveal about the potential sources of prospective teachers' knowledge development? (3) What do the events and incidents prospective teachers noticed indicate the development of and interplay between the components of PCK model? Qualitative methods, including the constant comparative method and thematic analysis were employed to analyze the participants' interviews, their observation journals, and the researcher's observation notes. A cross-case comparison was used to document the variations of knowledge development among the participants.

The third manuscript, Chapter 4, is titled as "Employing the concept of distinctiveness to understand prospective teacher noticing and acquisition of knowledge: A case study". The focus of this manuscript is on investigating the use of distinctiveness as a lens for understanding the mechanism of prospective teacher noticing and development of knowledge. Two research questions included: To what extent can the prospective teacher's attendance to some events be attributed to their perceptions of the distinctiveness of the events? And how does the use of distinctiveness framework facilitate our understanding of teacher's processing of incidents and events she noticed as well as the growth of their

knowledge for teaching? One participant's critical incidents constructed across the semester is the major data source for this manuscript.

Finally, chapter 5 summarizes the major findings of this research. Implications and further research ideas are also included in this chapter.

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CHAPTER 2

WHAT DO THEY SEE? CHARACTERIZING PROSPECTIVE SCIENCE TEACHERS' NOTICING DURING A BLOCK OF SCIENCE TEACHER EDUCATION COURSES[1]

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Abstract

Teacher noticing describes the processes of teachers' identification, evaluation and interpretation of the events and incidents in the midst of instruction. Despite bulk of research has been devoted to understanding how prospective teachers can improve their noticing skill, few focused on eliciting what they notice in authentic context when there is no given specific direction. This study seeks to characterize a group of prospective teachers' noticing as they participated in their practicum, observing and assisting teaching. Through a qualitative analysis with two different analysis approaches, their noticing was characterized and their changes in the way of noticing was documented across one semester. Findings suggest that prospective teachers' development of noticing is idiosyncratic, unrelated to which classrooms they were put or who they worked with and that their noticing change is not a one directional or quick process. The findings of this study add to our understanding of how prospective teachers learn in the practicum, which will inform how teacher educators can better support prospective teachers.

Introduction

The concept of teacher noticing was first introduced as a scholarly construct by the researchers from mathematics education (Goodwin, 1994). Science education scholars started to conduct research about noticing approximately two decades ago (Rodriguez, 2013). Researchers have expressed a variety of opinions about interpretations of the construct (Russ & Sherin, 2011). Some scholars understand noticing as teachers' observation of different aspects of classroom activities (Star & Strickland, 2008). This view focuses on what teachers attend to/what they don't attend to when they engage in teaching. Others believe that noticing includes not only teachers' initial attention but also their

following interpretations of what they have noticed (Sherin, 2007; Sherin & van Es, 2009). Additionally, Jacobs, Lamb, & Philipp (2010) defined teacher noticing as teachers' attention to, interpretation of, and responses to events and incidents. In addition to noticing, scholars have also used different terms such as professional vision and responsive teaching, to represent teachers' attending to, interpretation of, and/or responses to classroom events, (Dalvi & Wendell, 2017; Steffensky, Gold, Holdynski & Möller, 2015).

The bulk of noticing studies have investigated ways to equip teachers with the skill so that they can direct their attention to specific aspects of classroom activity as encouraged by reform documents (Levin, Hammer, & Coffey, 2009; Philipp, Fredenberg & Hawthorne, 2017; Weiland, Hudson & Amador, 2014). However, few papers examined what and how teachers noticed if no specific direction was given. Building on the framework of symbolic interactionism (SI), the purpose of this paper is to understand what and how prospective secondary science teachers notice as they observe and assist their mentor teachers when they enroll in a block of teacher education courses.

Theoretical Framework and Literature Review

Symbolic interactionism (SI)

This study is guided by the sociological theory of symbolic interactionism. Under the constructionism epistemology, which posits that truth or meaning is not discovered but constructed through engagement with reality (Crotty, 1998), symbolic interactionism (SI) is interpretive in nature and emphasizes that individuals make and modify meaning making through social actions, interactions, and reactions (Prasad, 2015).

Symbolic interactionism is a variant of interpretive scholarship. Symbolic interactionists believe that objects and events have no intrinsic meaning, and it is

individuals that assign meanings to them through everyday interactions (actions) (Prasad, 2015). The name "symbolic interactionism" reflects the two central concepts in SI: the meaning (symbol) and action (interaction). The symbolic interactionists assume that "the self-images influence the process by which people assign meaning to objects and events and mediate their eventual choices of meaningful action." (Prasad, 2015, p. 22).

In the SI theory, all social phenomena are symbolic. Individuals hold different meanings for objects, events and actions (Prasad, 2015, p. 21). Symbols are social objects, which are used to represent whatever individuals agree they shall represent (Charon, 2001, p. 46). Symbols are the building blocks of our human society. SI emphasizes the symbolic character of everyday life. First, the objects are not revealed as what they are, the individual labels objects with symbols. People do not directly respond to the reality but to the social understanding of reality. Furthermore, the social environment is not a physical stimulus to humans, "it is interpreted through symbols that we apply to it" (Charon, 2001, p. 61). Through the use of symbols, human beings do not respond to the world passively but create and recreate the world they live in through naming, categorizing, and perceiving.

Social interaction means that "actors take one another into account, communicate, and interpret one another as they go along" (Charon, 2001, p. 150). All the interactions are symbolic in that the acts have meanings to the actor him- or her-self and are also interpreted by the target of the acts. These interactions form an iterative process, as Blumer stated (1969, p. 20), "This process of interaction consists of making indications to others of what to do and in interpreting the indications as made by others."

Teacher noticing

Teaching is a complex endeavor, which requires teachers to attend to some activities and disregard others in the midst of instruction to monitor the complicated environment of classrooms (Erickson, 2010). An important objective of teacher education is to equip teachers with knowledge and skills to sift through the complex classroom environment and notice important aspects of teaching (Teuscher, Leatham & Peterson, 2017).

Definition of noticing

As discussed above, researchers employed different means to define noticing. In their work of investigating children's mathematical thinking, Jacobs, Lamb, & Philipp (2010) defined professional noticing with three interrelated parts: attending to students' strategies, interpretation of students' understanding, and decisions on how to respond. Their study suggested that the three specific skills, attention to, interpretation of and decisions on how to respond, were effective for the conceptualization of noticing. Barnhart & van Es (2015) adopted their definition and examined the relationship among attending to, interpreting of and respondence to student thinking with a group of preservice science teachers as participants. Benedict-Chambers (2016) also built on Jacobs, Lamb, & Philipp's (2010) work and investigated the novice science teachers' skills of identifying noteworthy events, interpreting meanings of the events, and deciding how to respond to the events.

Sherin & van Es (2014) characterized teacher noticing as professional vison, which involved both attention to classroom events and incidents and knowledge-based reasoning based on teachers' knowledge and understanding. Many researchers have investigated teachers' professional vison. For example, Todorova, Sunder, Steffensky & Moller (2017) studied pre-service teacher' professional vision and their results showed that this skill was

content specific. Seidel, Sturmer, Blomberg, Kobarg and Schwindt (2011) and Roose, Goossens, Banderlinde & Vantieghem (2018) also adopted this definition and examined teachers' professional vison.

Star & Strickland (2008) argued that the component of "attending to" was fundamental to teacher noticing, that teachers could only make sense of what was noticed, and that teachers' skill of noticing was dependent on what they paid attention to. They investigated what preservice teachers noticed and what they missed in viewing a classroom lesson.

Measurement of teacher noticing

Measuring teacher noticing is a complex task. Four common approaches have been used to document evidence of noticing, which include: wearable cameras, artifacts from other teachers' class experiences, artifacts from teachers' own classes, and researchers' inferences from observations of teacher instructional practices (Jacobs et al., 2010). One commonly used strategy is that researchers first present some artifacts (e.g., video recordings of teaching practices) for teachers to examine, and then ask them to reflect on what they have noticed from these artifacts. These reflections can take many forms, such as semi-structured interviews led by researchers (e.g. Luna, Selmer & Rye, 2018; Russ, 2018; Sezen-Barrie & Kelly, 2017), group discussions (e.g. Siry & Martin, 2014), and written reflections (e.g. Kleinknecht & Groschner, 2016), etc. Among them, videos are commonly used artifacts for teachers to examine because they captured the richness of classrooms and support teachers' reflections about their instruction (Sherin, Russ & Colestock, 2011).

Aspects of noticing being investigated

Most researchers investigated teacher noticing in relation to some specific classroom issues as advocated by reform documents. For example, teacher noticing in relation to student thinking is a popular topic as research and reform documents highlighted the importance of teachers' design and revision of their instructions based on student understanding (Weiland, Hudson & Amador, 2014). Talanquer, Bolger and Tomanek (2015) investigated prospective teachers' noticing to student understanding by analyzing students' written work samples. Their study illustrated the high level of sophistication of teachers' noticing and interpretation of students' understanding and suggested a framework for supporting teachers' ability to notice and interpret student work. Other aspects of noticing discussed included noticing applied to instructional supports, classroom management, and teachers' own practices (Bottoms, Ciechanowski & Hartman, 2015; Siry & Martin, 2014; Steffensky et al., 2015).

Research Questions

The purpose of this research is to characterize the noticing of a group of prospective science teachers (PSTS) as they enroll in a block of site-based courses leading to secondary science certification. PSTs pay attention to a variety of events and actions about teaching and learning as they observe and assist cooperative teacher instruction, engage in communications with cooperative teachers, students in the classroom, their university instructors, and their peers. Under the guidance of SI theory, PSTs interact with different agents in the authentic context. It is through these interactions that PSTs make selective choices about what events and incidents they pay attention to and how they assign meanings to them as a result of the interactions, which are the symbols they make. Their

noticing is different since their observation and interpretation of the events and incidents are based on their understanding about teaching and learning, their own learning experiences, and their previous teaching experiences. It is through multiple ways of noticing that PSTs build their knowledge and skills and improve their understanding about teaching and learning in different paths. Engagement in authentic teaching context will offer prospective teachers' opportunities to make sense of actual instruction and immerse in teaching. Eliciting prospective teachers' characteristics of noticing in real teaching context will allow researchers to capture prospective teachers' in-the-moment decision making and further understand how they learn to teach.

The research questions that guided the study include:

1. What do prospective teachers notice in classrooms as they enroll in the site-based science education block of courses?
2. In what ways do the PSTs alter their approaches to noticing across the semester?
3. What are the variations of PSTs noticing in terms of their noticing sophistication?

Method

The data analyzed in this manuscript is part of a larger study, the objective of which is to understand PSTs knowledge development as they enroll in a block of sit-based courses leading to secondary science certification. I investigated six PSTs noticing as they observed and assisted their mentor teachers in one portion of the block of courses, the practicum in science teaching. The six PSTs also conducted instructional activities as the primary teacher on limited occasions in their practicum classrooms.

The research context

In the Fall of 2018, a cohort of prospective secondary science teachers enrolled in a site-based block of courses, including secondary science methods, secondary science curriculum and practicum in science teaching. The PSTs were required to attend the site-based courses three mornings each week for the entire semester. Each day began with a 75-minute class period with their university instructors that was conducted in a classroom at in a local middle school and was followed by a 75 to 90 minutes practicum observation experience in either that same middle school or in a local high school. The goals of the block of courses were to provide PSTs opportunities of making sense of science topics, exploring fundamental ideas in science teaching and transforming their understanding of science teaching. While in their practicum classrooms, PSTs observed the cooperative teachers' classes, assisted teaching as needed, taught once or twice, and were provided opportunities of participating in other activities, such as morning tutoring and sitting in teachers' co-planning meeting.

Participants

The participants of this study are 6 science PSTs (each with a science content specialization in biology) who enrolled in the courses and volunteered to participate in the study. They were assigned to their first practicum placement for 8 weeks before transferring to another school for the following 6 weeks so that they could observe both middle school and high school science instruction. All six PSTs worked in groups of two except Carlie, who was by herself in her first placement. Rosie was in a group with another PST who did not participate in this study. Jane and Gabby's group and Rosie exchanged their placements

in week 9 and Carlie exchanged her placement with Cary and Simon's group. Participates' information is described in Table 2.1 and all the names used are pseudonyms.

Data sources

The major data source for this study is PSTs observation journals. PSTs started their practicum in the second week of the semester and were required to write their observation journals each day and submit their journals at the end of each week. For their observation journals, they were asked to write down what they noticed, why they paid attention to the events and incidents, and create a report of a critical incident based on their weekly reflections. An observation form and prompts for critical incident creation were provided.

Observation form

The participant PSTs were asked to make notes about what they noticed as they engaged in interactions with other agents every time they were in the classes. An observation table was provided, which asked them to make notes about what stood out for them and their thoughts in the moment they identified the events and incidents (Appendix A). In addition to their observations, PSTs were also advised to include their communications with cooperative teachers, students, peers, and university instructors.

Critical incidents creation

At the end of each week, PSTs were asked to construct one critical incident based on their noticing during the week. I employed Tripp's (1993) critical incident creation framework to construct guided prompts for their reflection (Appendix B). PSTs were asked to choose at least one question from each category to construct their written reflections.

Supplementary data sources

Supplementary data sources include background interviews which probed their previous teaching related experiences, as well as researcher's observations of PSTs in their practicum.

Data analysis

To analyze PSTs noticing, I began by segmenting PSTs weekly observation journals to analysis units with the aid of qualitative data analysis software Atlas ti.. One analysis unit contained one idea in which a particular event and incident was discussed. Each time the writing shifts to a different event, it was coded as another analysis unit.

After segmenting the data, I analyzed the analysis units with two approaches: coding the analysis units with five dimensions (see below for details of these dimensions) and scoring each analysis unit with a rubric adapted from the learning to notice framework (Jacobs, Lamb, Philipp, & Schappelle, 2011; Sherin & van Es, 2009; van Es, 2011; Van Es & Sherin, 2008). Deductive and inductive methods were employed for coding each analysis unit with five dimensions: domain, specificity, stance, agent, and topic. I coded deductively for the first three dimensions, domain, specificity, and stance, and inductive coding for the remaining two dimensions, agent and topic. The first dimension, domain, concerns whether the events and incidents are specific science related. Domain-independent refers to events that can happen during any classes, e.g. students' disciplinary problems. Domain-dependent refers to events that only happens in science classes, e.g. students learning difficulty with an abstract science concept. The dimension of specificity examines the richness of PSTs description of the events and incidents they have noticed. Overall description of the events and incidents flow where the description is lacking in specific

details is coded as *general* whereas events and incidents descriptions with details of what happened is coded as *specific*. The third dimension, stance, focused on how the PSTs analyzed what they noticed (description, evaluation, and interpretation). Description refers to PSTs recounting of what happened; Evaluation refers to PSTs comments on the events and incidents they have noticed, e.g. if the instructional strategy is effective; Interpretation refers to PSTs discussions of reasons of why the events and incidents happened or how the events and incidents relate to general principles of teaching and learning. The dimension of agent refers to who the PSTs focused on, e.g. the mentor teacher, all students, specific students, etc. The dimension of topic inspects what PSTs noticed. More detailed codes, descriptions, and quotes examples are listed in Appendix C. The percentages of codes within each dimension was calculated.

I used a second method of analysis also related to noticing. To compare PSTs noticing and track their changes of noticing across this semester, I adapted van Es (2011) framework for learning to construct my rubric (see Table 2.2). Next, I used this rubric to score the PSTs analysis units. PSTs average scores of each week was calculated: dividing the total score by the number of analysis units within one week. Different from analyzing the analysis units with 5 dimensions, this *learning to notice* framework focuses on analyzing teacher noticing from the lens of developmental trajectory, which examines both what and how teachers have noticed together. The objective is to characterize overall noticing with numbers which facilitates tracking of PSTs noticing development. At score 1, PSTs attend to wide range of issues, i.e. whole class discussions and class flow, and provide a general impression of what they noticed. Some examples include: “what a nice lesson”, “the activity is really engaging”, and “I feel sad that the students didn’t do their work”, etc. At

score 2, PSTs primarily identify the events and incidents in relation to their mentor teachers' instruction. They begin to identify the noteworthy events and incidents that happened in the classes, provide evaluations of the events and incidents, and start to check students' behaviors. At score 3, PSTs turn their attention to students, including students' understanding, learning difficulties, and students' behavior. They provide their evaluations of the events and incidents they've noticed and use the specific noteworthy events and incidents as evidences to support their evaluations. At score 4, PSTs attend to both the mentor teacher's instruction and student learning/behavior. At this level, PSTs make connections between the two. PSTs also propose alternative pedagogy solutions based on their interpretation of what happened. Examples of noticing units at each score can be found in Appendix D.

