SCIENCE TEACHERS' LEARNING TO NOTICE FROM VIDEO CASES OF THE ENACTMENT OF COGNITIVELY DEMANDING INSTRUCTIONAL TASKS

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Members of a profession develop a professional vision that enables them to see and understand complex situations in particular ways. This study focuses on developing science teachers' professional vision by supporting their learning to attend to particular classroom interactions and make sense of them in particular ways. Specifically, this study investigated high school biology teachers' learning to notice in a professional development (PD) setting from video cases that depict classroom interactions during the enactment of high-level, cognitively demanding science tasks. A seven-session, video-based PD intervention in which teachers analyzed short video clips that illustrated students' engagement with cognitively demanding tasks was designed and implemented. The findings focused on changes in teacher noticing from pre- to post-PD as revealed through the analysis of two sets of baseline and exit interviews with each individual teacher as well as the analysis of particular PD sessions. According to the findings, there were mostly significant changes in what teachers attended to in the video cases and how they made sense of what they saw. In addition, there was a shift towards connecting the specifics of what they noticed in the video cases to the level or kind of student thinking as outlined in the Task Analysis Guide in Science framework. The findings are promising in terms of developing science teachers' professional vision of classroom interactions during the enactment of cognitively demanding tasks. The study findings provide implications for designing effective PD programs to support teachers' professional vision.

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1.0 INTRODUCTION

> **Susan:** …[The student said] 'I know there are two alleles for each gene, so, I mean, is it separate two?' And so she [the teacher] says, "Right, it could be the black [allele] or the white [allele]." But she's just helping clarify. But then she lets them go through that whole process of putting two and two. She doesn't tell them, "Just go ahead and try it."
> **Facilitator:** Help me to write it. What was the difference [between the two video cases]?
> **Susan:** I said for the second teacher, the video-two, she redirected the students' question back to them or tried to get them to work through it.
> …
> **Linda:** I said teacher-two guided students to answers and materials and processes and teacher-one told students what materials [needed for the task] and processes were.
> **Nancy:** Yeah.
> **Barbara:** She [the teacher] did that. They [students] said, well, they have two alleles and a gamete and she said, "Okay, well, let's work through this." And then they realized on their own that oh, they can't have four [alleles for a gene].

Susan, Linda, Nancy, and Barbara were high school biology teachers who were participating in a video-based professional development about effective science teaching. The above discussion occurred after viewing video clips of two different classrooms in which the same biology task was being used. Their comments provide evidence regarding how teachers see and understand what happens in a video case in which the work of their profession is on display. This study is about what teachers see when they look at video records of instruction depicting the complex interactions between teacher and students that occur when they work together on cognitively rich tasks.

Prior research indicates that *learning to notice* in particular ways is related to developing expertise in a profession (Jacobs, Lamb, & Philipp, 2010; Sherin, Jacobs, & Phillip, 2011a). According to Goodwin (1994), members of a profession develop a *professional vision* that enables them to see and understand complex situations in particular ways. For example, an archeologist and a farmer who are looking at the same spot of sand will see different things—one sees soil that will support particular kinds of crops while the other sees a stain that provides evidence for earlier human activity at that spot. Sherin (2001) claimed that teachers need to develop a professional vision too, an "ability to see and interpret critical features of classroom events" (Sherin & Han, 2004, p. 179). Within the last decade, there has been a host of professional development efforts designed to improve teachers' professional vision. This study is one of these efforts, focusing on the development of science teachers' professional vision by supporting them learn to see particular classroom events and make sense of them in particular ways.

Goodwin (1994) used the jury trail of Rodney King[1] to illustrate how members of a profession (in this case, the police) were able to see and understand the actions of both police officers and Rodney King (as recorded on a videotape of the beating) through a common, professionally trained, perceptional lens. The defense's argument relied on the claim that experts can be counted on to describe authoritatively what the "police officers could legitimately see as they looked at the man they are beating" (p. 616). Analysis by expert police officers focused on whether or not King's body movements should be coded as aggressive or cooperative because if his actions were aggressive "then police were entitled to use force to protect themselves and take him to custody" (p. 616).

The point that I want to underscore is that a key aspect of the professional expertise of the police officers that provided expert testimony was their socially shared framework for what was

[1] This was a trial of four white police officers charged with beating Rodney King, an African-American motorist who had been stopped for speeding. Whether these four police officers should be convicted or acquitted were decided through analyses of the tape of that instance recorded by an amateur video photographer.

worth seeing and how to interpret what was seen. If teaching is a profession (as is police work), it follows that teachers should learn to attend to and makes sense of “teaching events” in professionally sanctioned ways. For example, one could argue that expert teachers should be able to identify the moves of a video-recorded teacher in terms of the ways in which she facilitates students’ engagement in rich, but demanding, instructional tasks.

This study is about science teachers’ professional vision. I investigate science teachers’ learning to *notice* (attend to particular instructional events and make sense of them) classroom interactions[2] *as students engage with high-level, cognitively demanding science tasks*. Like Sherin and Han (2004), I assert that the learning that happens in the video-based professional development setting “can be characterized as the development of teachers’ professional vision” (p. 179) because teachers learn to attend to particular kind of classroom events and to make sense of these events in particular ways through professional development. In this chapter, I situate my study within the research literature on teacher noticing as well as highlight why it is important to study teacher noticing, particularly teachers’ learning to notice from video cases of science classrooms in which cognitively demanding tasks are being enacted. I conclude this chapter by presenting the research questions that guided this study.

[2] I use the word “interaction” similar to how Cohen and Ball (2000) did, in that “interaction does not refer to a particular form of discourse, but to the connected work of teachers and students on content, in environments” (p. 3).

1.1 WHY IS IT IMPORTANT TO STUDY TEACHER NOTICING?

Teachers spend a significant portion of their days in the classroom taking in and interpreting information about their students. Some of this information is collected systematically—such as taking attendance, collecting homework, and checking for assignments. A large proportion of information, however, arrives continuously on its own, like the questions students ask, the comments they make, and the mistakes they reveal in their explanations (Hammer, 2000). Sherin and Star (2010) characterized this situation as the "blooming, buzzing confusion of sensory data" that the teacher is confronted with during instruction. In this complexity, does the teacher pay attention to the students' moving pencils or to their moving thoughts; staying quiet in the classroom or playing with the disciplinary ideas; following procedures to complete a given task or spending time to understand the conceptual ideas behind those procedures (Erickson, 2011)?