Results and Discussion

The objective of this study is to understand PSTs noticing as they enroll in and continue through a site-based block of science education courses. As was described in the previous section, I employed two analysis approaches to analyze their weekly observation journals. In this section, I will begin by describing the PSTs practicum and then present analysis of their noticing.

Jane, Gabby and Rosie's practicum

Jane and Gabby were put in a high school honor biology class for their first 8-week practicum placement. Their mentor teacher, Mr. L, has been teaching different science subjects, physics, physical science, environmental science and biology over ten years. There were extra tables in the classroom during their observation period, so Jane and Grace had their own seats and were allowed to use their own laptops to take notes. They usually

jotted down their observation notes on their laptops and finished their daily journals before leaving the practicum. In the second segment of practicum, they were placed in a middle school life science class, in which they observed their mentor teacher Mrs. T for the last six weeks of the semester. There was no extra table at which they could sit in Mrs. T's classroom, so they made notes with their notebooks and walked around the room observing and helping students most of the time.

Rosie was with Mrs. T for her first 8-week placement and observed in Mr. L's classes for the remaining 6 weeks. Her experiences mirrored those of Gabby and Rosie.

Cary, Simon and Carlie's practicum

Cary and Simon were with Mrs. P who taught middle school life science for their first 8-week practicum segment. They were seated at the two extra tables and both of them used notebooks to take notes when they were in the classes. Mrs. P usually spent 10 minutes debriefing with Cary and Simon and answering any questions they had after they finish their observation because her planning session was in the following period. In their second placement, they worked with Mr. Y in a high school inclusion biology class. Mr. Y's room also had extra tables and they could sit with the students.

Carlie began her first placement with Mr. Y who has been teaching for 17 years and she worked by herself. She spent the last six weeks with Mrs. P with another PST, who was not a participate for this study. Carlie took intensive notes as she was in the classes with her notebooks.

Analyze PSTs noticing with 5 dimensions

I analyzed PSTs noticing with five dimensions and calculated the percentages of codes within each dimension across the semester (see Table 2.3). In the dimension of domain,

five out of six PSTs noticed classroom events to accumulate similar ratio of domain-dependent to domain-independent events and incidents except Gabby, who paid more attention to domain-independent issues. This suggests that most PSTs paid attention to a wide range of issues including both science-specific and non-science-specific. Gabby's journals contained more instances of events and incidents not specifically related to science teaching and learning, such as students' behavior, class flow, resources her mentor had, and mentor teacher's general way of interacting with students, etc. For example, in week 2, she noticed a quiet student who didn't cooperate with his partner very much.

> "Every pair of students is working by each other except one pair - I notice that he usually keeps to himself most of the time; at previous lab, pretty quiet and doesn't talk much; teacher kind of noticed but did not really do anything; not sure if he noticed. Kind of feel bad for the student; feel like I can't do much; felt kind of helpless." (Gabby, 2:19)

Gabby noticed this student's behavior of "keeps to himself" but she didn't mention if this was because of the science instruction in the class so I coded it as domain- independent, which means not related to science teaching or learning.

Similarly, in the dimension of specificity, five of the PSTs described the events and incidents they have noticed in great details. However, Simon's journal contained more overall descriptions of what happened in the classes. In one of his journals, Simon stated:

> "Class today was very dynamic. Following the usual daily warm-up activity, students split into pairs. Each pair of students collaborated to answer each of 6 essential review questions on sticky notes. Students then stuck their answers onto large, corresponding pieces of paper arranged

> around the classroom, each of which asked an essential question. Students returned to their desks and were then split into six groups. Each group was given a small amount of time to review the questions and the answers left by the rest of the class, then rotate to the next posted question. The class then convened to discuss the responses they saw. This was a great example of how a teacher can keep students moving, active, and collaborative." (Simon, 5:19)

In this journal, Simon described what the students did from the beginning to the end of the class to illustrate his claim that the class "was dynamic" and students were kept "moving, active, and collaborative". He described students moving among different activities in a general way without mentioning the exact tasks that they were engaged in.

Under the dimension of stances, Carlie, Cary and Rosie's journals contain similar amount of descriptions, evaluations and interpretations. While Jane, Gabby and Simon's journals have less interpretative events and incidents comparing with the percentages of descriptive and evaluative events and incidents. About 65 percent of Gabby's noticing is evaluative, in which she began with a description of what happened and followed with her comments about whether the event or incident was beneficial for students learning. Close to 60 percent of Simon's journals only described what the events and incidents were without providing his opinions on what happened. Jane's noticing contains similar amount of descriptions and evaluations. In one of her journals, which was coded as descriptions, she described how her mentor teacher, Mr. L, prepared students to be ready for the lab:

> "Before lab, he went over the instructions that students should follow and once they went to the lab room. He told them his clear expectations and

> explained how they should use the microscope as a tool. Mr. L allowed the students to complete the lab in group." (Jane, 1:10)

In this journal, she gave information of her mentor teacher's instruction before a lab but didn't provide her evaluation of whether these strategies were helpful.

Based on the topics they noticed, the six PSTs can be divided to three groups. The three topics Gabby, Rosie, Simon and Carlie have noticed most are instructional strategies (IS), students learning (SL), and classroom management (CM). Jane noticed IS, SL and classroom flow (CF) most and Cary noticed IS, CF, and CM most. The top three topics PSTs noticed are over 65% of all the topics.

With regard to who the PSTs paid attention to, five of the PSTs noticed the entire class of students and their mentor teachers (MT) most, excluding Rosie, who paid more attention to specific students instead of regarding all students as one group. For the five PSTs who noticed the entire group of students and their mentor teachers most, I also checked the cooccurrence of the codes MT and all students as well as MT and specific students. It turned out that among 190 events that the five PSTs directed their attention to their MT, they also noticed what all students were doing in 32 of them, and there were 28 cases that they noticed MT and specific students at the same time. These results show that when PSTs noticed what their MTs were doing, about one third of the time they also checked on the activities of students. Similarly, 20% of the 78 times when PSTs noticed students learning, they were also paying attention to the MT's instructional strategies. For example, Cary described one event about how his MT dealt with behavior issues.

> "The second incident that stood out was the students were acting out (partly because they were not engaged, and partly because Ms. P had her

> back to many of the teams more frequently). Ms. P did catch some rough play in the lab and held four students behind, in the lab, to reprimand them. I agree with how Ms. P handled the bad behavior (swinging one student from the arms and legs like a jump rope) because this behavior was not typical from these four students. She treated the situation very seriously and the students were very well behaved when they returned from the laboratory." (Cary, JNL 4:22)

In this example, Cary observed students' behavior, how Ms. P dealt with the situation and the effects of her strategies: "well behaved after return". In this case, he noticed both the specific students and his mentor teacher Ms. P.

In the case of Rosie, 12.5% of her noticing to MT also includes specific students. However, Rosie's data showed no co-occurrence between instructional strategies and students' learning, which indicated that she paid attention to the two topics separately.

Comparison of PSTs noticing with 5 dimensions

Carlie's and Rosie's noticing patterns are very similar across the five dimensions even though they had never worked together in their practicum placements. Their noticing in the dimensions of domain and stances are almost the same. There is only 5% of difference in the dimension of specificity of their noticing. In the topic dimension, both of them noticed IS, CM and SL most. The similarity of their noticing was also apparent in the dimension of agents, where 50% of Rosie's noticing focused on her mentor teachers just as was true for Carlie. One small difference between Rosie and Gabby's noticing in the domain of agents is that Rosie paid more attention to specific students in the classes while Carlie tended to focus on all students. One possible reason is that Rosie volunteered as a science tutor in the

morning before she came to observe in her MT's classes. This experience provided her opportunities to interact with individual students.

In examining the noticing patterns of PSTs who worked together, I found that the both Jane and Gabby, and Cary and Simon's patterns were different at least in three dimensions from each other. Jane paid equal attention to both domain-dependent and domain-independent issues, had equal amount of descriptive and evaluative noticing, and focused more on students learning (28.7%). In contrast, Gabby's journal contained more domain-independent issues, about 65 percent of her noticing was evaluative, and 50.6 percent of her noticing was focused on instructional strategies. Their noticing is similar in the dimensions of specificity and agents. Both of them gave very detailed information of what happened in the practicum and above 70 percent of their journals were about all students and their mentor teacher. Cary and Simon's noticing are similar in the dimensions of domain and agents. Both of them paid equal attention to domain-independent and dependent issues and focused on their mentor teachers and all students in the classes. However, Cary's observations were more specific, his stance was more evaluative but also has a high percentage of interpretation, and he paid his attention to instructional strategies, students learning and classroom management. Most of Simon's noticing was general descriptions of what happened without providing his comments on the events and incidents and he focused on the flow of the class and the instructional strategies his mentor teachers used.

Analyzing teacher noticing with adapted learning to notice rubric

Overall noticing

The percentages of PSTs analysis units at each score are described in Table 2.4. All PSTs scored 1 and 2 more than 3 and 4. Rosie has the highest percentages of score at the 3 and 4 levels (38%) while 98% of Simon's noticing is at score 1 and 2. With regard to the PSTs who worked together, Jane has the highest percentage at score 1 while Gabby scored 2 most. Similarly, Cary's noticing was scored 2 most but Simon has the highest percentages at score 1.

As described above, Rosie's noticing has the highest percentage at score 3 and 4. Nineteen percent of her noticing segments contained her identification of noteworthy events and incidents and she also connected student behavior with teacher instruction. In one of her journals, she described how her mentor teacher, Mrs. T's strategy

> "Today, students were split into groups to work on creating a food web together. Just before we handed out……Mrs. T paused class, and designated exactly 1 minute for everyone to tell their group something about themselves. One student (I'll call Max)……Mrs. T told us that he was mostly in a self-contained special education class in previous years, and this is his first experience being in regular classes full-time. During the activity, the girl across from Max shared that he aspired to be a famous rapper. Mrs. T told him he was welcome to perform a (clean) rap for the class if he ever wanted to.

> Later, when the class was doing a Gallery Walk of the food webs they'd drawn, I heard Max quietly preforming improvised raps to go with each food web for his group members. Each time they rotated, one of the other kids would go "Okay Max, do this one." Even when he wasn't showing off his talent, the fact that his interest had been accepted by the others seemed to give him a new sense of confidence.
>
> This week I've been thinking a lot about promoting positive relationships between students. I felt the "take one minute" activity was a concrete and efficient way to foster this sense of community." (Rosie, 6:10)

In this example, Rosie first described Mrs. T's strategy of letting students get familiar within groups, then she focused on one student's, Max, behavior change and ultimately connected this event to more broad topic-"promoting positive relationships between students".

Based on the PSTs noticing scores, they can be divided into two groups which will be labeled as: Jane, Carlie and Simon's group, and Rosie, Gabby and Cary's group (see Figure 2.1). Among the four scores, Rosie, Gabby and Cary scored 2 most even though their percentages at score 2 are different. Gabby has the highest percentage, which means 55% of Gabby's analysis units contained her observation of her mentor teachers' instructional strategies and she also commented on them. For example, in one of her journals, she shared:

> "*What stands out to me*: Mr. L goes over new topic web-quest students will complete after test, before test; wants this to be an intro into next unit.

> *My thinking in the moment*: Makes sense and is logical that you would introduce the next assignment before starting test because everyone finishes test at different pace." (Gabby, 2:27)

In this quote, Gabby depicted how Mr. L introduced the web-quest before students started their daily quiz so that students would transit smoothly to the new unit even though they would spend different on their quizzes. She not only identified the strategy but also gave her comments and evaluations about it.

Jane, Carlie and Simon's journals scored 1 most. In Simon's observation journals, 62% of the analysis units were scored at 1, meaning that Simon attended to the whole class and provided the general impressions of what happened in the class. For example, in week 5, Simon described a lab problem he noticed:

> "Students worked in-lab to use microscopes find nematodes taken from soil samples. The design of the lab used a method of drawing water samples that did not work very well to include nematodes, so most students spent the majority of the class frustrated and unable to find what they hoped and expected to find." (Simon, 5:28)

Simon described the lab and students learning difficulties. In this case, he saw the class as a whole and stated that most students were frustrated.

Noticing across the semester

PSTs noticing developed differently across the semester (Table 2.5). Rosie and Gabby increased their scores from the beginning to the end of the semester. Jane, Carlie and Cary's noticing scores remained stable across the semester with only one or two weeks increase

or decrease. Simon's score changed between 1 and 2 several times and never stayed stable to one score.

Rosie and Gabby shifted from noticing whole class situations to focusing on noteworthy events and incidents happening within the group of students in the classroom, and from providing their general impressions to elaborating on how specific events and incidents connect to broad principles of teaching and learning. At the beginning of the semester, the first week, Rosie noticed her mentor teacher, Mrs. T used a ticket-out-door activity to do differentiation. After she described the activity, she commented:

> "I've always liked the idea of differentiation, but I wasn't sure how to do it efficiently. This method of using a quick "ticket-out-the-door" activity to decide groups and making small adjustments to an assignment was relatively easy to implement, and the students seemed to respond well to it. I could definitely see myself doing this in my own classroom." (Rosie, 6:4)

Here she mentioned her impression of "students seemed to respond well" and evaluated the approach as "easy to implement". In comparison, in the final week, when she described another strategy her mentor used, she wrote:

> "Today the teacher began class with a news clip on a recent breakthrough in genetic research. He said he had heard the story on the way to school that morning. I noticed that students in his class had shown considerable interest in the topic of gene editing and technology when they first discussed the topic several weeks ago, and since then he has begun the class with news stories related to this topic on multiple occasions.

> I know in our own classes, Dr. O frequently begins class with some form of current event or story. In his class as well as the high school class, it is definitely an effective way to bring students' attention into the topic of the day by making the content relevant." (Rosie, 6:50)

In this journal, Rosie related students interests in the topic to the teacher's use of stories about the same topic. She then connected the teacher's sharing of news clip to the broad principle of science teaching: make science concepts relevant. These two journals showed Rosie's shift from evaluating of events and incidents to connect students learning with teacher instruction, as well as relating it to broad science teaching principles.

Compared with Gabby and Rosie's increase of noticing scores, Jane, Carlie and Cary's noticing scores remained the same score (score 2) in 12 out of the 14 weeks. Carlie scored 1 in week 9. One possible reason is week 9 was her first week at her second placement and her mentor teacher was not there at the first time she came to observe. On that day students were assigned to watch a movie with the substitute teacher, so she didn't get a chance to see much instruction.

Simon's scores changed from 1 to 2 and 2 to 1 six times during the semester. His journals contained a lot of descriptions of what happened in the classroom without identifying events and incidents that drew his attention. He also included some instructional strategies his mentor used. In one of his score 2 journals, he shared:

> "Today, students watched two videos in class. Each student was given a set of questions to answer during the video, with the questions spread out to keep students' attention for the whole video. This is a better strategy than the one my 7th grade science teacher used, in which I just had to write

> down 10 facts from the video. In my case, I would quickly write down the first 10 facts presented, and quickly tune out the video." (Simon, 5:32)

Simon stated that students' answering questions as they watched the video kept their attention and compared this event with his own learning experiences to illustrate why this way was better. In this example, he identified the event of giving students questions to answer during video and provided his evaluations.

Conclusion

I analyzed six PSTs noticing with two methods: analyzing with five dimensions and with the adapted learning to notice framework. Based on the analysis results with the two approaches, two conclusions can be made.

Conclusion 1: the PSTs noticing is idiosyncratic and are not related to the context, in this case, which classrooms they were placed for their practicum experiences.

Based on the above analysis, the PSTs who worked together exhibited different patterns of noticing. Among the five dimensions, Gabby and Jane's noticing is different at four of them. The one dimension they are in common is specificity, which means both of them described the details of events and incidents they have noticed. With regard to their noticing scores, Jane scored 1 most while Gabby scored 2 most. Gabby experienced a development of her noticing during across the semester, but Jane's noticing score remained 2 for 12 of the weeks, except for week 2 and week 7 when she scored at 1. Similarly, Simon and Cary's noticing are only similar in the dimension of domain. About 58% of Simon's noticing lacks detailed descriptions of what happened, he took the stance of description at about 58% when he analyzed the events and incidents he noticed, and he attended to the whole students in the classes instead of his mentor teachers as Cary did. Cary's noticing

scores didn't change much during the 10 weeks but Simon's scores kept fluctuating between 1 and 2 across the semester.

Another interesting point is that Rosie and Carlie's noticing is very similar in every dimension even though they never worked together in the practicum or worked with the same mentor teacher. They both paid equal attention to domain-dependent and domain-independent issues; 90% of their notes provided specific information of what had happened in the classes; their stances of noticing were equally distributed among descriptions, evaluations and interpretations; they focused on their mentor teachers' instructional strategies and all students' learning.

These data showed that when the PSTs were not provided specific directions of what to focus on, they chose to notice various issues in the classes as they observed. The contexts, including their peers, with whom they worked in a group and the classes they were in, do not play a big role on what and how PSTs choose to pay attention to.

Conclusion 2: The PSTs development of noticing is a slow process.

This study collected PSTs noticing data for 14 weeks in one semester. Based on the analysis, I found that the PSTs noticing changed slowly. Even though two PSTs noticing scores increased at the end of the semester, one of them, Gabby's scores stayed stable for 11 weeks before changed to score 3. Her noticing was categorized as increasing because she began with score 1 in the first week. Rosie started with score 2 in week one. Her score increased to 3 in week two and three but came back to score 2 in week 4 through 6, and finally she scored 3 in week 13 and 4 in week 14. Rosie's noticing is more apparent as an increasing pattern but still there are some fluctuations in the middle of the semester. Jane and Carlie's noticing scores were at 2 for 12 weeks. Carlie scored 3 in week 6 but her score

went back to 2 in the following weeks. In his 10 weeks of observation journals, Cary scored 2 for 8 weeks. Simon's scored changed between 1 and 2.

Based on these results, even though Rosie and Gabby's score experienced increase, their score is not a direct increase from 1 to 4. Considering the other four PSTs whose scores changed little during the semester, I can conclude that changing of PSTs noticing as they are in the practicum is neither a one directional nor quick process.

However, given this conclusion, it is important to note that most of the PSTs began the semester as complete novices with regard to their experience in observing science classes. Further, it is important to note that the actions of both students and teachers that were observed by the PSTs were different every day when the PSTs were in the classrooms. A third factor was also a powerful shaping force in the PSTs learning from their observation: the PSTs were observing in their practicum placement classrooms on Monday, Wednesday and Friday each week and not able to observe the complete implementation of the curriculum. For the most part, these factors listed above were not captured by the data collection in the students' journals. But, the combined impact of these factors contributes to the conclusion that the development of noticing as described in the journals by the PSTs is neither a one directional nor a quick process.

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Table 2.1 Participants Information

Name	**Gender**	**Level**	**Placement information**
Jane	Female	Undergraduate	HS: 8 weeks with Mr. L (Honor class) MS: 6 weeks with Ms. T (On level)
Gabby	Female	Undergraduate	HS: 8 weeks with Mr. L (Honor class) MS: 6 weeks with Ms. T (On level)
Rosie	Female	Undergraduate	MS: 8 weeks with Ms. T (On level) HS: 6 weeks with Ms. L (Honor class)
Carlie	Female	Undergraduate	HS: 8 weeks with Ms. Y (inclusive class) MS: 6 weeks with Ms. P
Cary	Male	Graduate	MS: 8 weeks with Ms. P HS: 6 weeks with Mr. Y(inclusive class)
Simon	Male	Graduate	MS: 8 weeks with Ms. P HS: 6 weeks with Mr. Y(inclusive class)

Note:
HS: high school; MS: middle school

Table 2.2 Noticing Score Rubric

	Score 1	Score 2	Score 3	Score 4
What are they noticing?	Attend to whole class environment, behavior, and learning and to teacher pedagogy.	Primarily attend to teacher instruction.	Attend to students' learning, and/or students' behavior	Attend to the relationship between students' learning/behavior and teacher instruction.
	Own feelings.	Begin to attend to students' learning and behaviors	Pay some attention to teacher pedagogy	
How do they notice?	Provide general impressions of what occurred	Form general impressions and highlight noteworthy events	Highlight noteworthy events	Refer to specific events and interactions as evidence
		Provide primarily evaluative comments.	Provide evaluative and some interpretive comments	Elaborate on events and interactions
			Begin to refer to specific events and/or interactions as evidence.	Make connections between events and principles of teaching and learning
				On the basis of interpretations, propose alternative pedagogical solutions.

Table 2.3 Sophistication of PSTs Noticing

Domain	Jane	Gabby	Rosie	Simon	Cary	Carlie
Dependent	46.4%	32.6%	44.2%	53.3%	53.8%	44.6%
Independent	53.6%	67.4%	55.8%	46.7%	46.2%	55.4%
Specificity						
General	28.6%	20.9%	5.8%	58.3%	10.8%	10.8%
Specific	71.4%	79.1%	94.2%	41.7%	89.2%	89.2%
Stance						
Description	40.5%	16.5%	30.8%	58.3%	30.8%	31.1%
Evaluation	42.9%	64.7%	34.6%	35.0%	41.5%	33.8%
Interpretation	16.7%	18.8%	34.6%	6.7%	27.7%	35.1%
Topic						
Assessment	8.0%	3.4%	1.9%		7.0%	1.3%
Class discipline	1.1%	5.6%	3.7%	4.8%	7.0%	5.1%
Class flow	14.9%	2.2%	1.9%	33.3%	7.0%	5.1%
Classroom management	10.3%	12.4%	20.4%	11.1%	16.9%	10.3%
Curriculum	4.5%	10.1%	13.0%	4.8%	11.3%	3.8%
Instructional strategies	28.7%	50.6%	38.9%	36.5%	33.8%	34.6%
Teaching efficacy			1.9%	1.6%	1.4%	3.8%
Students learning	31.0%	15.7%	18.5%	7.9%	15.5%	25.6%
Teaching orientation	1.1%					5.1%
Own feeling						5.1%
Agents						
All students	40.0%	31.4%	10.9%	40.6%	37.5%	19.4%
Groups of students	5.0%	2.9%	6.3%		5.0%	1.0%
Specific students	4.0%	8.8%	17.2%	7.8%	7.5%	11.2%
MT	35.0%	49.0%	50.0%	37.5%	43.8%	48.0%
Other teachers	3.0%	1.0%	9.4%	4.7%	2.5%	4.1%
Peer			3.1%	1.6%	1.3%	3.1%
Self	13.0%	6.9%	3.1%	7.8%	2.5%	13.3%

Table 2.4 PSTs Noticing Scores

PSTs Name	Score 1	Score 2	Score 3	Score 4
Rosie	25%	37%	19%	19%
Jane	49%	29%	15%	7%
Gabby	28%	55%	11%	6%
Carlie	42%	35%	9%	14%
Cary	26%	46%	16%	12%
Simon	62%	35%	3%	0%

Table 2.5 PSTs Noticing Scores across Weeks

	Rosie	Gabby	Jane	Carlie	Cary	Simon
Week 1	2	1	2	2	2	1
Week 2	3	2	1		3	2
Week 3			2		1	1
Week 4	2				2	
Week 5						
Week 6				3		2
Week 7	3		1	2		
Week 8			2			
Week 9	2			1		1
Week 10				2		
Week 11					N/A	
Week 12						2
Week 13	3	3				1
Week 14	4	2				

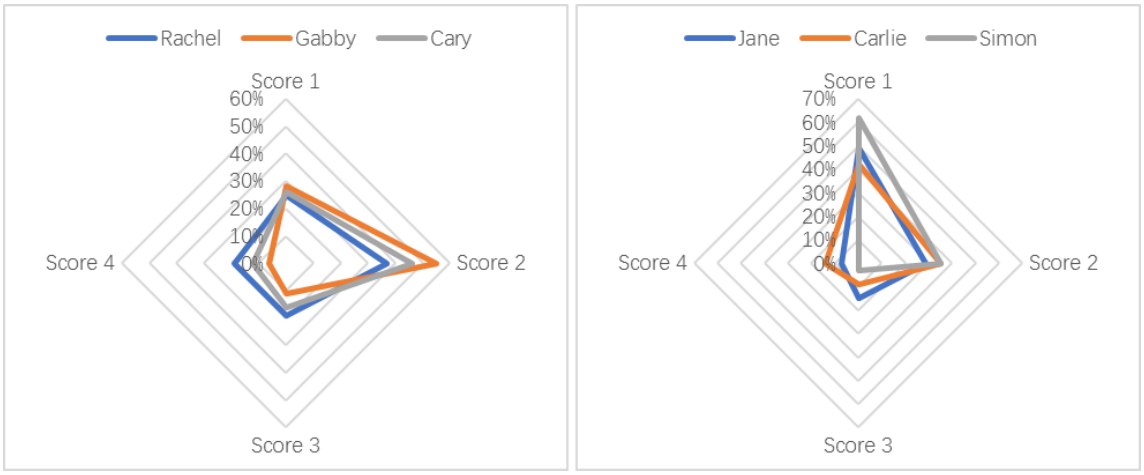

Figure 2.1 PSTs Noticing Scores

CHAPTER 3

EXPLORING PROSPECTIVE TEACHERS' DEVELOPMENT OF KNOWLEDGE FOR TEACHING DURING A BLOCK OF SECONDARY SCIENCE TEACHER EDUCATION COURSES: THE IMPACT OF NOTICING[2]

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Abstract

Engaging in practicum is an important part in teacher education program as it provides prospective teachers opportunities of learning to teach in an authentic context. Understanding prospective teachers' knowledge development in this context as they observe their mentor teachers will contribute to our understanding of how they learn and further provide adequate supports for them. The objective of this study is to investigate a group of prospective teachers' knowledge development as describe by the PCK framework in site-based teacher education courses which include practicum. This study also connects what and how prospective teachers noticing in their mentor teachers' classes with their knowledge development. Results indicated that even though prospective teachers were put in the same context, they developed different PCK components and the ways they learned were different from each other. However, their knowledge development is dependent on what and how they noticed in the practicum. These results add to our understanding of teacher knowledge development in the practicum, which facilitated teacher educators to design adequate supports for their students.

Introduction

Since the 1960s, theoretical foundations have been developed to understand how teachers build their knowledge for teaching (Abell, 2007). Among them, pedagogical content knowledge (PCK) is a framework that has been widely adopted to understand teacher knowledge since Shulman put it forward in the 1980s. Shulman defined PCK as the amalgam of pedagogical knowledge, subject matter knowledge and context knowledge (Shulman, 1986, 1987). After Shulman's original conceptualization of PCK, the bulk of related research concerning science teacher knowledge has been devoted to understanding

the components of PCK, the ways teachers developed their PCK, and measurement of PCK (Grossman, 1990; Magnusson, 1999). Shulman described PCK development as a process of transforming the subject matter knowledge for the purpose of pedagogical use (Shulman 1986, 1987). Research has shown that this transformation takes place through knowledge-in-action and knowledge-on-action (Park & Oliver, 2008). In their study of high school teachers' PCK, Park & Oliver (2008) found that teachers developed and enacted their PCK both in the moment of teaching and after completing their instruction when they realized the need to modify their repertoires and further "made additions to, reorganized, or modified their existing body of PCK for teaching the topic" (p. 269). Their results indicated that conducting classroom instruction was one way that teachers developed and enacted their PCK. This idea that teachers developed their PCK through knowledge-in-action and knowledge-on-action was also advocated by other researchers (Harris & Hofer, 2011; Loughran et al., 2000; Gess-Newsome, 2015).

The above studies documented in-service teachers' development of PCK. But what about the teacher candidates, who have limited teaching experience during the teacher education program? Studies with prospective teachers as participates suggested that prospective teachers need to be exposed to some sort of practical experiences to develop their PCK (Barnett & Friedrichsen, 2015; Beyer & Davis, 2012; Van Driel, de Jong & Verloop, 2002). But the question of how prospective teachers' engagement in teaching related activities, such as observing their mentor teachers in classes, promote their PCK development has not been adequately researched.

The objective of this research is to investigate how teacher candidates build their knowledge as described by the PCK framework as they participate in the classroom

activities associated with site-based teacher education courses. Although this knowledge may not qualify as PCK due to the prospective teachers' lack of teaching experience, the use of the PCK components to categorize their knowledge development is, I believe, a useful approach. Employing the frameworks of PCK and teacher noticing, I characterize PSTs' PCK and examine how noticing supports PSTs development of PCK.

Literature Review

Conceptualization of PCK

The concept of pedagogical content knowledge was first proposed by Shulman (1986). Shulman and his colleagues defined PCK as knowledge developed by teachers to support their students learning, and as an amalgam of teachers' subject matter content knowledge, pedagogical knowledge and knowledge of context (Shulman, 1986, 1987; Grossman, 1990). Magnusson, Krajcik, and Borko (1999) put forward a pentagon-shaped PCK model, which contains five components (the abbreviations shown for these terms will be used hereafter): orientations towards science teaching (ORNT); knowledge of science curriculum (KSC); knowledge of assessment for science (KAS); knowledge of student understandings (KSU); and knowledge of science instructional strategies (KIS) (see Table 3.1). These labels for the components offer a broader view of original conceptualization and focuses on the topic-specific nature of PCK (Abell, 2007). Building on research and models put forth by Grossman (1990), Magnusson et al. (1999), Tamir's (1988) and others, Park (2005) developed a hexagon PCK model, which represented the components of teachers' PCK as well as an affect dimension of PCK. In particular, Park (2005) added a new component to the pentagon model: teacher efficacy. She referred to this component as teachers' beliefs about their ability to perform teaching.

This study employs Park's (2005) hexagon model to characterize teacher candidates' development of PCK.

Measurement of PCK

Assessing PCK is a complex task. Researchers have used multiple methods to assess teachers' PCK. Observation of teachers' instruction is a popular approach for researchers to capture PCK when their participants are in-service teachers because they can infer what teachers know from what their instruction in the classes (Nilsson & Vikstrom, 2015; Rozenszajn & Yarden, 2014). For example, Park & Chen (2012) investigated the interconnectedness of PCK components with four in-service teachers as participants. They observed their instruction and supplement the observation data with teacher interviews, which enabled the researchers to understand what the teachers know and the reasons behind their action in the classes. When working with prospective teachers, who had limited teaching experience, interview can become a common method for PCK assessment (Wang, unpublished work). Researchers also employed other measures to triangulate with their interview data. For example, Van Driel et al., (2002) investigated a group of 12 prospective teachers' PCK as they enrolled in an instructional methods course and also observed mentor teachers in schools. They administered a baseline questionnaire at the beginning of the methods course to measure prospective teachers' PCK and their subject matter knowledge and interviewed them to infer their knowledge change during the semester. Interviews provided researchers opportunities to probe what PSTs know, which is an effective way to infer their knowledge especially when instruction observation is not available.

Teacher noticing in relation to teacher knowledge

The concept of teacher noticing was first introduced by the researchers from mathematics education and has been making inroads in science education during the past two decades (Rodriguez, 2013). Research on teacher noticing explores how teachers build on what they notice during instruction to make in-the-moment decisions to support student learning (Sherin & van Es, 2009). Although diverse perceptions exist about conceptualizations of noticing, a common accepted definition includes teachers' differentially paying attention to, evaluation of and interpretation of events and incidents. (Jacobs, Lamb, & Philipp, 2010; Russ & Sherin, 2011; Star & Strickland, 2008).

Empirical studies have shown that noticing is a knowledge-based process, which is an indicator of the quantity and quality of teachers' knowledge (Steffensky, Gold, Holdynski & Möller, 2015). As indicated from mathematical education research, the process of identifying distinctive events "is influenced by teacher's expectations and their knowledge about teaching and learning" (Russ & Sherin, 2011). This argument was confirmed by Meschede, Fiebranz, Möller & Steffensky's (2017) study in science education which investigated the relationship between teacher noticing and PCK, with preservice and in-service teachers as participants. Employing a quantitative research design, they regarded teacher noticing as teachers' attention to, interpretation and sense-making of the situations. They measured participants' PCK with a paper and pencil test They required participants to watch video clips and answer the associated rating-scaled items to probe teacher noticing in relation to instructional support. Their results revealed moderate positive association between teachers' noticing to instructional supports and their PCK.