There is a general agreement in the literature that what the teacher sees and does not see in the classroom shapes what a teacher can act on (Erickson, 2011; Jacobs, Lamb, Philipp, & Schappelle, 2011; Schoenfeld, 2011). For example, Jacobs and her colleagues (2011) considered teachers' planning for how to respond based on students' understanding as an important component skill of professional noticing. They claimed that the skills of attending and interpreting "are not ends in themselves but are instead starting points for making effective instructional responses" (p. 100). Findings of their study on teacher noticing indicated that being able to describe children's strategies and interpret their understandings is foundational for responding on the basis of children's thinking (Jacobs, Lamb, Phillip, Schappelle, & Burke, 2007). Similarly, Hammer (2000) noted that, based on what teachers attend to in their students (e.g., that a student was confused, that students were not able to explain their work, etc.), they decide to proceed in different ways (e.g., pose a less-challenging question, provide examples of good explanations, etc.). Moreover, this noticing and responding relationship is the main assumption behind studies of teachers' in-the-moment noticing (i.e., Levin, 2008; Sherin & van Es, 2009) where inferences about what teachers attended to while teaching is inferred from teachers' instructional responses (Sherin, Russ, & Colestock, 2011b).

Prior literature shows that what teachers see and do not see in the classroom also shapes what their *students* attend to. For example, Levin (2008) presented a case of a teacher who drew her students' attention to vocabulary, conceptual correctness, and misconceptions by primarily attending to those features in students' ideas in her classroom. This relation between teachers' and students' attention was also evident in Erickson's (2011) discussion of a set of propositions that he developed based on the findings of a study of teacher noticing in the early 1980s. He claimed that what teachers notice (e.g., about deportment, students' ideas, mistakes in students' responses) affects what their students notice in the classroom. In short, what teachers notice is consequential, affecting both their own actions as well as to what their students pay attention.

1.2 TEACHERS' LEARNING TO NOTICE WITHIN THE CONTEXT OF PROFESSIONAL DEVELOPMENT

Studies of professional development efforts in which artifacts from classroom practice (e.g., video clips, transcripts, samples of student work) are used to support teachers' learning to see classrooms in new ways have proliferated over the past decade. Most of these studies focused on helping teachers learn to attend to and interpret *what* students are thinking (i.e., Hammer & Schifter, 2001; Jacobs et al., 2010; Sherin & Han, 2004; van Es & Sherin, 2008), because attending to the substance of student thinking is considered to be absent from most teachers' practice (Levin, 2008). These professional development efforts have supported many teachers becoming more attentive to students' ideas and getting better at making sense of what their students mean. This study is another effort to examine teachers' learning to notice using video-based professional development. However, it is different than prior work primarily because of its focus on examining teachers' learning to notice classroom interactions in a particular kind of classroom environment, *one in which cognitively challenging science tasks are enacted*.

1.2.1 Teachers' learning from the video cases of enactment of cognitively demanding science tasks

My focus on enactment of cognitively demanding tasks is purposeful. Prior literature, primarily in mathematics education, shows that how tasks are enacted in the classroom is important because this shapes students' opportunities to think and reason during their work in the classroom: Do students memorize facts and formulas? Do they follow a set of given procedures without sense making? Or do students engage in high-level reasoning about [the content]? In addition to influencing what they learn (Stein & Lane, 1996; Stigler & Hiebert, 2004; Roth et al., 2006), their engagement with classroom instructional tasks leads students to form judgments about the nature of school subjects and how hard they should have to work to make sense of them. Equally important is the finding that sometimes teachers unwittingly turn cognitively challenging, complex tasks into procedurally-based activities in which students simply reproduce previous knowledge without making sense of the disciplinary ideas (Stein, Grover, & Henningsen, 1996). This suggests that teachers need to attend to the kinds of interactions that take place during the enactment of cognitively challenging tasks in their classrooms; in particular, they should learn to interpret *how* their students are thinking while trying to make sense of the disciplinary ideas and how their actions may lead to the maintenance or decline of high-level student thinking. Prior research provides promising evidence for the consequences of what teachers notice during the enactment of high-level tasks in the classroom. In his recent study of teachers' professional noticing, Choppin (2011) found that mathematics teachers who attended to the details of student thinking while teaching cognitively-challenging tasks maintained the complexity of the tasks, while those who failed to attend to student thinking reduced task complexity.

Video-based professional development can provide teachers with opportunities to prepare themselves to notice particular things during their actual classroom practice. This is in line with Mason's (2002) *discipline of noticing* idea, which emphasizes the need to train oneself to "notice-in-the-moment" (Sherin et al., 2011a)—in other words, sharpening sensitivity to notice particular things while teaching. Mason (2002) claimed, "…developing the sensitivity to notice particular things, and to notice them when it would be useful to have noticed (and not merely later, in retrospect) requires effort. Disciplined noticing is really about making that effort" (p. 31). Sustained effort—such as that which can be invested during carefully planned professional development—is needed for teachers to be able to develop sensitivity to notice particular things while teaching. In addition, possible actions can be accumulated through noticing other people or yourself doing them so that one can remember these actions before an automatic reaction in a particular situation. Thus, the discipline of noticing increases the likelihood of having these actions come to mind (Mason 2002; 2011). In the professional development conducted within this study, teachers analyzed video cases of enactments of cognitively challenging tasks in science classrooms in which teachers were instrumental in maintaining or declining the cognitive demand of high-level tasks. In line with Mason's reasoning, viewing these video cases from their own and others' classrooms should have the potential to support teachers' future actions that are necessary for maintaining or inhibiting the decline of high-level thinking during the enactment of cognitively demanding science tasks in their own classrooms.

In prior teacher noticing studies, teachers' learning was facilitated in professional development settings with discussions of video excerpts from the participating teachers' own classrooms without an explicit orienting framework for selection. For example, Sherin and Han (2004) conducted what they refer to as a "video-club" for middle school mathematics teachers. Before each meeting, one of the researchers video recorded a teacher's class. Then, the researcher and the teacher met to review the video and to select a short clip to view in the video club meeting. In other studies (e.g., Sherin & van Es, 2009), video clips were selected by the researcher to portray students' thinking about mathematics by following the dimensions described by Sherin, Linsenmeier, and van Es (2009) for characterizing video clips of student mathematical thinking. These dimensions include the extent to which a clip provides windows into student thinking, the depth of thinking shown, and the clarity of the thinking. By contrast, in this study, the video clips were specifically selected to show a cognitively demanding task unfolding during a science lesson by using a framework that helped to differentiate the level or type of student thinking during the enactment of instructional tasks.