As discussed above, researchers have documented that teachers' selective attention and their following evaluation and interpretation of what they have noticed is based on their knowledge about teaching and learning. However, few studies examined teacher knowledge changes as a result of noticing practices (Wang & Oliver, unpublished work). Most noticing literature in the field of science education have been largely directed toward understanding the improvement of teachers' noticing skills (Benedict-Chambers, 2016; Dalvi & Wendell, 2017; Siry & Martin, 2014).

Research questions

The objectives of this research are two-fold: first, it is an attempt to gain understanding regarding prospective teachers' (PSTs) knowledge development as they participate in a site-based science teacher education courses and second, an approach to investigate any linkage between their knowledge development and noticing. The hexagon PCK model (Park, 2008) is used to characterize PSTs PCK. However, as mentioned earlier, it is necessary to state that in this study, the group of PSTs knowledge is considered as a form of proto-PCK, and not the same as experienced in-service teachers' development of PCK engaging in teaching practices. However, for simplicity the knowledge developed by the PSTs will be referred to as PCK. As discussed above, teachers cultivate their PCK through engaging in instruction. Even the studies with prospective teachers as participants, the prospective teachers were exposed to teaching practices in their research context to develop their PCK (Käpylä, Heikkinen, & Asunta, 2009; Seung, Bryan & Haugan, 2012; Van Driel et al., 2002). However, in this study, the group of PSTs were participating in their practicum, during which they have limited chances of leading the class but observe and assist their

mentor teachers. In this regard, the PCK framework is regarded as a conceptual framework and a tool to characterize PSTs knowledge in this study.

The research questions for this study include:

(1) How does prospective teachers' knowledge for teaching develop when analyzed using a PCK framework?

(2) What does an analysis of classroom noticing reveal about the potential sources of prospective teachers' knowledge development?

(3) What do the classroom events and incidents that prospective teachers noticed indicate about the development of and interplay between the components of PCK model?

Method

Data collection

The major data source is interviews. Four semi-structured interviews were conducted during the semester. The first interview was carried out in the first two weeks of the semester's classes, the objective of which was to probe participants' previous teaching experiences and orientations to science teaching. This first interview lasted about 20-30 minutes. The second, third and fourth interviews were conducted in week 4, week 9 and week 13 of the semester, respectively. In each of those subsequent three interviews, PSTs were asked to elaborate on what they had noticed while in their practicum classrooms and what they learned from observing and assisting their mentor teachers. All interviews were audio-recorded and transcribed verbatim. Each of those interviews lasted about 60 minutes. PSTs weekly journals and researcher's non-participant observations serve as the supplementary data sources.

The participants for this study are Carlie, Jane, Gabby and Cary. These PSTs completed all four interviews. Their background demographic information is listed in Chapter 2, see Table 2.1.

Data analysis

PSTs had limited opportunities to teach during their practicum experiences in their mentor teachers' classes. As a result, their knowledge for teaching was reflected from their delineations of what they each observed during their time in those classrooms. In order to infer PSTs' PCK from the interview data, I began the analysis by segmenting their interview transcripts to identify the segments related to PCK. In order to qualify as a PCK segment, the following aspects needed to be included: 1. Descriptions of what teachers/students were doing; 2. PSTs interpretation or evaluation of what and why the teacher/students did what they did. 3. PSTs comments on the behaviors of mentor teachers and students. If a PCK segment contains information that the PST also shared in their weekly journals, the relevant descriptions from the journal was also added to construct the PCK segment. An example of a PCK segment is included in Appendix E.

After identifying the PCK segments, each was coded using the six components of the hexagon PCK model (Park, 2005) to identify the PCK statements and observations reflected on by the PSTs. The sources through which PSTs developed their PCK were also coded and the source and PCK component correlations were also represented. If there are more than one source within one PCK segment, the correlation of PCK components with each source was marked separately. For example, in one PCK segment, the PST developed their understanding of KIS and KSU through interacting with students and observation of his/her mentor teacher. To represent this correlation, I marked 1 under "interacting with

students" with KIS and another 1 with KSU. Then I marked 1 under "observation" with KIS and again another 1 with KSU (Table 3.2). A thematic analysis using a constant comparative approach was conducted to investigate the themes in relation to the PCK components (Glaser & Strauss, 1967).

Finally, to portray the interplay of PCK components, a PCK map was constructed for each of the participant based on the components reflected from all his/her PCK segments. Adapted from Park & Chen's (2012) method, I used the hexagon PCK model as an analytic tool. After identifying the PCK components within each segment, if more than two components were recognized, one interplay was recorded between any of the components. For example, if KIS, KSU and KSC were identified within one PCK segment, one connection was recorded between KIS and KSU, KIS and KSC, and KSU and KSC respectively. Following with Park & Chen's (2012) assumptions, even though the strength of the interplay may be different, I gave all the interplay the same strength 1. An example of one PCK segment, within which three components KIS, KSU and KSC were recognized, was demonstrated with Figure 3.1. After constructing the PCK map for each segment from one PST, I combined all of the segments to make an overall PCK map for each PST, which represent the PST's interplay of PCK components he/she developed across the semester.

Findings

Below I describe the findings of PSTs PCK. I first discuss the PSTs development of PCK as they participate in their practicum. Then I examine how PSTs PCK is related to their noticing skills. In other words, I investigate what and how PSTs noticing influence their knowledge development described by PCK framework.

PSTs PCK development

The four PSTs PCK was summarized in Table 3.3, which includes the number of PCK segments identified, the PCK components for which evidence was found, themes under each component, and the sources of their learning. My analysis through the constant comparative approach indicated five features of their PCK: (1) PCK development is idiosyncratic; (2) KIS and KSU are the two common components of PCK that PSTs developed; (3) KAS is the least PCK component that PSTs developed; (4) KIS and KSU connection is central for all connections that PSTs make between PCK components; (5) PSTs draw from different sources to build their PCK.

PCK development is idiosyncratic

Even though the four PSTs enrolled in the same block of courses, they developed different aspects of PCK. Gabby developed knowledge for teaching related to all six PCK components, Carlie and Jane exhibited knowledge connected to four PCK components and Cary developed knowledge related to three components (Figure 3.2). Gabby is also the PST from whose interview I identified the highest number of PCK segments even though I asked the same interview questions with the same order during all the interviews.

Furthermore, the PSTs who worked together with a partner in the practicum across the semester exhibited different knowledge related to PCK. Gabby and Jane worked together as a pair for both the first and the second practicum placements. Both of them developed PCK components of KIS, KSU, ORNT and TE but Gabby also developed two more components, KAS and KSC, than Jane. In addition, even within same PCK component they developed, Gabby and Jane focused on different aspects of the components. For example, they both developed knowledge of students understanding.

However, Gabby's knowledge of student understanding tended to focus more on students' learning difficulties and misconceptions, whereas Jane's knowledge was about what teachers could do to address students learning difficulties. For example, in the second interview, Gabby shared that in one lab class, one question students received was about the ratio of carbon, hydrogen, and oxygen atoms in one glucose molecule. She was walking around and helping students and she realized that the students understood what a glucose molecule looked like but didn't know how to put the associated numbers into a ratio. She then shared:

> "So I realized a lot of the problem is that students faced with these questions, is they don't know like an important part of the question to be able to answer the questions even if they are familiar with the knowledge or the content knowledge. If there is that one part of the question or it's like talking about what ratio or correlation things like that, they're like, oh we get this and this but how do you answer the way they want it. I was in trouble with that." (Gabby, S-3).

In this example, Gabby identified the specific learning difficulties students encountered as she interacted with them: they didn't know how to put numbers in a ratio. Jane came across a similar situation when students experienced learning difficulties:

> "While lecturing he taught about concentration and diffusion. Some students had a hard time grasping this concept so Mr. L asked the students about their sweat tea recipes." (Jane, S-2)

She then continued discussing how Mr. L used the sweet tea example to explain concentration. Following that, Jane mentioned that most of the students apparently

understood better. In this example, instead of focusing on students learning difficulties, Jane paid more attention to her mentor teacher's strategy of dealing with students' learning difficulties and the effects. She explained how her mentor teacher adapted his instruction based on students in-the-moment understanding, which indicated her knowledge of students' learning status.

Similarly, Carlie and Cary worked with the same two mentor teachers at different times of the semester (Carlie worked with Mr. Y for the first 8 weeks before she started her second practicum with Mrs. P for the remaining 7 weeks. Carlie worked with Mrs. P for 8 weeks first and then transferred to Mr.Y's classroom for his second 7-week practicum). Even though Carlie and Cary both exhibited two components, KIS and KSU, Carlie's PCK also include another two PCK components: teacher efficacy and orientation while Cary didn't exhibit knowledge of the two components. But he developed the component of KSC based on his interviews whereas Carlie did not. One possible reason of their different PCK components developed is that they were at very different places in their development as teachers at the time of their switch since the semester was half over the time.

This idiosyncratic development of PSTs PCK has also been documented by other researchers (Loughran, Mulhall, & Berry, 2008; Park & Chen, 2012; Park & Oliver, 2008). This finding suggested that PSTs made sense of the same events and incidents in the same context in a variety of ways and subsequently developed different PCK components.

KIS and KSU are the two most common PCK components that PSTs developed

Despite the variations in PSTs knowledge for teaching development as documented by this analysis, all of them developed knowledge of instructional strategies and knowledge of student understandings. In addition, among all the components each PST developed,

these two components were exhibited within the highest number of PCK segments. This suggests that the PSTs developed KIS and KSU more than other components. Considering that the PSTs were observing in their mentor teachers' classes, it is not surprising that they focused on what strategies their mentor teachers used as well as on the status of what students were learning.

Furthermore, the connection frequencies between the two components are the highest comparing to all other connections in their PCK maps (Table 3.4). Carlie and Gabby's KIS and KS connection frequencies are 4, Cary's is 3 and Jane's is 2. This implies that PSTs related their understanding of instructional strategies with students learning behaviors. In other words, the co-occurrence of KIS and KSU within one PCK segments means when PSTs made senses of their mentor teachers' instructional strategies, they also checked the effects of the strategies: student understanding.

Considering that KIS and KSU are the two most common components of the PSTs knowledge for teaching and the strong connections between these components, it seems clear that these two components are the central features of the PSTs knowledge for teaching. In other words, KIS and KSU guided what other components were included. As shown in Figure 3.2 and Table 3.3, the only one PCK component that PSTs developed that was not attached to KSU or KIS is Gabby's knowledge of teacher efficacy. In that PCK segment, which Gabby described during a discussion session, her mentor teacher had received a student question for which she did not have adequate science knowledge to answer and asked help from the two teacher candidates in the classroom. Based on what Gabby said about this situation, it was clear that she had expanded her knowledge for teaching as a result of experiencing her mentor teacher's response to the situation. The teacher

communicated that not knowing everything is okay and students need to be encouraged to ask questions. Below is her comment after seeing this happen:

> "So I think that kind of attitude, that helps. I think it's okay for teachers not knowing everything. That doesn't discourage not knowing, yeah and that they're encouraged to ask questions and they're good questions or they're there's not really a bad question" (Gabby, INTV-3)

KAS is the component of knowledge for teaching that PSTs developed least

Knowledge of assessment of science learning is the component that PSTs developed least and therefore has the most limited connection to other components. Knowledge of assessment of science learning refers to teacher's knowledge of what are important issues to be assessed and knowledge of the appropriate approaches to use to assess students' learning (Park, 2005). The assessment approaches considered in the evaluation of PSTs development of knowledge for teaching included both formative and summative assessments. Gabby's understanding of assessments included her knowledge of how teachers use formative assessments to guide subsequent instruction, the reasons behind students' low performances, and the way tests were delivered. However, this development of assessment knowledge was not reflected in other PSTs PCK segments. For example, Jane was also exposed to opportunities of observing her mentor teachers' use of informal assessments because she worked in the same classrooms with Gabby. But there was no assessment-related issue demonstrated in her PCK segments. This suggests that her reflections and working memory of her experiences didn't include explorations of this topic even though it is clear she observed it. Her experiences did not seem to build her knowledge of assessments as a component of her knowledge for teaching.

As discussed above, the PSTs were not provided directions of what to observe in the practicum. The PSTs made their own sense of what happened in the classes, so it is natural that they developed different PCK components even when observing within the same context.

PSTs draw from different sources to build their PCK

As shown in Table 3.3, the four PSTs developed their PCK though different sources. Carlie's major source for her PCK development is interaction with students. Gabby and Cary developed their PCK through both interaction with students and observation. Based on their PCK segments, the numbers of their learning instances from observation and interacting with students are very similar. Most of Jane's learning happened from her observation of her mentor teachers. She is also the only PST who processed her learning by comparing what she observed with her own learning experiences and developed her knowledge by building on her own learning experiences as a student.

In the second interview, she described her mentor teacher's explanation of symbiotic relationship by just describing the process without writing the words on the board. She believed that if students could see the word, they would grasp the concept better. Then she discussed her own learning experiences:

> "I think that when I'm in lecture, I will be paying attention. But I'm going to get distracted and maybe out of like a lecture, I will only actually remember 30% of the information and so it's important to have other context, like where you are able to write this information." (Jane, S-4)."

In this example, Jane noted that her mentor didn't provide students opportunities to see the words written on the board. She then built on her own learning experiences to

illustrate that pure lecture would be difficult to continuously attend to and that writing down the important concepts would facilitate students learning. This segment demonstrated Jane's understanding of instructional strategy, which was built on both her observation of her mentor teacher and her own learning experiences.

PSTs PCK in relation to their noticing

Based on the above analysis of PSTs PCK combined with the analysis of the level of sophistication of their noticing in the previous chapter, I found that PSTs knowledge development is dependent on what and how they have noticed in their practicum. First, the two topics PSTs paid most attention to correlates to the two PCK components they developed most. In the topic dimension, instructional strategies and students learning are the two topics PSTs noticed most. More than 60% of Carlie, Gabby and Jane's noticing segments identified from their observation journals are about instructional strategies and students learning (In the case of Cary, 16.9% of his noticing is about classroom management while 15.5% of his noticing is about students' learning. But his noticing data only included his first 10-week observation. It is also notable that the percentages of classroom management and students' learning are very close to each other). Accordingly, the two PCK components PSTs developed most (the data source of which is PSTs interviews) are the knowledge of instructional strategies and knowledge of students understanding.

Furthermore, PSTs different levels of sophistication of noticing also aligns with their various development of PCK. In the case of Gabby, she improved her noticing skills across the semester, which is demonstrated by her increase of noticing scores. She is also the only PST whose noticing is least descriptive in stances among the four PSTs. Gabby's noticing

stance contains 16.5% descriptions, which means that among all the events and incidents she noticed, in about 84% of cases, she either made evaluations of what happened or interpreted the reasoning of why those things happened. In other words, she explored and elaborated what she noticed in addition to just describing what happened. However, Carlie and Cary's descriptive noticing are both about 30%, while over 40% of Jane's noticing stance is descriptive in nature. With regard to PSTs PCK development, Gabby demonstrated all six PCK components and had relatively higher numbers of instances of each component. Accordingly, there are more frequencies of PCK components interactions in her PCK map comparing to the other three PSTs.

The finding that teachers noticing is related to their knowledge for teaching and learning has been documented previously in the field of mathematics education (Kersting, Givvin, Sotelo, & Stigler, 2010; Moscardini 2014; Russ, 2018). Moscardini's research showed an increased level of teacher knowledge benefited their noticing of students' mathematical thinking. Kersting, et al. (2010) examined the relationship between mathematics teacher noticing and their knowledge as described by the mathematics knowledge for teaching. Their results indicated the strong relationship between the two. However, to my knowledge, there is no research in the field of science education that investigated the relationship between teacher noticing and teacher knowledge development as a result of noticing practices. Furthermore, the major purpose of these mathematics education studies was to understand what knowledge the teachers need in order to pay attention to important issues as advocated in reform documents in the classes. The question of knowledge changes as a result of noticing practices is under investigated. This study

adds to the knowledge base in that it shows noticing practices facilitate prospective teachers' development of knowledge as described by the PCK framework.

Conclusion

This study examined four PSTs development of PCK and investigated how their PCK is related to their noticing sophistication. Based on the analysis results, two conclusions can be made:

First, although PSTs were placed in the same learning context, the outcomes and experiences of their learning are different. They drew from different sources to build their knowledge, developed different components of PCK, as well as cultivated different learning aspects within the same component. These results suggest that teacher candidates as learners have diverse learning strategies when they were prepared to be science teachers during practicum. The facts that all four PSTs were placed in the same context and that two PSTs worked together as partners across the semester, indicate that which classrooms they were put in does not appear to be a major factor that influences their learning.

Second, PSTs development is dependent on what and how they noticed in their mentor teachers' classes. Their sophistication of noticing seems to decide what they learned. PSTs evaluated and interpreted the events and incidents they noticed and through these processes of evaluation and interpretation, they add and modify their knowledge of teaching and learning. One implication of this result is that improving teacher noticing during the practicum will benefit their knowledge development. And supports for noticing are needed to help teacher candidates to learn.

Based on the results of this chapter and chapter 2, PSTs development of noticing and PCK components are idiosyncratic in nature although they developed them in the same

context. A follow up question is what makes the differences? What are some possible reasons contributed to their diverse development of noticing and PCK? Investigations of these questions will shed lights on how teacher educators can better prepare prospective science teachers.

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Table 3.1 PCK Components Based on Magnusson et al. (1999)

Orientations towards science teaching (ORNT)	Teachers' beliefs about the purpose of science teaching and learning
Knowledge of Science Curriculum (KSC)	Teachers' knowledge of curriculum materials both horizontally and vertically.
Knowledge of Assessment for Science (KAS)	Teachers' knowledge of the important concepts needs to be assessed and how to deliver assessments.
Knowledge of Student Understandings (KSU)	Teachers' knowledge of what students already know, their learning difficulties, learning needs.
Knowledge of Science Instructional Strategies (KIS)	Teacher's knowledge of strategies to represent science content, including subject-specific strategies and topic-specific strategies.

Table 3.2 PCK Components and Learning Sources

PCK segment	PCK components	Sources	
		Interacting with students	Observation
Gabby, segment 1	KIS	1	1
	KSU	1	1

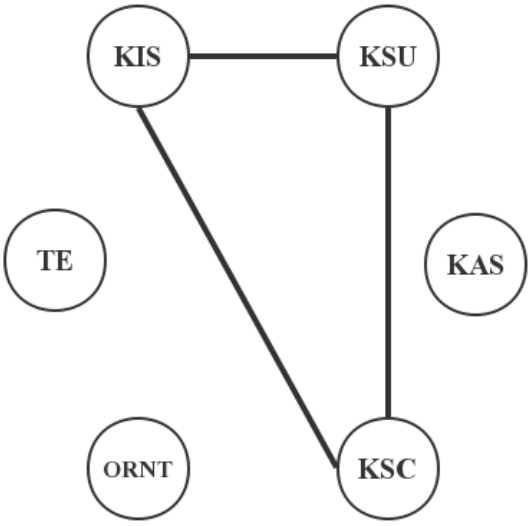


Figure 3.1 An Example of PCK Components Interplay

Table 3.3 PSTs PCK Table

PSTs	Number of PCK segments	PCK components	Themes	Sources			
				IWS	POT	OBSV	PLE
Carlie	6	KIS	Various representations of same concept. Eliciting students' previous knowledge to build on.	4	2	1	
		KSU	Learning difficulties. Learning habits.	4	2	1	
		ORNT	Science is connected to our lives	1	1		
		TE	Revise instruction based on students in-the-moment understanding.	3	2		
Gabby	7	KIS	Make science relatable to students. Check learning progress with daily quizzes.	3		4	
		KSU	Learning difficulties. Misconceptions.	4		3	
		KAS	Retesting. Low performances result from other factors. Assess learning every day.	2		1	
		KSC	Vertical curriculum.	1		1	
		ORNT	Science is a human endeavor. Students are active learners.			2	
		TE	Teachers seeking supports for difficult concepts.			1	

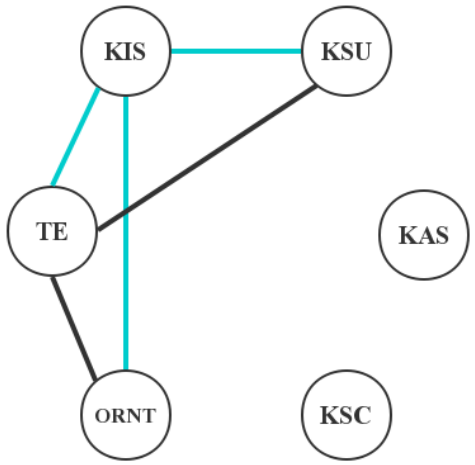
Cary	4	KIS	A good phenomenon connects both previous learning and current learning goals. Make in-the-moment changes based on students' learning progress. Need to be careful about the materials in lab.	2		3	
		KSU	Students understanding. Students are not motivated when they experience difficulties.	2		3	
		KSC	What students already learned.	1		2	
Jane	5	KIS	Make science concepts relatable. Lectures need to be clear and engaging.			4	2
		KSU	Learning difficulties. Insufficient knowledge.		1	2	1
		ORNT	Science should be related to students lives. Students learn by doing.			2	1
		TE	MT make science engaging. Familiar with ways of how students learn science.			2	

Note:
Interaction with Students: IWS
Observation: OBSV
PSTs own teaching: POT
Previous learning experiences: PLE

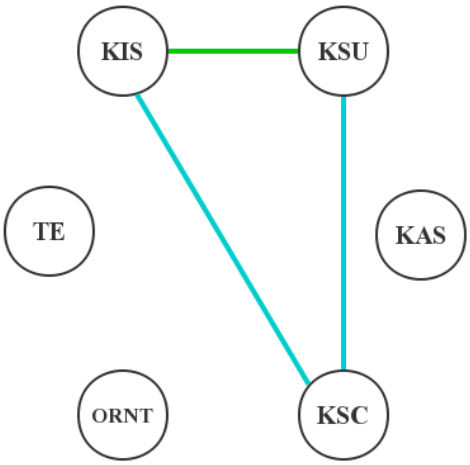
Figure 3.2 PSTs PCK Components

Table 3.4 PSTs PCK Map

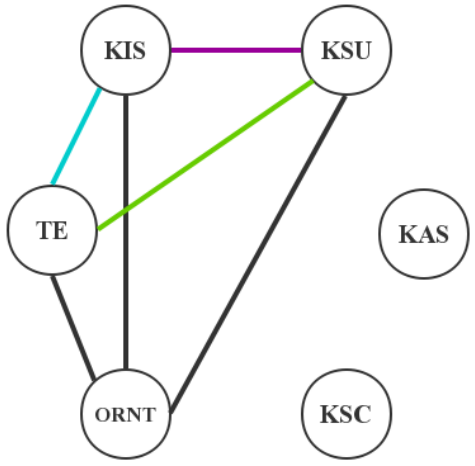
Jane



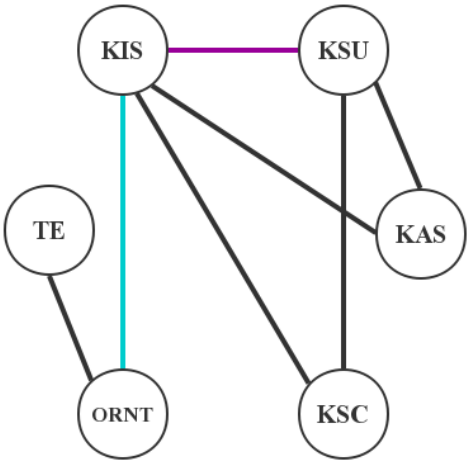
Cary



Carlie



Gabby



Interplay frequencies:

1:

2:

3:

4:

CHAPTER 4

EXPLORING THE CONCEPT OF DISTINCTIVENESS TO UNDERSTAND PROSPECTIVE TEACHER NOTICING AND ACQUISITION OF KNOWLEDGE: A CASE STUDY[3]

[3] Wang, L and Oliver, J. S. To be submitted to Science Education

Abstract

Reflection is the driving force of teacher knowledge growth. But the role of stimuli which initiate teacher reflection is under investigated. This study describes a distinctiveness framework and examines the feasibility of using the psychological concept as a lens to understand how a prospective teacher processed the distinctiveness of the events and incidents as she observed her mentor teachers in the practicum. Results showed that the use of distinctiveness framework made teacher's processing of the differences and similarities among events and incidents visible. Through tracking the prospective teacher's ways of processing distinctiveness, this study indicated participant's changes from novel to significant and from progressive differentiation to integrated reconciliation processing.

Introduction

Over the past 30 years, a great deal of educational research has been conducted to create and deepen understanding of teacher knowledge. Among the theoretical frameworks and methodologies, pedagogical content knowledge (PCK) has been a popular framework since Shulman (1986, 1987) initially described PCK as "the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by students" (p.15). Magnusson, Krajcik, & Borko (1999) and others have put forward models of PCK that builds on the work on Shulman (1986, 1987), to suggest that PCK can be described within five or six major components of the expert science teachers' knowledge. Further, these models are built on evidence that reflection is the driving force in the growth of teachers' knowledge parsed within those components (Park & Oliver, 2008).

Reflection on teaching that happens after the fact of teaching is often called "reflection-on-action" and is often a planned activity that is guided. But what can be said about the role of stimuli, events, or incidents that serve to initiate reflection that happens spontaneously? Teaching is a complex endeavor. Teachers are confronted with many simultaneous and conflicting demands for immediate attention and action in the classes. How do teachers decide to pay attention to some specific events and incident and to allocate their cognition to reflect on them in the midst of instruction? In this paper, building on Oliver, Wang & Park' (2019) work, I first articulate a conceptual model which attempts to describe a mechanism for teachers' development of noticing and PCK. At the heart of the model is teachers' recognition of "distinctiveness" among the stimuli, events and incidents in the classroom instruction. I then use data from a prospective teacher who participated in her practicum to illustrate how the concept of distinctiveness can be used as lens to understand the knowledge acquisition process.

Conceptual Framework

Teacher noticing

Teaching is a complex endeavor, which requires teachers to attend to some activities and disregard others in the midst of teaching to monitor the complicated environment of classrooms (Erickson, 2010). To support student learning, teachers need to focus on key features that are related to student understanding. An important objective of teacher education is to equip teachers with knowledge and skills to sift through the complicated classroom situations and notice important aspects of teaching and learning (Teuscher, Leatham & Peterson, 2017). The concept of teacher noticing was first put forward by the researchers from mathematics education and has been making inroads in

the field of science education since the 2000s (Rodriguez, 2013). Most research of noticing in science education focuses on documenting teachers' development of noticing skills (Benedict-Chambers, 2016; Dalvi & Wendell, 2017; Siry & Martin, 2014; Steffensky, Gold, Holdynski & Möller, 2015). Few of these studies examined the psychological processes underpinning teachers' identification, interpretation of, and/or responding to the events. Similarly, in the mathematical education field, researchers have also realized the lack of investigation on the psychological processes behind noticing and called for collaboration with educational psychologists to explore how teachers made the in-the-moment decisions to support student learning (Criswell & Krall, 2017). Mathematics education scholars have identified some psychologists, whose work may hold potential insights for understanding noticing (Criswell & Krall, 2017). For example, Gestalt psychology, which describes how human beings perceive figure and ground, is related to the notion of highlighting, awareness, or attending; Inattentional blindness can be used to explain the discard of events in high cognitive load situations (Criswell and Krall, 2017). This research on perception and inattentional blindness may help identify ways to make objects more apparent (Schnudrch, Kreitz, Gibbons, & Memmert, 2016). Although some of these theories have been applied in other fields, (e.g. Gestalt psychology helped to build understanding object recognition in computers (Wu & Zhang, 2013), none of them has been used to unpack the mechanisms underline teachers' practices of noticing.

Relating teacher noticing to critical incidents creation

The notion of critical indents was originated from the study of reflective practice. The term "critical incidents" have slightly different definitions. Measor (1985) defined the critical incidents as events that "provoke the individual into selecting particular kinds of

actions, they in turn lead them in particular directions, and they end up having implications for identify" (p. 61). Another definition which is related to schools and teacher career, of critical incidents is "highly charged moments and episodes that have enormous consequence for personal change and development" (Sikes, Measor, & Woods, 1985, p. 230). Tripp's definition is more applicable to teacher professional development which includes the commonplace events in the context of teaching (Tripp, 1993). He described the critical incidents that:

> "The vast majority of critical incidents, however, are not at all dramatic or obvious: they are mostly straightforward accounts of very commonplace events that occur in routine professional practice which are critical in the rather different sense that they are indicative of underlying trends, motives and structures. These incidents appear to be "typical" rather than "critical" at first sight, but are rendered critical through analysis" (p. 24-25)

Also, Tripp (1993) mentioned that

> "…the critical incidents are not "things" which exist independently of an observer and are awaiting discovery…but like all data, critical incidents are created…are produced by the way we look at a situation. To make something as a critical incident is a value judgement we make, and the basis of that judgement is the significance we attach to the meaning of the incident" (p. 8)

From Tripp's (1993) perspective, critical incidents are not events that are dramatic, or turning points during the instruction, rather they can be minor incidents, everyday events that happen in every classroom. It is the teacher's judgement and interpretation that makes

events critical. In other words, it is analysis that renders an incident "critical". Tripp (1993) also argues that to create critical incidents, the event must be seen to have a more general meaning and significance in a wider context.

Tripp's (1993) work showed that critical incidents were not something to be discovered but were created. They were produced by how teachers looked at a situation and how they interpreted the significance of events. The creation of critical incidents involves both the noticing of event (descriptions of what happened), and interpretation of and reflection on what have been noticed. According to Tripp (1993), a formal reflection on critical incidents consists of two phases: description and explanation. In the description phase, a specific phenomenon is observed and documented. In the following, the incident is explained by teachers in terms of its symbol, value, or role (Farrell, 2008; Measor, 1985). Combining this idea with the teacher noticing framework, the first step is paying attention to certain events happening in the moment of teaching, while the second interpretation process is the creation of critical incidents during a process of reflection on the events. The two-step procedure improves teacher understanding about teaching and thus adds to their knowledge for teaching, i.e. their development of PCK. The description phase, when teachers observe and select the events, happens in the midst of instruction. As discussed above, the events that teachers pay attention to can be minor, or common ones in every classroom. Teachers may have varied opinions towards the same event.

The other components of teacher noticing, the interpretation of events, can also be understood by critical incidents construction. Teachers' explanation of the events and meanings assigned to them makes the events critical. In this regard, this meaning assignment is something happens both during and after instruction. In the midst of teaching,

teachers recognize the uniqueness of the event based on their existing understanding about teaching and learning. Teachers then create the critical events through interpreting the event in terms of something that has significance in the wider context. With these experiences, teachers' taken-for-granted ways of thinking about teaching is challenged and new understanding of teaching/learning process is added to their repertoire (Brennon & Green, 1993; Richards & Farrell, 2005).

Teacher education researchers and teachers have used critical incidents analysis in two primary ways. The first approach allows researchers to probe teacher knowledge and capture their learning deeply by stimulating teachers to talk and reflect on the critical incidents rooted in their classroom experiences (Nott & Wellington, 1998). Nott and Wellington (1998) employed the critical incidents analysis method to probe teachers' views about nature of science. Irez and Cakir's (2006) study showed that critical incidents analysis stimulated teacher discussions and reflections, which supported their learning to teach science. Howitt & Venville (2009) investigated pre-service teacher's experiences of learning to teach science through analyzing pre-service teachers' critical incident vignettes in the method course. The latter approach provides opportunities for teachers to demonstrate their new understandings about teaching and learning as they engage in reflections on critical incidents (Farrell, 2008; Richards & Farrell, 2005). The major purpose of the latter approach is to promote teacher knowledge development.