1.3 FOCUS OF THE STUDY

This study examines science teachers' learning to notice through video-based professional development. I designed and implemented a seven-session video-based professional development intervention (hereafter referred to as Noticing-PD) in which teachers analyzed short video-clips[3] that illustrated enactments of cognitively challenging tasks in science classrooms, and then discussed what they noticed and how they interpreted the level or type of student thinking in these video cases. Teachers' analysis of the video cases was supported with an analytical framework that was developed to identify the cognitive demand of science tasks (Tekkumru Kisa, Stein, & Schunn, in preparation).

1.3.1 Research questions

This study examined what science teachers attended to and how they made sense of what they attended to in the video clips depicting enactment of cognitively-challenging science tasks. I investigated the extent to which teachers changed their analysis of video cases from the beginning to the end of the Noticing-PD. Specifically, the study addressed the following research questions:

1. In what ways and what did teachers *attend to* in the video cases change from the beginning to the end of the Noticing-PD?
2. In what ways did the teachers approach *making sense of* what they attended to in the video cases change from the beginning to the end of the Noticing-PD?
3. To what extent did teachers learn to *recognize video cases as an instance of* a particular level or type of student thinking?

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[3] From now on, I will call these video clips "video cases" to call attention to the fact that they were selected to be and used as "cases of" particular kinds of enactment of cognitively demanding tasks in science classrooms (Shulman, 1996).

1.4 SIGNIFICANCE OF THE STUDY

This study contributes to the current knowledge base on teacher noticing in several ways. First, by focusing on developing high school biology teachers' expertise in noticing, this study expands prior work on teacher noticing that was limited to mathematics. Studies of teacher noticing through professional development have proven to be effective for supporting mathematics teachers' learning to notice important features of classroom interactions (i.e., Jacobs et al., 2010; Sherin & Han, 2004; Sherin & van Es, 2005). This study is a first attempt to extend this work on mathematics teachers' learning to notice into science.

Second, unlike prior research, this study aims to develop teachers' noticing by focusing on classroom episodes in which cognitively challenging tasks are enacted. More specifically, this study examined what professional development participants noticed in the video cases that showed the classroom interactions that occur as high-level cognitively challenging science tasks are enacted and how they made sense of the level and type of student thinking in these classrooms. Moreover, it analyzed the participants' learning to notice how teachers' moves and actions influence students' thinking and actions. Attending to the relationship between students thinking and teacher actions is generally considered the highest level of noticing expertise that teachers can develop (i.e., Sherin & Han, 2004; van Es, 2011). In this study, attending to this relation may allow PD participants to recognize how a teacher's actions can lead to the maintenance or decline of high-levels student thinking during the enactment of cognitively challenging, complex science tasks.

By focusing on enactment of cognitively demanding tasks, the study also extends mathematics education research on implementing cognitively demanding tasks in mathematics classrooms (i.e., Stein, Smith, Henningsen, & Silver, 2000; Stein et al., 1996) with a study of teacher noticing.[4] In particular, the present study has the potential to add a new factor to the already identified set of factors in the mathematical tasks framework (Stein et al., 1996), which have been shown to contribute to the maintenance of high-level thinking and reasoning: teachers' capacity to interpret how students are thinking when they are engaged with cognitively demanding tasks.

Lastly, this study attempts to improve the design features of video-based professional development programs that aim to support teachers' learning to notice. The main venue for supporting teachers' learning to notice is video club meetings. In these meetings, a group of teachers view video-excerpts from their own or others' classrooms and discuss what they noticed in the video excerpts (Sherin, 2000; Sherin & Han, 2004). This study included new design features for "video club" professional development. Drawing on previous research that demonstrates the influence of contrasting cases on what somebody notices (Bransford & Schwartz, 1999; Schwartz, Bransford, & Sears, 2005), the design of the Noticing-PD in this study involves the use of contrasting video cases of task enactment. More specifically, midway through the seven sessions of Noticing-PD, I incorporated contrasting cases selected to represent the level of student thinking (high and low) during the enactment of a cognitively demanding biology task.

In addition, the video-based professional development in this study is supported by the use of an analytical framework designed to differentiate science tasks based on their cognitive demand levels (Tekkumru Kisa et al., in preparation). This framework was incorporated into the design of the Noticing-PD to help teachers connect the specifics of what they see in the video case to the larger set of ideas about teaching and learning as represented in the framework. Prior

[4] As such, the study also extends Stein and her colleagues' work that was limited to mathematics education to science.

literature indicates the importance of making this link between the specifics of what was noticed and larger concepts and ideas that help teachers to make sense of and reason about what is noticed (Shulman, 1996; Stein et al., 1996; Sykes & Bird, 1992; van Es & Sherin, 2002).

1.5 LIMITATIONS OF THE STUDY

This study allowed me to identify, at a detailed level, what, if any, changes occurred in teachers' noticing from the beginning to the end of the Noticing-PD. It did not, however, allow me to identify the cause (in terms of the mechanism responsible) of the changes that were observed. That said, the findings provided insight into what aspects of the Noticing-PD might have influenced the change in teachers' noticing. Thus, I provided a detailed description of the Noticing-PD, the critical intervention of this study. Particularly, I provided detailed information about the PD activities that took place in sessions 3 and 4 (the two sessions that were used for the data analysis) and the design rationales of these activities. The study's findings allowed me to develop a set of propositions regarding the design features of the intervention that may have shaped what teachers paid attention to and how they made sense of what they saw in the video cases.

It is also important to underscore that this study did not aim to investigate the effect of the Noticing-PD on teachers' practice. There is a limited empirical knowledge base on the influence of video-based professional development programs that are designed to support teachers' noticing on their instructional practices. Sherin and van Es (2009) examined how teachers' experiences in the video club influenced their subsequent teaching practices and found an increase in teachers' capacity to attend to and reason about students' mathematical thinking in the classroom, which was consistent with their professional vision exhibited in the video club meetings. It is clear that more research is needed in this area.