Teachers are confronted with many simultaneous and conflicting demands for immediate attention and action in the classes. Their recognition of the critical incidents involves their awareness of the uniqueness of the events and incidents and this awareness reflects their influential cognition structure that facilitate/inhibit what they choose to attend

to. In this regard, teacher's critical incidents construction is both a way of eliciting their existing knowledge, and a support for their development of knowledge.

Distinctiveness

Distinctiveness is a psychological construct (Hunt, 2006), which defines parameters of how an event can be labeled as distinctive based on how and why it is remembered (Oliver, Wang & Park, 2019). Even though psychologists described this idea in a variety of ways, they have established strong support for it. Hunt (2006) defined the psychological distinctiveness as "the processing of difference in the context of similarity" (p. 12). His study showed that the participants recalled a representation better if he/she identified one aspect of the representation that was different from others. For Hunt, distinctiveness is a cognitive act of processing differences within a context characterized by similarities (Oliver & Park, 2016). Schmidt's (2006) definition makes more sense in explaining why teachers choose to pay attention to some aspects instead of others. He defined distinctiveness as novel and significant aspects of events as he wrote "two kinds of stimuli appear to attract special attention and cognitive resources: the novel and the significant" (p. 47). From Schmidt's perspective, teachers tend to notice events that they may have never seen before, or events that show something important for them.

As discussed above, in the complex classroom, during instruction teachers are facing multiple events at the same time. The concept of noticing is used to describe teachers' in-the-moment choice of events that they decide to pay attention to and/or response to immediately. The psychological construct distinctiveness can be used to further understand why teachers process the differences among events they are confronted in the midst of teaching and why they decide to allocate their cognitive resources to some events instead

of others. When an event is distinctive, it is easily remembered and attracts more attention. In the context of teaching, if an event indicates some cues of students' understanding, or generates teachers' concerns about teaching and learning, it becomes distinctive for those teachers and subsequent attention and allocation of their cognitive resources are directed to specific details of the event. In other words, the psychological concept of distinctiveness can be used to understand how teachers recognize, interpret events, and stimulate their further decisions about possible strategies for responding to the related actions. And these processes of recognition, interpretation and/or further response are what have been described as noticing (Jacob, Lamb & Phillips, 2010). Investigations of these processes will help to unpack noticing mechanisms. In addition, teachers' processing of the distinctiveness of events and incidents through critical incidents creation is a way for them to add to and to revise their existing understanding of teaching and learning or their knowledge development.

Hunt (2006) argued that distinctiveness referred both to the characteristic of an event, the independent variable of one event or incident, and to a kind of processing, through which the event is interpreted to be distinctive. As described above, Schmidt (2006) described how two kinds of stimuli attract attention: novelty and significance. He continued to explain that novel stimuli "are those that are unlike information represented in memory" and that significant stimuli "match important memory representations" (p. 60). The novelty and significance characteristics can be ways of thinking about distinctiveness as an independent variable. Another way to think of distinctiveness as a characteristic of an event is primary and secondary distinctiveness (McDaniel & Geraci, 2006). Primary distinctiveness is defined as an aspect of an event that is unusual within the immediate

context. Secondary distinctiveness applies to items unusual in a general context, which involves comparison with the information in the permanent memory to see their distinctiveness (McDaniel & Geraci, 2006). Hunt (2006) also described distinctiveness as a process which includes item-specific processing and relational processing. According to Hunt, relational processing refers to "the processing of dimensions common to all items within an event" (p. 11). While item-specific processing refers to "the processing of properties of individual items not shared by other items" (p. 11). These two types of distinctiveness processing captured the essence of his definition that distinctiveness is "the processing of difference in the context of similarity" (p. 12).

Theses descriptions of distinctiveness link to concepts put forward in Ausubel's educational psychological scholarship. Ausubel identified two learning processes: progressive differentiation and integrative reconciliation (Ausubel, 1968). When learning something new, the progressive differentiation is a process through which we identify the uniqueness of the new knowledge to make sure it doesn't confuse with what we already know. The integrative reconciliation process helps us to see the similarities between the new and the existing knowledge and to build the bridge to connect the two. (Ausubel, 1968).

An example of using distinctiveness to analyze teacher noticing

Russ & Luna (2013) investigated teacher noticing by providing the participant teachers wearable cameras to capture instances when they felt they had noticed something important. The wearable cameras allowed the teachers to save short segments of video immediately after something happened. They interviewed the teachers after their instructions to probe why teachers noticed some events. In one of the after-teaching interviews, one teacher shared:

> "The only reason it was interesting is because Zeb never asks questions. So I was like, wow, Zeb's volunteering to ask a question, and it's a good question. That's interesting to me" (Russ and Luna, 2013, p. 301)

In this interview excerpt, the teacher explained that s/he found this instance interesting because "Zeb's volunteering to ask a question". In this situation, the event of Zeb's asking question is distinctive for the teacher as Zeb never asked questions. It is the distinctiveness of the event (Zeb's asking question) that drew the attention of the teacher and promoted his/her noticing. The authors categorized the teachers' reason for noticing this instance as student engagement without further exploring what made the common phenomenon, Zeb's engagement, noticeable to the teacher. This example illustrates the potential of distinctiveness as a lens to explore teachers' attention to some events by explaining how he/she compared Zeb's current behavior with his previous performances in the class.

The use of distinctiveness, which is a psychological construct, as lens to examine teachers' attention to events of the classroom, would shed lights on mechanism of teacher noticing and their knowledge development.

The conceptual framework

As described above, when teachers are confronted with multiple events and incidents during their instruction, they need to decide what they will pay attention to and allocate their cognition resources to interpret them and come up with responses to them. The concept of distinctiveness can be used as a lens to see how teachers identify the noteworthy events and incidents.

Research Questions

This study focuses on understanding how prospective teachers process the distinctiveness of the events and incidents as they observe their mentor teachers in the practicum. When they observe in their mentor teachers' classes, multiple things happen at the same time, but they only choose to pay attention to certain things instead of others. The process of how they make the choice and construct a critical incident based on their observation is the focus of the study. Using the psychological construct of distinctiveness as a lens, the mechanisms of prospective teachers' noticing is investigated. This study provides an example of using distinctiveness to understand teacher's identification, evaluation and interpretation of the incidents and events.

The two research questions are framed as:

1. To what extent can the prospective teacher's attendance to some events be attributed to their perceptions of the distinctiveness of the events?
2. How does the use of distinctiveness framework facilitate our understanding of teacher's processing of incidents and events she noticed as well as the growth of their knowledge for teaching?

Methodology

This is a case study. The participate Gabby is a teacher candidate in the secondary science teacher education program. Gabby's information and her practicum context are described in Chapter 2, Table 2.1.

Data sources

The major data source is Gabby's 13 critical incidents. She was required to submit one critical incident every week across the semester. During the week, Gabby made notes of

the events and incidents that drew her attention when she observed in her mentor teacher's classes three mornings a week. Then at the end of the week, she identified one incident from her observation journals of the week and constructed a critical incident based on Tripp's critical incident creation framework (Tripp, 1993). Prompts were provided to support her creating of critical incidents (Appendix B). Tripp's critical incidents creation framework guides teachers' construction of critical incidents with four dimensions: (1) Describe the events; (2) Suggest an explanation and meaning within immediate context; (3) Find a general meaning and classification/significance of incident; (4) Overall evaluation of the event (Tripp, 1993). Under each dimension, there are series of questions that Gabby can choose to respond to (Appendix B). Gabby followed strictly with Tripp's (1993) framework and chose at least two questions from each dimension to construct her critical incidents.

Data analysis

A deductive coding approach was employed to analyze Gabby's 13 critical incidents submitted across the semester. Two sets of codes were developed based on Schmidt's (2006) and McDaniel & Geraci's (2006) understanding of distinctiveness as a variable. As described above, Schmidt (2006) defined novel and significant stimuli drew people's special attention. McDaniel & Geraci's (2006) divided distinctiveness as primary- and secondary-distinctiveness. These two types of understanding distinctiveness as variables provide me different perspectives to understand how the participate understand the distinctiveness of the events and incidents she noticed. Similarly, to capture Gabby's processing of distinctiveness, I employed Ausubel's (1968) and Hunt''s (2006) two types of processing approaches. Hunt's (2006) method focused on describing how the individual

items within one event were different and similar to other items. While Ausubel's (1969) approach portrayed the process of comparing the similarities and differences between the new event and the ones stored in the repertoire of knowledge. An analysis framework depicts both the variables and the processes of the distinctiveness was created (see Table 4.1). For each of the critical incident, I coded the distinctiveness variables and processes with two types of codes respectively. Characterizing both the variables and processes of distinctiveness provide information of both what and how Gabby understood the distinctiveness of the events and incidents she noticed.

Results

In this section, I start with explaining how distinctiveness as a variable and as a process is rendered in Gabby's critical incidents creation respectively. I then analyzed Gabby's changes of how she approached the distinctiveness of the events and incidents she observed across the semester.

Distinctiveness as a variable

As describe above, Tripp's critical incidents framework (Tripp, 1993) provided me opportunities of capturing how the PST, Gabby, processed the distinctiveness of events and incidents she noticed. One of the guided questions under the second dimension (suggest an explanation or meaning within the immediate context) asked why you paid attention to this event. This question captures her reason of picking this event and the distinctiveness variables were reflected from her answers to this question. It turns out that Gabby regarded events and incidents as distinctive in various ways. Based on her answers to the guided questions, the reasons of her choosing specific events and incidents include all four types: novel, significant, primary distinctiveness and secondary distinctiveness. Below I will

illustrate how Gabby processed the distinctiveness variables in the four different ways with quotations from her critical incidents.

Novel and Significant events

Among the 13 critical incidents, there are five occurrences in which Gabby noticed the events and incidents because she observed some characteristics of the event/incident she had never seen before. In the first week, to make sure every student was ready for the lab that day, her mentor teacher, Mr. L, randomly picked students to answer questions about the lab handouts they worked on during the first 10 minutes of the period. After finding out that most of the students were not ready, he told the students that he would "pretend" that the class just started and he came out of the classroom. After a few minutes, he came back and students used that moment when he was out to review the lab handouts and most of them were ready after he came in and asked them questions. After describing this event, Gabby shared her reason of paying attention to this event:

> "I paid attention to this incident because I never experienced my teacher doing this when I was in high school; I thought it was a new way to make sure the students knew what they were going to do in lab before getting there." (CI, 2:21)

Gabby paid attention to Mr. L's strategy of getting students ready for lab because this is something she "never experienced" before. It was "new" to her. Therefore, in this example, her noticing is due to the novelty of the event/incident.

There are 8 instances that Gabby's noticing of events and incidents is because of their significance. For example, in week 4, she shared that her mentor teacher used the example of sweet tea to explain the concept of diffusion. Since every student had their own sweet

tea recipe at home, this example got students' attention effectively. When Gabby explained why this event drew her attention, she discussed:

> "I paid attention to this incident because I thought it was a good way to explain this concept without the students getting too bored and not pay attention, especially because this concept can be hard to understand and confusing…The teacher is also enabling the students to provide input into the scenarios he is constructing as examples of the concepts. I believe this allows trust and familiarity between student and teacher to increase…Because I find this method helpful to engage students in addition to teaching them the topic of diffusion and osmosis, which is a rather hard topic to understand if learning for the first time. I will try to use similar methods, some example that the students can relate to when trying to teach these topics!" (CI, 2:31)

In this example, Gabby paid attention to this event because this sweet tea example enabled students to make input, so they were engaged. And engaging students in teaching a difficult topic was very important. In this example, it is not the teacher's instructional strategy, use of analogy, that drew Gabby's attention. Her attention to this event results from her realization that the specific example, sweet tea recipes, facilitated students' understanding of the difficult concept, diffusion. This example is very effective in this specific situation because it included students' contribution in illustrating the concept. It is the impact of the strategy, engaging students when teaching a difficult concept, that matches her previous understanding of how important students should be engaged in

learning a difficult concept. This is an example that Gabby identified distinctiveness of an event because of its significance.

Primary distinctiveness and Secondary distinctiveness instances

Hunt (2006) and Schmidt's (2006) psychological studies indicated that people regarded the unusual properties of one thing in two proxies: unusual in the immediate context and unusual comparing to the information stored in permanent memory (general knowledge/context). When one event is unique in the immediate context, they defined as primary distinctiveness. When one event is unique comparing to the general knowledge, it is called secondary distinctiveness (Hunt, 2006; Schmidt, 2006). In Gabby's critical incidents, both examples of the primary distinctiveness and secondary distinctiveness can be found.

One example where Gabby noticed the uniqueness of the event in the immediate context happened in week 9. On Wednesday, she and her partner got a chance to grade students' assessments. She found that more than half of the class's grades were below 25% of the total score, very few achieved the grade of top 75% of the total points possible, and their writing levels were apparently below average. She commented on what she found by stating:

> "Paid attention to this experience because these answers lacked so much and revealed the lacking level of writing, reading, formulating answers, and explaining; Immediately, we saw that the level of the students in this class is below average and needs support." (CI, 2:53)

Then she continued with sharing her confusion:

> "From this incident, I personally felt confused and concerned. What can be done to help students who need a much higher level of support? Can these students even receive the help that they need? Are these needs being taken care of at homes? Do the parents/guardians know the severity of support that these students need?" (CI, 2:53)

For Gabby, this event is unique because there were so many students who scored below 25% and whose writing levels were under average. She did not compare their performances with her expectations of what 7th graders should achieve, which is a general knowledge in her cognition. But she focused on the questions of how to help this particular group of students from both the teachers' and parents' perspectives. Her comments on students' unusual performances on assessments demonstrated her thinking of ways to help this particular group of students in the moment that the class period was happening. This qualifies as an example of primary distinctiveness.

Below is an example of secondary distinctiveness when Gabby compared the event with information organized in her permanent memory. Gabby noticed her mentor teacher used a game to teach the carbon cycle and she explained why she paid attention to this event:

> "I paid attention to this incident because I haven't seen an instructional strategy with a game involving the carbon cycle; also was first time seeing Mr. L had students play a game as instructional strategy" (CI, 2:38)

This quotation indicated that Gabby regarded this even as distinctive for two related reasons. For one thing, she never seen teaching of the carbon cycle with a game before,

which related to her understanding of using different instructional strategies. For another, this is her first- time seeing Mr. L using a game to teach. The first reason reflects her understanding about the common instructional strategies, which is a secondary distinctiveness while the second part, when she referred to the specific teacher, Mr. L, reflects her focus on the immediate context, the practicum classroom, which is a primary distinctiveness. It seems in this critical incident, she compared this event with both what she observed in Mr. L's classes and with her understanding of different instructional strategies. Following that, in her responses to finding a general meaning of the incident, she stated:

> "This incident shows that teachers are able to utilize instructional strategies that involve games in a way to engage the students and practice or get familiar with the concept being taught by the strategy…. This instructional strategy allows me to think of fun ways I can incorporate games in a way it can be effective in teaching difficult concepts such as the carbon cycle" (CI, 2:38)

Here she commented on how the instructional strategy of game use were engaging for students and how her thinking was enlightened to include fun things to do in her future classes. These discussions showed her understanding of how to make science teaching engaging, which involved checking with instructional strategies she already knew or experienced. Based on this, I coded this critical incident as her secondary distinctiveness even though I can see some primary distinctiveness at the beginning of her critical incident.

Distinctiveness as a process

Distinctiveness processing: item-specific and relational processing

Hunt (2006) described two types of distinctiveness processing based on his definition of distinctiveness as "processing of difference within a context of similarity" (p. 12). The item-specific processing focuses on the uniqueness of items within one event while the relational processing describes processing of item similarities (Hunt, 2006). In her critical incidents, Gabby exhibited her foci on both the differences and similarities of items comparing to others. Below is an example of her item-specific processing.

In week 2, Gabby noticed the way her mentor teacher, Mr. L, was using a study guide to review the cell unit the students had been learning. Her mentor teacher asked students to go through the study guide together and each student needed to answer one question. The students would take turns based on the order of their seating. When a student answered the question correctly, Mr. L added details to it. When students didn't get the correct answer, Mr. L gave another opportunity and guided them through to the right answer. After making this observation, Gabby stated that going through a study guide to review was not uncommon but involving each student in an efficient way was unusual. She commented:

> "This incident shows that all of the students in the class can be asked questions and enhance understanding of answers in rather a more interesting and attention-captivating way, since each student needs to be on-task to be able to answer the question. This is probably a more efficient way than to having students answer questions on their own and go over them in class. It also allows the teacher to know what the students know and what topics/concepts students are having a hard time with." (CI, 2:25).

In this example, Gabby focused on one item of the going through the study guide event: asking each student to participate in going through the study guide. She compared this item with "having students answer questions on their own and go over them in class" and believed that this difference "allows the teacher to know what students know" and to know students learning difficulties. This example illustrated Gabby's item-specific processing.

There are also examples of Gabby's relational processing of distinctiveness when she emphasized the similarities of items within the events and incidents she noticed. One instance of her relational processing happened when her mentor teacher showed her, and her practicum placement partner, students' performance on one test. The mentor assigned students the task of completing a review worksheet for homework to prepare them for the quiz but 70% of students did not complete the review. This lack of completion was seen as a causative factor in their low performances on the test. Gabby expressed her frustration with the students' lack of motivation to learn when the instructions seemed to be clear. She then continued to discuss the problem of students' motivation:

> "This incident shows that some students, or most, may not be motivated in the general sense for school, not just in biology; this lack of motivation or how good grades can be achieved may be rooted in the whole system of education/school for the student, which can be reflected through in each individual class." (CI, 2:49)

In this scenario, students' lack of motivation drew Gabby's attention. But she did not regard this item as unique in Mr. L's biology classroom. She suggested that lack of motivation was a problem for the whole school system. In this regard, she paid more

attention to the similarity: unmotivated students can be found "in the general sense for school". Here she processed the distinctiveness in a relational way.

Distinctive processing: progressive differentiation and integrative reconciliation

Educational psychologist Ausubel described two ways of how learning happened: progressive differentiation and integrated reconciliation (Ausubel, 1968). When people learn something new, they need to identify the uniqueness of the new knowledge so that they won't get confused with what they already knew. This is progressive differentiation. Meanwhile the integrated reconciliation process enables people to see the similarities between the new knowledge and their existing knowledge. It is these similarities that connect the two forms of knowledge and which facilitate the encoding process (Ausubel, 1968). Different from the psychological concept of distinctiveness, Ausubel's argument emphasized the learning process. Understanding Gabby's processing of the distinctiveness of events and incidents she noticed from an educational psychological perspective will facilitate understanding of how her processing of distinctiveness benefited her knowledge development.

Gabby noticed in one instance that her mentor used a natural phenomenon, growing mushroom on a log, to teach about the life cycles of fungi. Students' observation of mushroom growth, what happened when mushrooms were shocked, and the fun part of cooking and eating the mushrooms were noteworthy events for Gabby. She explained why these events were distinctive for her:

> "I paid attention to this incident because students seem to be very engaged when the teacher taught about mushrooms…. This incident shows that teachers are able to utilize a concept in which students can see growth

> (fungi growth) and connect it to the overall topic of fungi in a fun and interactive way (eating mushroom), which shows that teachers can teach a concept over a period of time instead of one day while engaging students." (CI, 2:44)

Gabby regarded her mentor's use of mushrooms to teach fungi engaging for students. She noticed the differences between "teaching a concept over a period of time" and teaching it within one day. From this quotation, it seems that the event of spacing out instruction is something unique to her and through this progressive differentiation, she learned a new strategy (spacing out instruction) that she would "implement in future teaching".

In her second practicum, Gabby tended to process the distinctiveness of events through identifying how the new things she noticed relate to her existing repertoire of knowledge. One example is about the school-wide retest policy in her second practicum. The students were allowed to retake the test if their initial score was below a cutoff of 80 percent. The teacher did not like this policy as it seemed to create in her students a mindset of not being sufficiently concerned about the first taking of the test as retesting was always available. It also seemed to Gabby that the students were not confident about their ability to succeed when taking the test. Gabby commented:

> "(This) shows that students may not be knowing what they have to study because they don't know the expectations or even learning objectives clearly…. This incident can reflect the importance of clear, set expectations and/or learning objectives to help students feel more prepared

> for exams; otherwise, they will have a mindset of failing the test so that they can retest." (CI, 2:60)

When exploring the reason for students lack of readiness, Gabby connected this new phenomenon with some possible reasons based on her previous knowledge: teachers didn't give clear expectations. Although it is hard to see from her critical incident that her mentor didn't set clear expectations, it seems she just built on her own inference and her understanding of possible reasons for students' lack of confidence. This example demonstrated how Gabby processed the distinctiveness of the event with integrated reconciliation.

Gabby's changes of distinctiveness across the semester

I described Gabby's processing of distinctiveness of the events and incidents she noticed as both variables and processes above. In this section, I tracked Gabby's changes with regard to the processing of distinctiveness as variables and processes respectively (see Table 4.2).

Gabby's changes of processing distinctiveness as variable

At the beginning of the semester, Gabby tended to notice events and incidents which rendered some characteristics she had never seen before. Starting from critical incident 9 (that's the week 10 of the semester), the reasons of her identification of distinctive events and incidents are all because of the significance of them, which involves her comparison of the new events she came across and the ones she noticed before. This change is not surprising because this semester was the first time Gabby was placed in science classes to do observations. As a result, she had limited resources to process on at the very beginning of the semester. As the semester progressed, she accumulated more and more knowledge

about events and incidents happened in the classroom so that she could build on what she already knew to appraise the events and incidents to make them distinctiveness to her. In other words, as she learned more in the semester, she made more comparisons and appraisals than just seeing something as new.

With regard to the variable of primary distinctiveness and secondary distinctiveness, although the number of instances of her processing secondary distinctiveness is higher than the cases of primary distinctiveness, there is no apparent change from one to the other across the semester. This data indicates that when Gabby identified events and incidents from her observation, she focused on not only the ones that were unusual in the immediate context, i.e. how to help the group of students whose writing levels were below average, but also events and incidents that were unusual in general ways. She paid similar attention to these two types of distinctiveness across the semester.

Gabby's changes of processing distinctiveness as processes

In the first five critical incidents, Gabby processed the distinctiveness of the events and incidents through identifying their unique properties. In other words, she focused on how some specific characteristics of one event or incident made it unique from others. Then from the sixth critical incident (the 7th week she was in the practicum), she turned to processing the new events and incidents through finding the similarities to what she already noticed or knew. One possible reason is that by the middle of her practicum, she had gained a variety of experiences and acquired knowledge for teaching so that she has more things in her cognition to build on. Thus, with this more diverse knowledge, she was better able to see the connections between new things and what she already knew.

For the other two ways of processing, item-specific and relational processing, she used both ways to process the distinctiveness of the events and incidents she observed and didn't demonstrate any change during the semester. This suggests that when processing the distinctiveness of the events and incidents, she checked both the unique properties within the event and the common items within it, which indicated her processing of the differences of items in the context of similar ones.

Conclusion

The above description of the findings demonstrated the feasibility of using distinctiveness as a lens to understand how teachers identify the stimuli to start their learning process. By using the distinctiveness framework, teachers' processing of the differences and similarities among events and incidents is made visible. This study also tracks the changes of Gabby's ways of processing distinctiveness. Apparent changes from novel to significant and from progressive differentiation to integrated reconciliation processing are demonstrated from the data. But it is also important to note that these results are based on the critical incidents she constructed. Before the start of her practicum, Gabby didn't have any experience of constructing critical incidents. Although prompts were provided as support, she may also need time to learn to explore deeper to create the critical incidents. Her writing and learning to construct critical incidents have been factors that influence the results of her analysis of the critical incidents. Thus, one important implication of this study is the significance of creating a journal for recording daily events and the creation of critical incidents. Eliciting teachers' in-the-moment thinking and their interpretations of what they have noticed facilitate researchers to understand teachers' processing of the distinctiveness of events and incidents. Meanwhile, research has shown

that critical incidents creation, through which prospective teachers critically interpret their observation of instruction and in-service teachers reflect on their own teaching practices, benefits them for their professional growth (Hanuscin, 2013; Tripp, 1993).

The demonstration of using distinctiveness as a lens to unpack the mechanism of teachers' identification of noteworthy events and creation of critical incidents have been demonstrated here to be important tools to facilitate our understanding of how teachers' learning starts. And perhaps most importantly, this study creates understanding of a cognitive mechanism that is used by teachers to build their knowledge of teaching and learning.

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Table 4.1 The Distinctiveness Analysis Framework

Distinctiveness	Distinctiveness as a variable	Novel	Stimuli that are "unlike the information represented in memory", (Schmidt, 2006, p.60) never seen before.
		Significant	Stimuli "match important memory representations" (Schmidt, 2006, P. 60). Involves appraisal.
		Primary Distinctiveness	Events that are unusual to the immediate context.
		Secondary Distinctiveness	Events that are unusual to general knowledge/context.
	Distinctiveness as a process	Item-specific processing	"Processing of properties of individual items not shared by other items within the event" (Hunt, 2006, p.11)
		Relational processing	"Processing of dimensions common to all items within an event" (Hunt, 2006, p.11)
		Progressive differentiation	Identification of the uniqueness of the new knowledge.
		Integrative reconciliation	New knowledge is compared with existing knowledge to find similarities

Table 4.2 Gabby's Changes of Distinctiveness Processing

Critical Incidents number	Distinctiveness Variable				Distinctiveness Process			
	NVL	SIG	PD	SD	ISP	RP	ProD	IntR
CI-1	✓			✓	✓		✓	
CI-2	✓			✓	✓		✓	
CI-3		✓	✓			✓	✓	
CI-4	✓			✓	✓		✓	
CI-5		✓	✓		✓		✓	
CI-6	✓			✓		✓		✓
CI-7		✓		✓		✓		✓
CI-8	✓		✓			✓		✓
CI-9		✓	✓			✓		✓
CI-10		✓		✓	✓			✓
CI-11		✓	✓		✓			✓
CI-12		✓		✓		✓		✓
CI-13		✓		✓	✓			✓

NOTE:
Novel: NVL
Significant: SIG
Primary Distinctiveness: PD
Secondary Distinctiveness: SD
Item-Specific Processing: ISP
Relational Processing: RP
Progressive differentiation: ProD
Integrative Reconciliation: IntR

CHAPTER 5

CONCLUSION

This dissertation explored a group of prospective teachers' learning experiences and learning outcomes as they enrolled in a block of secondary science teacher education courses. The scholarships of symbolic interactionism (SI), teacher noticing, critical incident creation, the psychological concept distinctiveness, and pedagogical content knowledge (PCK) framework informed the study.

Symbolic interactionists believe that objects and events have no intrinsic meaning and it is individuals that assign meanings to them through everyday interactions (actions) (Prasad, 2015). Within the research context, prospective teachers interacted with university instructors, their mentor teachers, students in the secondary classes and their peers who worked with them. Under the guidance of symbolic interactionism, I assume that prospective teachers make sense of and assign symbols to the events and incidents as they interact with the agents in the authentic context. It is through these meaning making process that prospective teachers develop their knowledge of teaching and learning. In this regard, the central of this study is to explore prospective teachers' knowledge development as a result of communicative acts.

Teaching is a complex endeavor, which requires teachers to attend to some activities and disregard others to monitor the complicated environment of classrooms (Erickson, 2010). To support student learning, teachers need to focus on key features that are related to student understanding. Research on teacher noticing has argued the significance of

teachers' recognition and interpretation of the events because these processes enable teachers to identify student learning information so that they can adapt their instruction based on students learning status. An important objective of teacher education is to equip teachers with knowledge and skills to sift through the complex classroom environment and notice important aspects of teaching (Teuscher, Leatham & Peterson, 2017). In this research context, prospective teachers were exposed to various types of events and incidents when they participated in the practicum, observing and assisting teaching as needed in their mentor teachers' classes. Prospective teachers paid attention to issues about teaching and learning as they observed their mentor teacher instruction, engaged in communications with their mentors, students in the classroom, the university instructors, and their peers. Depending on their interactions with the agents, they may choose to attend to diverse events and incidents although they are in the same context or interpret the same events and incidents they encountered in various ways. The events and incidents they have noticed are raw materials they build on to transform their understanding and knowledge about teaching and learning. The first portion of this dissertation is devoted to investigating what prospective teachers directed their attention to, and how they evaluated and interpreted the events and incidents they had observed in the practicum. Compared to video analysis, which is a common approach researchers have used to elicit teacher noticing (Dalvi & Wendell, 2015), engaging in the practicum offered prospective teachers' opportunities of making more sense of the actual instruction and immerse in teaching. Eliciting what and how prospective teachers choose to pay attention to and their evaluation and interpretation of the events and incidents in a real teaching context allowed me to capture prospective teachers' noticing.

Teachers developed their pedagogical content knowledge (PCK) by both knowledge-in-action and knowledge-on-action (Park & Oliver, 2008). Prospective teacher noticing captures their knowledge development in the moment of their observation, evaluation and interpretation of the events and incidents in their mentor teachers' classes. To determine how their reflection on what they have noticed after their observation facilitates their knowledge acquisition, a critical incidents framework was employed.

Tripp's (1993) critical incidents framework was used to probe how prospective teachers reflected on what they have noticed. Building on the critical incident creation framework, I designed prompts to facilitate prospective teachers' reflections, which included describing the events and incidents, interpretation of what they have noticed, as well as their evaluation of how this event is related to general principle of teaching and learning. These prompts serve as guidelines for prospective teachers to reflect on what they have noticed. Meanwhile, their writing of the critical incidents is a tool for me to understand their reflection. In other words, the critical incident creation is both a guide for prospective teachers' reflection and a tool for the researcher to understand their thinking processes. Combined with the noticing framework, prospective teachers' knowledge development through both knowledge-in-action and knowledge-on-action was investigated.

To understand how prospective teachers build their knowledge through noticing and critical incident creation, I zoomed in to examine their decision-making process with the distinctiveness framework. The psychological concept distinctiveness describes how people process the differences within a context of similarity (Hunt, 2006). When prospective teachers are confronted with multiple events and incidents in the practicum, they need to decide what they would direct their attention and allocate their cognition

resources to. After one-week observation, they also have to pick one event or incident to reflect on and create their critical incident. The concept of distinctiveness was used as a lens to examine how prospective teachers identified the noteworthy events and incidents in the midst of their observation as well as how they chose one event each week to elaborate on and constructed their critical incident. Through analyzing these processes, I attempted to understand prospective teachers' knowledge acquisition as described by the PCK in the block of teacher education courses.

As indicated above, this dissertation is comprised of three major pieces. I began with characterizing prospective teacher noticing. Then I explored their knowledge developed as described by the PCK framework and connect their PCK with what and how they noticed. Finally, I examined their noticing and knowledge acquisition processes at the microscopic level with the distinctiveness framework. Three manuscripts were constructed to delineate the three parts of the dissertation. The first manuscript focused on characterizing prospective teachers' noticing. I analyzed six participate prospective teachers' noticing with two different analytic methods. I explored prospective teachers' knowledge development as described by PCK framework in the second manuscript and investigated the relation between their PCK and their noticing. In the final manuscript, I examined the use of distinctiveness framework to elicit how one prospective teacher chose the events and incidents to notice and to reflect on to so her knowledge experienced an improvement. I describe the conclusions of each manuscript below.

Summaries of Manuscripts

Manuscript 1 Prospective teachers' noticing

Prospective teachers' weekly observation journals are the major data source. Two approaches were employed to characterize prospective teachers' noticing, which include analyzing prospective teacher noticing with five dimensions and with a noticing score rubric. Results indicate that prospective teachers' noticing is idiosyncratic and are not related to the context, in this case, which classrooms they were placed for their practicum experiences. On one hand, prospective teachers who were placed in the same classes together during both their first and second placement, developed different patterns of noticing. When analyzing the five noticing dimensions of two groups of prospective teachers who worked together across the semester, their percentages of codes under at least three dimensions were quite different from each other within the group. Similarly, noticing scores of prospective teachers within one group are also different. On the other hand, the two prospective teachers, whose percentages of codes were very similar under four dimensions, observed and assisted teaching in two different science classes. The prospective teachers who scored similarly, e.g. both increased their noticing scores towards the end of the semester, were also placed in different classes.