Even though looking at the effect of Noticing-PD on teachers' practices is beyond the scope of the current work, focusing teachers' attention on a particular classroom environment—one in which cognitively demanding tasks are enacted—may have supported teachers' applying what they learned in the professional development to their classroom practices, because analysis of video cases generally involved consideration of what specific teacher practices facilitate high-level student thinking. I agree with Hammer and Schifter (2001) who argued (in the context of meetings with a group of physics teachers around issues of teaching and learning) that:

> We often speak of these conversations … as forms of exercise, related to teaching the way shooting-and-passing drills are related to playing basketball. The conditions of the exercises are different from the conditions of the game, but that is their value: They allow a more extended, intensive focus on those aspects of the game (basketball or teaching) than is possible during the game itself. (p. 11)

In line with this reasoning, the Noticing-PD provided an intensive focus on how to maintain the cognitive demand of high-level tasks during classroom lessons, ideally helping the teachers to notice declines in student thinking and to develop a repertoire of teacher actions that they might call upon to support high-level student thinking in their own day-to-day practice. Indeed, past research that utilized professional development focusing on teachers' learning to identify levels of cognitive demand in mathematics has shown improved teacher maintenance of cognitive demand of tasks in contrast to a control set of teachers who did not receive PD (Boston & Smith, 2009). This suggests that the current study may provide a promising space for exploring the link between the professional development and teachers' actual practice.

2.0 LITERATURE REVIEW

In this study**,** I examined what teachers attend to and how they make sense of what is happening in a classroom environment, in which cognitively challenging tasks are enacted. In this chapter, I first provide background on prior research on academic tasks and their enactment in the classrooms. This will lay the groundwork for developing an argument for the significance of integrating research on cognitive demand with the current study of teacher noticing, particularly the rationale for why I decided to focus teachers' attention on *classroom interactions during the enactment of cognitively challenging tasks*. Then, I review how teachers' noticing has been defined and studied by others in the literature and explain how I define and use the construct in this study. Finally, I summarize major findings of studies on teachers' noticing, which helped me to develop the analytical framework that I used for the data analyses.

2.1 COGNITIVELY DEMANDING TASKS AND THEIR ENACTMENT IN THE CLASSROOM

2.1.1 Instructional tasks form the basis of students' opportunities for learning

Prior academic task research (i.e., Doyle 1983; 1988; Stein et al., 1996) has underscored the significance of the nature of instructional tasks that the students are exposed to in the classroom.

Students spend a good deal of time in the classroom working on tasks given to them by a teacher or generated from a print (textbook) or electronic source. Their work on these tasks sets the stage for the way students come to think about the subject matter (Doyle 1988; Henningsen & Stein, 1997). According to Doyle (1983), “tasks influence learners by directing their attention to particular aspects of content and by specifying ways of processing information” (p. 161). Therefore, the nature of the tasks with which students engage in the classroom form the basis of their opportunities for learning the content (Hiebert & Grouws, 2007; Stein, Remillard, & Smith, 2007; Stein, Smith, Henningsen, & Silver, 2009). They not only shape the substance of what students learn but also how students think about and make sense of the subject matter (Stein et al., 1996).

Research in mathematics education has revealed that not all tasks provide similar opportunities for students to engage with the content, because different tasks require different levels and kinds of student thinking (Doyle 1983; Hiebert & Wearne, 1993; Stein et al. 1996). The kind and level of thinking and reasoning required of students in order to successfully engage with a mathematical task is referred to as its “cognitive demand.” Cognitively demanding tasks are often less structured, more complex and longer than more routine and procedural tasks. Students often perceive these tasks as highly ambiguous (not having a predictable precise pathway to approaching them) and/or risky (likelihood of not meeting the evaluative criteria) because it is generally not very clear what to do in these tasks and how to do it (Doyle, 1983; 1988; Stein et al., 1996). For example, a science task that requires students to reproduce previously learned knowledge about cells by describing the differences between plant and animal cells is clearly very different in terms of its cognitive demand than another task that requires students to investigate the factors affecting seed germination.

The Task Analysis Guide (Stein et al., 2000) is a classification scheme that has been used extensively in mathematics education research to identify levels of cognitive demand of mathematical tasks. Instructional tasks are viewed as placing low levels of demand on student thinking when they require memorization or the use of procedures *without* connections to understanding, meaning, or concepts. Low-level tasks require students to reproduce previously learned rules, definitions, and formulas or engage students in algorithms and routine procedures without any attempt to foster conceptual understanding. On the other hand, tasks are viewed as placing high levels of demand on student thinking when they require the use of procedures *with* connections to understanding, meaning, or concepts or doing mathematics. Some high-level tasks require students to use procedures for developing deeper levels of understanding of mathematical concepts and ideas. Others consist of open-ended problems that require students to engage in complex, non-procedural thinking and reasoning such as framing problems, representing relationships, and looking for patterns (Stein et al., 2000).

A similar framework has recently been developed to analyze science tasks based on their cognitive demand (Tekkumru Kisa et al., in preparation). According to the Task Analysis Guide in Science (TAGS), science tasks have various combinations of "science content" and "scientific practices"[5] that require students to think at different levels of depth. Science tasks can be categorized into five levels. While the first two levels characterize low-level tasks, the last three

[5] According to the Next Generation Science Standards (NGSS), scientific practices include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanation, engaging in argument from evidence, and obtaining, evaluating and communicating information. These practices were listed in the Science Framework for K-12 Science Education (NRC, 2012), which provides a foundation for the development of the NGSS. This Science Framework for K-12 Science Education was highly influential in the development of the TAGS framework.

levels characterize high-level tasks. The hallmarks of tasks at each of these levels of the TAGS are summarized in the Table 1. (Please see Appendix A for the detailed version of the TAGS).

Table 1: The Hallmarks of Tasks at Each Level of the TAGS

		Level-1: Memorization
Level 1A	*Scientific Practice Only*	▪ Task requires memorization of definition of any scientific practice ▪ Task does not require making conceptual links with science content
Level 1B	*Science Content Only*	▪ Task does not require engagement in any scientific practice ▪ Task involves reproducing previously learned body of knowledge without conceptual understanding
		Level-2: Scripted Procedures without Connections to Meaning
Level 2A	*Scientific Practice Superficially Linked to Science Content*	▪ Task requires students to follow a sequence of actions associated with the scientific practice because they are told but not for understanding of how this scientific practice works and is connected to content
Level 2B	*Science Content Only*	▪ Task requires application of previously learned concepts consistently but without understanding of why the concepts apply here or what they really mean. ▪ Task does not require engagement in any scientific practice
		Level-3: Scripted Procedures with Connections to Meaning
Level 3A	*Scientific Practice Only*	▪ Task involves following the steps necessary to engage in a scientific practice with an understanding of how this scientific practice works. ▪ Task does not require making conceptual links with science content
Level 3B	*Science Content Only*	▪ Task requires application of previously learned concepts consistently with understanding of why the concepts apply here or what they really mean. ▪ Task does not require engagement in scientific practices but it requires deep understanding of the science content.
		Level-4: Guided Engagement in Scientific Practices with Understanding of Science Content
▪ Task focuses students' attention to the use of scientific practices for the purpose of developing deeper levels of understanding of "body of scientific knowledge"		
		Level-5: Engagement in Scientific Practices with Understanding of Science Content
▪ Task requires students to explore and understand a natural phenomenon. To do that students engage in scientific practices and access relevant science content.		