Further examination of prospective teachers' noticing who were placed in the same classes working as a group suggests that they directed their attention to different events and incidents. In addition, when the two prospective teachers worked in one group directed their attention to the same event, they evaluated and interpreted what they had observed in diverse ways, which results in their different noticing scores. Bulk of noticing literature has documented teacher noticing in a way that teachers were directed to pay attention to

specific aspects of teaching. This study adds to the evidences of what and how prospective teachers notice in an authentic context when no directions were provided.

With regard to prospective teachers' development of noticing across the semester, it is a slow process. Prospective teachers' noticing scores were different at the beginning of the semester, which reflected their individualized ways of approaching the events and incidents they were exposed to. During the semester, only two prospective teachers experienced the increase of their noticing scores and the increase occurred at the very end of the semester. The remaining prospective teachers noticing scores either remained the same or changed between two scores across the semester. It seems that prospective teachers have their own preferred way of paying attention to, evaluation of and interpretation of events and incidents when they observe in their mentor teachers' classes and the change of their ways is not a quick process.

Given these results, it is worth to mention that these results were mainly based on prospective teachers' weekly observation journals. Therefore, their writing of the journals influenced how I interpreted their noticing. The observation journal template was provided to the prospective teachers at the beginning of the semester, which asked prospective teacher to write what drew their attention and their thinking in that moment. One prospective teacher followed this template consistently across the semester while the other five participate prospective teachers chose their own way of making notes of what they observed in the practicum. Following the template made the prospective teacher, Gabby's observation journals rich with details of what and she observed in the practicum.

Manuscript 2 Prospective teachers' knowledge development

Interview has been a common way of assessing teacher PCK especially for prospective teachers who have limited instruction experience in the teacher education program (Weiland, Hudson & Amador, 2014). Three semi-structured interviews were conducted at the beginning, middle and end of the semester to capture prospective teachers' PCK. Park's (2005) hexagon PCK model was employed as an analytic tool to explore prospective teachers' development of PCK components, themes under each component, their learning sources, as well as the interplay among the components. Among the six prospective teachers who were the primary participants for the noticing piece of the dissertation, four of them completed all three PCK interviews. Therefore, these four prospective teachers were included as the participates for the second manuscript.

The prospective teachers' learning outcomes and experiences are diverse. They developed different PCK components. One prospective teacher developed all six components, two of them who were placed in different science classes developed the same four PCK components, and one developed three components. In the cases that prospective teachers developed same components, their themes under each component are different from each other. The prospective teachers drew from different sources to build their PCK, which included observing their mentor teachers, interacting with students in the classes, reflecting on their own teaching, and their previous learning experiences. Given that the two PCK components, knowledge of instructional strategies (KIS) and knowledge of students understanding (KSU), are the two most common components prospective teachers developed, it is not surprising to find that the interplay between KIS and KSU are the central among all the connections among components. The only PCK component that one

prospective teacher developed but was not in any way related to KIS or KSU is teacher efficacy.

With regard to the connection between teacher noticing and PCK development, it seems that prospective teachers' PCK development is dependent on their noticing. Prospective teachers' noticing to specific events appears to be the prerequisite for their knowledge development. For example, to learn the knowledge of instructional strategies, they need to first pay attention to the instructional strategies their mentor teachers implemented in instruction. Prospective teachers' selective choice of events and incidents are the raw materials that they need to process on to build their knowledge. However, only paying attention to the events and incidents does not lead to knowledge development. The following reflecting processes of evaluation and interpretation on the events and incidents are also required for their knowledge development. After prospective teachers' identification of the noteworthy event, their reflections on why the events and incidents happened, what were the consequences of what happened, as well as how the events and incidents relate to the general principle of teaching and learning facilitated their knowledge improvement. As shown in the data, the more sophisticating of a prospective teacher's noticing, the more components of PCK he/she has developed. These results also confirm that reflection is the driving force for teachers' development of PCK (Park & Oliver, 2008).

Manuscript 3 Distinctiveness as a lens to understand prospective teacher noticing and knowledge development

When prospective teachers are confronted with multiple events and incidents during their observation in the practicum, they need to decide what they will pay attention to and allocate their cognition resources to evaluate and interpret them. Their PCK developed as

a result of reflecting on the events and incidents. The concept of distinctiveness was used as a lens to examine how prospective teachers identify the noteworthy events and incidents and how their knowledge developed resulting from the recognition and processing of the distinctiveness of the events and incidents.

I analyzed the 13 critical incidents one of the prospective teachers, Gabby, submitted to elicit her processing of distinctiveness of the events and incidents. I understand the concept of distinctiveness as both a variable and as a process. Analyzing Gabby's critical incidents with the distinctiveness framework made her processing of the differences and similarities among events and incidents visible. Her changes of approaching the events and incidents from novel to significant, and her events and incidents processing from progressive differentiation to integrated reconciliation from the beginning to the end of the semester indicated that she had limited resources to process and appraise at the beginning of the semester. However, as the semester progressed, she accumulated more and more resources so that she started to compare the new events and incidents she identified with the ones she noticed before. This study demonstrated that the concept of distinctiveness seems to be an effective tool to facilitate our understanding of how teachers' learning starts.

Conclusion of the Dissertation

To sum up, the prospective teachers' noticing is idiosyncratic as they participate in the practicum. When they observed and assisted teaching in their mentor teachers' classes, they chose to direct their attention to various events and incidents. Based on the results of one case study, both events and incidents that they have never seen before, and those that "match important memory representations" (Schmidt, 2006, p. 60) drew prospective teachers' attention. After identification of the noteworthy events and incidents, they

employed diverse methods to process them, through item-specific processing, relational processing, progressive differentiation or integrative reconciliation. Depending on their allocation of cognitive resources, they exhibit different levels of noticing sophistication. The differentiation of noticing sophistication results in their individualized development of knowledge as described by the PCK framework. Prospective teachers whose noticing is more sophisticated, developed higher numbers of PCK components and their PCK components exhibited more connections with each other.

This dissertation implies that prospective teachers learn in the practicum in diverse ways. They choose different events and incidents to focus on, assign different meanings to them, processing the events and incidents differently, and as a result, their learning outcomes and experiences are different too. Further questions regarding prospective teachers noticing and knowledge development include: what are some potential factors that influence prospective teachers' selective choice of events and incidents they decide to pay attention to? What guidance prospective teachers need to guide their reflection when they are in the practicum?

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APPENDICES

Appendix A

PSTs Observation Form

Please describe "what stands out to you" as you observe in the classroom today. In the space below, please write down moments that stand out to you and get you thinking about your own practice in some way. This table is a recording of your thinking in real time.

Date: Name:
Name of the school: Class observed:

Time	What stands out to me	My thinking in the moment

Remind the PSTs: they can jot down the events that they feel interesting, surprising, unanticipated, etc. Talk to the teachers when you feel confusing about any of his/her talking/instructions. Also, something that emerged from class discussions with university instructors and your peers, or students.

Appendix B

Guided Questions for Weekly Journal

Critical incidents creation framework	Guided questions
Describe the incident	- Please describe the incident you have observed in great details.
Suggest an explanation and meaning within the immediate context	- Why did you pay attention to this incident? - What information (regarding teaching and learning) can you tell from this incident? - How could you explain this incident in the situation?
Find a more general meaning and classification/significance of incident	- What does this incident mean in a general meaning of teaching and learning? - What does this incident get you thinking about your own teaching/practice/understanding? - In what ways do you think this event is significant?
Position	- What are your other comments about this incident? - How would you deal with this situation if you were the teacher at that moment? - What did you learn from this incident? - How would you evaluate this event?

Appendix C

PSTs Noticing Analysis with Five Dimensions Code Book

Dimension	Codes	Descriptions	Example
Domain	Domain-dependent	Specifically relate to science teaching and learning.	"Students go to lab and complete lab of seeing chloroplasts in different water solutions, one with more salt, one freshwater; then students see if changes occur; this lab is to learn and experience how diffusion is different from osmosis and overall hypotonic/hypertonic solutions" (Gabby, 2:26)
	Domain-independent	Not subject-specific or topic specific.	"The class starts when the teacher walks in and begins talking. To begin class Mr. L begun discussing the schedule for today and the week. This was helpful because students knew what they needed to study and what to expect for today. After the summary of what to do, the kids took a quiz over the information they were covering." (Jane, 1:12)
Specificity	General	Overall descriptions of what happened	"Students continued to discuss ecosystem interactions today. Students split into groups and, once again, only answered questions from their assignment sheet that Mrs. P deemed necessary." (Simon, 5:22)
	Specific	Focuses on specific events, give detailed information of what had happened, and provide evidences.	Coach Y transitions to the second lab by simply saying "Okay, when you finish the lab…" then explains the next activity. Students have two labs then use the in-class laptops to take online post-

			lab quiz, answering questions about what they learned from the labs or what they should have discovered. The post-lab questions give Coach Y a grade for them for the day, they don't turn in the lab. Coach Y ends class by saying "straighten up and sit down", which is a repetitive daily phrase I have noticed. (Carlie, 3:18)
Stances	Description	Recount what happened	"Students finished activity 10, the ecosystem dynamics activity that they had been working on for the past week. Students worked in their groups to analyze a specific graph depicting a biotic or abiotic relationship. Students also had analysis questions for each to answer. At the end of class, Mrs. P led the class in a discussion to compare their responses." (Simon, 5:24)
	Evaluation	Comment on what is good or bad.	"One technique that Ms. P had to use today, was clapping or call and response to bring the students' attention back to her. She would use "clap once if you can hear me," and other similar techniques. Ms. P clearly does not like raising her voice and one of her expectations is that the class is quiet when she is speaking. I think this technique is fantastic. While it is a bit elementary for high school, I think it could be adjusted in a way that does not patronize high school students." (Cary, 4:16)

	Interpretation	Give reasons of why events are good or bad, discussions of what can be done differently, how the event is related to general principles of teaching and learning	Begin with descriptions of what happened, then comment the event: "I was very surprised that the lab very much allowed the students to design a poor experiment, but I think there were a couple of topics this could address in the future. She could later talk to the students about how they would design the experiment again, why they think different groups gathered different data, and what do scientists do if their data does not match their predictions. Unfortunately, I was unable to ask Ms. P why she did everything the way she did at the end of the class." (Cary, 4:5)
Topics	Assessment	What was assessed, the way it was assessed, students feeling for the assessments and teachers approaches of facilitating students learning based on assessment results.	"Today the students had their first exam. As students came into class, a few were prepared and others seemed quite nervous. Before the test, some students asked questions before the test and other students answered their question with some assistance from the teacher." (Jane, 1:5)
	Class Discipline	Students discipline in the class unrelated to science teaching and learning, such as disruptive behaviors.	"When teacher leaves because of administration who came to the class; students begin to whisper and not stay silent; they break silence without teacher present" (Gabby, 2:56)
	Class flow	Overall descriptions of how the class is delivered and steps of instruction.	"After all of the students completed the quiz, the teacher began to speak about how they would be discussing some of the prefixes from their quiz in

			the lab today. He later went through and explained the lab." (Jane, 1:24)
	Classroom management	Teachers strategies of managing classes, which are not related to disciplinary issues, including: grouping students, seats arrangement, catching students attention, etc.	"Before class, I talked with Coach Y about how he groups students. Because of the variety of academic ability in the class, I was curious. He told me that it is a fine balance of achievement, personality, compromise, and straight-up guesswork. He doesn't pair his highest achieving with his special education students, saying that that almost always ends in the advanced student just doing the work for the sake of both of them, which makes sense to me." (Simon, 5:50)
	Curriculum	Curricular saliency, teaching materials and resources	"Friday's class focused primarily on Mendel's genetics. Once again this is a logical step after the students saw meiosis earlier in the week. They had vocab to practice this week that covered terms in genetics (along with a quiz on Friday) so they are becoming familiar with homologous pairs and sister chromatids, but they have not seen crossing over, so they do not necessarily know how segregation works, which has led to some confusion in the class." (Cary, 4:56)
	Instructional Strategies	Subject specific strategies, representations of content and activities.	
	Orientation	Beliefs about purpose of science teaching and	

		learning, beliefs about nature of science	
	Students learning	Students motivation and interests, misconceptions, learning difficulties, and affective outcomes.	
	Teaching efficacy	Beliefs about teaching capability.	
Agent	All students	Students as a whole group	
	Groups of students	Specific groups of students	
	Specific students	One or two students behavior/learning	
	MT	Mentor teacher	
	Other teachers	Other teachers came across or talked to in the practicum, such as substitutes.	
	Self	Focuses on what their own were doing in the classes.	
	Peer	The other PSTs in the practicum. practicum.	

Appendix D

Examples of Noticing Units at Each Score

Score	Examples of Noticing units
1	"Today's class was centered around reviewing for Wednesday's test. At the start of class, students came in and took their seats. They conversed with the teacher and talked about their quiz they would have to take in a few minutes. This quiz consisted of 10 questions that covered prefixes that they had to learn. Today I discovered that they had this vocab quiz every Monday and Mr. L also gave me a copy of the list of vocab words that are used to create each quiz." (Jane, 1:1)
2	"Another puzzling incident occurred when Ms. P started telling me that she made the groups herself and she based them off students' reading comprehension results from standardized testing earlier in the week. She grouped students with similar reading comprehension together instead of mixing students with high scores with students with low scores. I assumed putting mixed levels together would allow the students to help teach each other as they worked through the problems. I would be worried that the groups that struggled the most with comprehending the words on their lab sheets might get stuck and progress less. Once again, this will also need to be addressed at a later date since I did not have time to discuss this with Ms. P at the end of class." (Cary, 4: 6)
3	"Students worked in a lab today, but their lab assignment was designed in a way that promoted critical thinking in a way that I never had in middle school. When I was in 7th grade, lab assignments always had their methods listed out meticulously. For the assignment in Mrs. P's class, students were only given a question, told their available resources, and given the freedom to design their own experiments. The experiment was set up in a way to lead all students to very similar methods, but the extra bit of thinking required of them to get there is a critical aspect of science that is often overlooked." (Simon, 5:4)

4	*"How can I make all students feel like a valuable part of the class community?* Today, students were split into groups (based on where they were sitting, not by choice) to work on creating a food web together. Just before we handed out butcher paper and markers, however, Mrs. T paused class, and designated exactly 1 minute for everyone to tell their group something about themselves (see "techniques to remember" below for more detail). One student (I'll call Max) has been particularly quiet the entire time we've been here; Mrs. T told us that he was mostly in a self-contained special education class in previous years, and this is his first experience being in regular classes full-time. During the activity, the girl across from Max shared that he aspired to be a famous rapper. Mrs. T told him he was welcome to perform a (clean) rap for the class if he ever wanted to. Later, when the class was doing a Gallery Walk of the food webs they'd drawn, I heard Max quietly preforming improvised raps to go with each food web for his group members. Each time they rotated, one of the other kids would go "Okay Max, do this one." Even when he wasn't showing off his talent, the fact that his interest had been accepted by the others seemed to give him a new sense of confidence. This week I've been thinking a lot about promoting positive relationships between students. I felt the "take one minute" activity was a concrete and efficient way to foster this sense of community." (Rosie, 6:10)

Appendix E

An Example of PCK Segment

Carlie (Segment 6-1)	PCK components
Today I was talking to a student. They asked me a question about the lab and it was about diffusion versus osmosis and then hypertonic and hypotonic cells or whatever. And we got osmoses. It's water moving. We got osmosis. She said that. I didn't even say that word. She said osmosis and then I was like, right, so what did you see the water do with the cell? Like did it move in or out? And they were like, I think they said something else. Okay so what's that called and they're like hypotonic solution. I'll take no, that's just simply not right. And so like I don't know how to be like no it's hypertonic. Like I help them get there but like they didn't get there still and it wasn't because of the path that I took, it was about they didn't actually know what that term was. So then how do you go back and say, well remember… and I think I end up saying: remember when they were talking about IVs and why you can't just put water in an IV you have to have like a solution… I think next time if I had the same situation when they throw out that random answer even though it's along the right lines, what's not correct, you're like so why, why do you think that like what does hypertonic mean? And then they will like, oh, oh, actually that's not right. I think I need to ask them yeah I think that's what I would do next. (INTV-1-L255)	K of IS K of SU KIS: Eliciting students existing understanding helps teachers facilitate their learning. SU: Students guess answers, learning difficulties. Sources: interacting with students