Note. For level 1, 2, and 3, the task can be at either A or B because some tasks exclusively involve either science content or scientific practices.

As depicted in Table 1, the TAGS framework indicates a continuum in the cognitive demand of the tasks from level-1, which simply requires memorization of the scientific facts or scientific practices, to level-5, which requires students to engage in the practices of the discipline to make sense of the scientific ideas and principles. Cognitively demanding science tasks, as defined in TAGS, have the potential to engage students in the kinds of learning opportunities called for in the recent Conceptual Framework for New Science Education Standards, recently released by the National Research Council (2012). As emphasized by that framework, “learning science and engineering involves integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering” (p. 11).

Although there are five levels, there are actually eight different categories into which a science task can be placed in the TAGS. In science classrooms, some tasks can be exclusively about a particular scientific practice, such as asking questions, modeling, conducting experiments, etc. Such tasks aim to teach students practices needed to engage in scientific inquiry and do that without aiming to teach any science content to the students. However, other tasks ask students to engage in scientific practices in order to make sense of particular science content. In yet other tasks, the goal might be to teach science content without requiring students to engage in any scientific practices. In short, there are different combinations of science content and scientific practices in a science task; they are sometimes interwoven with each other as can be seen in level-2A, level-4, or level-5 tasks; at other times, they are presented separately from each other, as can be seen in level-1, level-2B, or level-3 tasks. However, having scientific practice and science content together in a task does not guarantee a high level of cognitive demand. For example, a level-2A task requires students to follow a set of scientific practices related to particular science content but one can complete this task without really making sense of any science content. On the other hand, in level-5 tasks, students naturally engage in some scientific practices and this helps them to develop a better understanding of the science content.

2.1.2 How instructional tasks are enacted shapes students' opportunities for learning

The effect of a task on students' learning is determined by how they are enacted in the classroom. Prior research revealed that academic tasks are transformed once they are placed into real classroom settings (i.e., Doyle, 1983; Stein et al., 1996). This is particularly true for high-level, cognitively demanding tasks. Because students often find these tasks ambiguous and/or risky, they urge teachers to make them more explicit mostly by reducing the sense making aspects of the task. As students are faced with these difficulties, teachers find it hard to orchestrate enactment of these tasks in the classroom and they often end up focusing on the procedures devoid of conceptual meaning (Stein et al., 1996). Therefore, it becomes difficult to implement tasks in ways that will have the most positive long-term consequences for students (Doyle, 1983). Teachers consciously or unconsciously change the nature of tasks by focusing on their less challenging aspects (Stein et al., 1996). Doyle (1988) underscored the role of the teacher in task enactment; according to him, "teachers affect tasks, and thus students' learning, by defining and structuring the work students do… In addition, teachers serve as resource while students are working and manage accountability for products" (p. 169).

Stein and her colleagues (Henningsen & Stein, 1997; Stein et al., 1996) researched what happens when higher cognitive demand tasks are enacted in US classrooms and developed the mathematical task framework (Figure 1), which indicates that cognitive demand of tasks often change as they pass from *written materials* to how they are *set up* by the teacher in the classroom to how they are actually *enacted* or carried out by the students (Stein et al., 1996). Although several patterns of change have been identified (Stein et al., 2000; Henningsen & Stein, 1997), two that are particularly pervasive are when tasks that are set up as doing mathematics decline into procedures without connections or unsystematic exploration during the enactment. In the first case, the teacher—often responding to student anxiety about how to proceed—"takes over the thinking" and ends up short-circuiting students' thinking and reasoning. In the second case, students are left to flounder and, without adequate scaffolding, engage in a series of nonproductive attempts to solve the task. This final phase—task enactment—is particularly important because it identifies how students are actually thinking and reasoning during their work in the classroom (Stein et al., 1996). Similar to the results of Stein and her colleagues' studies, others have revealed a variety of ways in which students' thinking can be reduced by the teachers during the enactment of cognitively challenging tasks in literacy and science classrooms[6] (Doyle & Carter, 1984; Sanford, 1987).

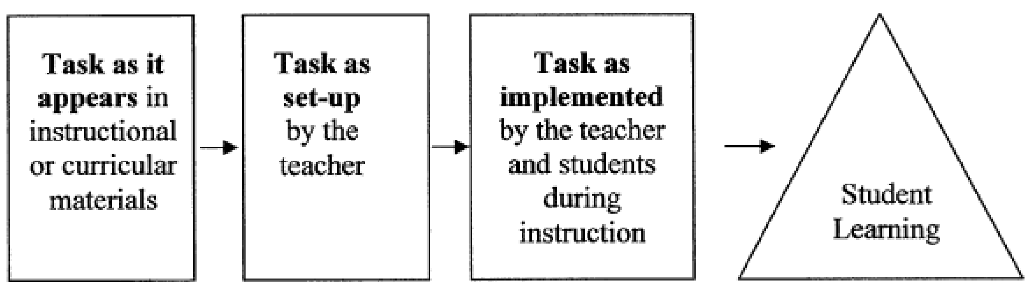

Figure 1: The Mathematical Task Framework (Stein et al., 1996)

[6] Sanford (1987) categorized the tasks as higher-order or comprehension "when they included at least some components which by design students could not complete by a) simple memory, b) routinely or automatically applying an algorithm, or c) search and match (find the answer by matching similar elements and copying)" (p. 253).

All in all, prior work on the enactment of cognitively demanding tasks revealed that, even though teachers may chose to use high-level tasks in their classrooms, due to various reasons their students often end up engaging in low-level cognitive processes. This is an important instructional problem to solve. A major step toward solving it is helping teachers better understand classroom interactions during the enactment of high-level tasks. When we show teachers video cases of task enactments in a professional development session, we actually present them a three-way interaction between a cognitively demanding task, a science teacher, and the students in a classroom setting. This three-way interaction has been referred to in the literature as the “instructional triangle”—the interaction between students and teacher around the educational material (Cohen & Ball, 1999; Cohen & Ball, 2000). While analyzing these video cases, it is important for teachers to be able to attend to important classroom interactions during the enactment of high-level tasks, make sense of the ways their students *are* thinking as they enact high-level complex tasks, and make sense of *how the teacher’s actions influence the way students think and reason about the task.* Both of these are required if we expect teachers to be able to encourage and support student understanding rather than resorting to memorization or mindlessly following procedures as an end goal of a task.

By summarizing prior research on enactment of instructional tasks, I provided the background as well as rationale for why I focused on teachers’ learning to notice classroom interactions during the enactment of cognitively demanding science tasks. I will now review how noticing has been defined and studied by others in the literature and explain both how I understand the construct and how I use it in this study.

2.2 UNDERSTANDING TEACHER NOTICING

This study is about teacher noticing, a construct that has become a focus of educators mostly in mathematics education within the last decade. Generally, those researching teacher noticing try to understand: What do teachers look at within the complexity of classrooms while teaching? How do they make sense of what they see? (Sherin et al., 2011a) How teachers notice and make sense of complex classroom environments has become an important researcher agenda given that teachers cannot be aware of or respond to everything that is occurring in the classroom (Jacobs et al., 2010). In this part of the chapter, I unpack what it means to notice and summarize recent conceptualizations of teacher noticing to articulate the approach in this study. Finally, I summarize current methodologies that are used to study teacher noticing.

2.2.1 Conceptualization of "noticing" in teacher education

The predominant body of literature on teachers' ability to see important features of classroom interactions is discussed under the umbrella of the term "noticing" in mathematics education. Different researchers include different aspects of a teacher's thinking and practice in their conceptualization of noticing (Sherin et al., 2011b). Some researchers focus on noticing as a process of attending to particular events in an instructional setting (i.e., Star & Stickland, 2008; Star, Lynch, & Perova, 2011). They investigate what pre-service teachers do or do not attend to while viewing a classroom episode. According to Star and his colleagues (2011), identifying what is important or noteworthy about a classroom situation—the first component of noticing according to van Es & Sherin (2002)—is the most foundational for pre-service teachers. They claim that pre-service teachers' ability to notice in a broad sense, which includes interpreting events and connecting them to broader teaching and learning issues, largely depends on what they attend to in the first place. Thus, considering the goals of their study (i.e., pre-service teachers' noticing types of classroom features), their research focuses on the process in which teachers notice certain aspects of classroom activity (without considering their interpretations of what they notice).

Another group of researchers have focused not only on teachers attending to particular events in an instructional setting but also on how they make sense of these events (Sherin et al., 2011a; Sherin et al., 2011b). This is the stance of Sherin and her colleagues, who have offered the most extensive work on teacher noticing in mathematics education (Jacobs et al., 2010). They focused on "noticing as professional vision in which teachers selectively attend to events that take place and then draw on their existing knowledge to interpret these noticed events" (Sherin et al., 2011b, p. 80).

Sherin (2001) introduced the term *professional vision for reform teaching* to teacher education by building from Goodwin (1994)'s work on professional vision, which he defined as "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (p. 606). Sherin (2001) argued that teachers need to develop professional vision. It consists of two sub-processes: selective attention and knowledge-based reasoning (Sherin, 2007a). The phenomena that are of interest to teachers are classroom events, so teachers' professional vision involves the ability to see and make sense of what is happening in their own classrooms (Sherin, 2007a). For example, what a science teacher will see in her 8^{th} grade classroom would typically be very different than what a parent visitor would see. While students are discussing results of an experiment on density, the teacher might notice how students are making sense of the concept of "density," while the parent visitor will more likely notice the level of student participation. Similarly, subtle student misconceptions will be more visible to the science teacher than to the parent visitor.

Finally, some researchers included another process in their study of teacher noticing: planning for how to respond to the classroom activity that the teacher attended to and interpreted (i.e., Jacobs et al., 2007; 2010; 2011). Jacobs and her colleagues (2010) define *professional noticing of children's mathematical thinking* as composing of three interrelated skills: 1) attending to children's strategies, 2) making sense of children's understandings, and 3) deciding how to respond on the basis of children's understandings. They focused on teachers' noticing of children's mathematical thinking rather than identifying a range of aspects of instruction that teachers notice (Jacobs et al., 2011). After viewing a video clip of instruction, they asked teachers to identify what students did in response to the given problem and what they learned about these students' understandings. Then, to capture *planning for how to respond*, they asked, "Pretend that you are the teacher of these children. What problem or problems might you pose next?" (Jacobs, et al., 2010, p.179).

In this study, I consider teachers' learning to notice as involving learning to attend to particular classroom interactions and reason about those interactions in particular ways. This is what Sherin and her colleagues characterize as the development of teachers' professional vision (Sherin & Han, 2004; Sherin, 2007a). For example, teacher noticing is not only a teacher paying attention to students' ideas in a video clip of classroom instruction but also interpreting what students meant by those ideas (Sherin et al., 2011b). I used the *Learning to Notice Framework* that was introduced by van Es and Sherin (2002) to explore teachers' learning to notice salient classroom interactions.

The skill of noticing for teaching consists of three main aspects: 1) identifying what is important in a teaching situation, 2) using what one knows about the context to reason about a situation, and 3) making connections between specific events and broader principles of teaching and learning (van Es & Sherin, 2002). The last two aspects of this framework uncover the reasoning processes that are particularly important for teachers (Sherin, 2007a). This study aims to examine what teachers attend to and how they interpret classroom interactions in video cases. Table 2 summarizes how noticing has been conceptualized by different researchers and the approach I take in this study to investigate science teachers' learning to notice.

Table 2: Conceptualization of Noticing in the Literature

Research Studies	***Attending to*** **particular events in an instructional setting**	***Making sense of*** **events in an instructional setting**		***Planning for how to respond*** **to particular classroom events**
		Ability to interpret classroom events	**Connecting to a larger teaching and learning principle**	
Star & Stickland, 2008; Star et al., 2011	Pre-service teachers' learning to identify salient features of classroom instruction (e.g., structure of the group work, presentation of the mathematics)			
Sherin & Han, 2004; van Es & Sherin, 2008	Change in what teachers attend to in classroom events	Change in teachers' approach in analyzing video clips		
Jacobs et al., 2007; 2010; 2011	Teachers' learning to attend to children's strategies	Interpreting children's mathematical understanding		Deciding how to respond on the basis of children's understanding
Current Study	Teachers' learning to attend to features of classroom interactions during the enactment of cognitively demanding tasks (e.g., teacher moves in response to students' comments)	Change in teachers' approach in analyzing video cases	Teachers' learning to identify each video case as an instance of the level/type of student thinking based on the TAGS framework	

Note. Gray boxes indicate that study does not focus on investigating that aspect of noticing.

As Table 2 indicates, although making connections between specific events and broader principles of teaching and learning is presented as a component of the Learning to Notice Framework, prior research has not set out to specifically examine this aspect of teachers' reasoning. In the few studies that did attend to teachers' capacities to connect what they attended to larger ideas, teachers' ability to make such connections were presented as one of a set of reasoning processes that some teachers engage in. For example, van Es (2011) developed a framework for learning to notice student thinking. The framework describes a trajectory of development from Baseline to Extended Noticing in terms of what teachers attended to and how teachers reason about what they observe. According to this framework, at the Extended Noticing level, which is the highest level in the trajectory, teachers can connect what they observe with broader principles of teaching and learning, such as assessment or equity in learning.

Different from prior work, in this study teachers' learning to identify each video case as an instance of a broader teaching and learning principle has been a primary goal from the outset. It was *designed for* the intervention and was *investigated* as a primary research question. Specifically, each video case that was discussed in the Noticing-PD was selected as representing high or low-level student thinking based on the TAGS and the discussions in the PD involved analyzing the level or type of student thinking that was going on in each video case. In addition, the third research question examined the extent to which teachers developed their expertise in linking the specifics of what they saw in the video cases with the larger principles that explain the level or type of student thinking at different levels as described in the TAGS framework. Developing this expertise among the teachers is important because as Stein and her colleagues (2000) argued "to 'grab hold' of an event, to learn from examples, and to transfer what has been learned in one event to learning in similar events, teachers must learn to recognize events as instances of something larger and more generalizable" (p. 34).

To this point, I have summarized how noticing has been conceptualized by researchers in the field of mathematics education and the approach I adopt to study science teachers' learning to notice in this study. There is very little work in science education that addresses science teachers' noticing; the research is silent on practicing science teachers' learning to notice within a video-based professional development setting, the subject of this study.

Research in science education has referred to a related field of inquiry in mathematics education—mathematics teachers' noticing. For example, Levin and his colleagues studied how candidate teachers attend to the substance of student thinking in a science teacher preparation course that focused on watching classroom videos and reviewing students' written work (Levin & Richards, 2010; 2011; Levin, Hammer, & Coffrey, 2009). Levin and Richards (2011) specifically noted that their work mirrors that of Sherin and her colleagues' work on teacher noticing. An examination of these sets of studies suggests both similarities and differences. Both of these lines of work focus on the importance of teachers' attending to student thinking. In point of fact, Levin and Richard (2011) stated, "Following work on teachers' 'noticing' in mathematics education (Sherin & Han, 2004; van Es & Sherin, 2008) we take attending to the substance of student thinking as an important aspect of 'professional vision' (Goodwin, 1994) consistent with science education reform" (p. 2). Results of Levin and his colleagues' studies provided insight for understanding candidate teachers' abilities to attend to substance of student thinking. They showed that teacher candidates were attending to student ideas in the early pedagogy classes but their practices of attending developed over time (Levin & Richards, 2010; 2011).

This line of work related to teacher attention in science education is different from the work on teacher noticing in mathematics education (i.e., Sherin & van Es, 2009) because of their perspective of framing which is critical to how they understand teacher attention. Levin and his colleagues' (2009) study of novice teachers' attention provided evidence for that "whether and how novice teachers attend to student thinking depends significantly on how they frame what is taking place" (p. 146). They argued that institutional context, which focuses on issues such as classroom management and curricular fidelity, inhibits novice teachers to frame teaching as attending to substance of student thinking.

Another difference between these lines of research is that researchers in science education used the term *attention* instead of *noticing* to frame their work. Levin (2008) stated that he used the term *attention* to frame his work because he viewed noticing and interpreting as co-constructive. In contrast, I use the term *noticing* to frame my work and decompose aspects of noticing into two particular skills: attending to and interpreting classroom events. Although there is an interaction between attending and interpreting (reasoning) (Sherin, 2007a), they are still two different processes, each of which needs to be developed by teachers. By treating attending and interpreting as unique processes, I can examine change in the development of each of them from the beginning to the end of the professional development. In what follows, I summarize how I interpreted and used Sherin and her colleagues' work around teacher noticing (see Table 3). After that, I describe in detail each aspect of noticing that I investigated in this study.

Table 3: Conceptualization of Noticing in the Current Study

Aspects of Noticing according to the Learning to Notice Framework	Sub-processes of Professional Vision	Inquiries in the Current Study
1) Identifying what is important in teaching situation	Selective attention	What do science teachers pay attention to in the video cases?
2) Using what one knows about the context to reason about a situation	Knowledge-based reasoning	How do science teachers make sense of what is happening during the enactment of cognitively demanding tasks that they viewed in the video cases?
3) Making connections between specific events and broader principles of teaching and learning		To what extent can science teachers recognize video cases as an instance of a particular level/type of student thinking during the enactment of cognitively demanding tasks?

Note. This table is my interpretation of Miriam Sherin and her colleagues' work on mathematics teachers' professional vision and teacher noticing (Sherin, 2007a; 2011b; van Es & Sherin, 2002).

2.2.2 Learning to Notice Framework

2.2.2.1 Identifying what is important in a teaching situation

Teachers need to constantly deal with information overload while teaching, so they notice very selectively. The degree to which attention is limited in the context of complex tasks has been demonstrated by Simon in an investigation related to inattentional blindness (Miller, 2011). Simon and Chabris (1999) showed that viewers performing a difficult video-based task—counting passes in a basketball play—failed to attend to a gorilla entering into the scene and beating its chest at the center of the visual field. This study indicates the difficulty of attending to everything while observing complex events. Therefore, while orchestrating complex classroom environments, teachers necessarily focus on certain things but pay limited or no attention to others (Erickson, 2011). For example, during the course of instruction, the teacher may focus on whether all the students are following the right procedures of a laboratory experiment. In another case, the teacher's attention may be focused solely on the students' scientific argument. In yet another case, the teacher may focus on off-task behavior. In each of these examples, the teacher pays attention to particular types of events happening in the classroom. What is important to understand is that certain aspects of the classroom interactions should receive more attention from the teacher compared to the others (Sherin 2007a).

Researchers used different terminology to refer to this first aspect of noticing. According to Sherin (2007a), this is one of the processes of professional vision, which she calls *selective attention*. Goodwin (1994) referred to this first aspect of noticing as *highlighting*, which helps to make the relevant information more salient and visible. As van Es and Sherin (2008) stated, highlighting is "the act of deciding what is noteworthy and deserves further attention" (p. 246).

In this study, I refer to the first aspect of noticing as attending. Furthermore, I argue that—in the context of cognitively challenging instructional tasks—teachers should pay attention to the interaction between the teacher and the students that can play a critical role in shaping the maintenance or decline of the cognitive demand of the task during enactment (e.g., how the teacher responds to what students say; what students say or do surrounding the task in response to what the teacher does). This interaction of the task, teacher, and the students is critical for engaging students in high-level thinking and reasoning about the subject matter.

2.2.2.2 Making sense of what is attended to

We know that "teachers are not simply passive observers" (Sherin et al., 2011a). Teachers begin to reason about the event that they pay attention to based on their knowledge and understanding. The second aspect of noticing involves teachers' analyzing events that they see (van Es & Sherin, 2008). Teachers need to use their knowledge of subject matter, knowledge of how students think of the subject matter, and also the knowledge of their local context to make sense of classroom events that they pay attention to (van Es & Sherin, 2002). To do that, it is important that teachers develop an interpretative stance (Hammer, 2000; Putnam & Borko, 2000), which means analyzing a teaching situation for the purpose of making sense of what happened, what students think and how teacher's actions influenced students' thinking (van Es & Sherin, 2002).

Prior research indicates that teachers generally do not have an interpretative stance while analyzing classroom practice. Nemirovsky, DiMattia, Ribeiro, and Lara-Meloy (2005) identified two discourse types that teachers use while analyzing video cases of classroom instruction. The first one is *grounded narrative discourse* in which the teachers' goal is to express narrative accounts of classroom events that unfolded over time. The second one is *evaluative discourse* in which teachers make judgments about a teaching situation. They found evaluative discourse to be the most prevalent type used in conversation about video recorded classroom episodes. According to van Es (2011), noticing requires a third discourse type called *interpretation*, in which teachers try to make sense of what they see and use evidence to support their reasoning.

Some researchers consider being able to describe a situation as an important step toward interpreting. Jacobs and his colleagues (2007) focused on *describing* as one of the skills necessary to develop teachers' professional noticing. This is very much in line with how Mason (2002) separated the "accounting ***of*** a situation" (describing) from "accounting ***for*** a situation" (interpreting). He claimed accounting for a situation requires someone to interpret, explain, and make some value judgments; accounting of a situation, on the other hand, requires someone to describe and define a situation. He considers accounting ***of*** a situation as an *a priori* step in learning how to perform the accounting ***for*** it (Mason, 2011). Extending this idea further, Jacobs and her colleagues hypothesized that being able to describe and interpret children's strategies is foundational for responding based on children's thinking. They tested this hypothesis with 132 teachers by examining whether teachers followed expected trajectories. Their hypothesized trajectory was validated for 83% of the teachers. This suggests that only teachers who can describe children's strategies have necessary foundation for interpreting those strategies in terms of students' understanding, and only teachers who can interpret have the foundation for responding based on students' understanding. These studies imply that even though describing is not as crucial as interpreting, it is an important step to establish towards developing teacher's interpretation skills.

In the current study, it is important that teachers develop an interpretative stance to make sense of classroom events that they see with regards to students' thinking about scientific ideas presented in the task as well as teacher's actions that are needed to support students' sense making of the scientific ideas. This implies that instead of evaluating students' understanding, they should assess the extent to which students can develop an understanding of the ideas that are elicited in the presented tasks. Similarly, instead of evaluating the teacher's actions or describing what they see, they should try to analyze how the teacher in the video scaffolds students' thinking. This may allow teachers to interpret to what extent cognitive demand of high-level tasks could be maintained in the video cases and what kind of teacher actions are associated with high and low-levels of student thinking.

2.2.2.3 Linking specific events to broader principles

Prior research reveals that experts can see specific events in connection with the broader principles that they represent (van Es & Sherin, 2002; Glaser & Chi, 1988). Similarly, expert teachers can connect a specific event that they see to a larger concept or principle they know about teaching and learning, such as equity or how students learn the best (van Es & Sherin, 2002). For example, Copeland, Birmingham, DeMeulle, D'Emidio-Caston, and Natal (1994) investigated the meaning that teachers with different levels of experience make of a teaching and learning case. They found that expert teachers made more direct links between their recognition of specifics in the lesson that they viewed in a video to more generalized knowledge.

Shulman (1996) encourages teachers and teacher educators to think after analyzing a teaching episode, "What is this a case of?" She argued that responding to this question helps teachers to recognize a teaching episode as representing a larger principle of teaching and learning. Similarly, Colestock and Sherin (2009) claimed that making connections between particular instances of teaching that are represented in the video to more general knowledge about teaching might help teachers draw upon these *cases* in the midst of instruction. Therefore, to support the development of teachers' noticing, it is important to provide them opportunities to connect specifics of a teaching situation to broader principles of teaching and learning.

One of the main goals of this study is to help teachers recognize each video case as representing a particular level or type of student thinking. Analytical tools can be used to support teachers to notice (Sherin, 2007b). In this study, the TAGS was used to facilitate teachers' noticing within the Noticing-PD, because it can help teachers connect the specifics of what they noticed to the larger set of ideas about science teaching and learning as represented in the TAGS.

The Learning to Notice Framework provides an analytical frame to examine teachers' learning to notice during the Noticing-PD in this study. Before moving to talk about current methodologies that have been used in the literature to study teacher noticing, I will note that while Sherin and her colleagues' contribution to teacher noticing research was productive in various ways, their approach to professional vision has been criticized by some researchers. For example, in their recent paper, Lefstein and Snell (2011) criticized the current research on teachers' professional vision by arguing that, "One way of seeing is authorized as professional; deviations from it are positioned as lacking expertise" (p. 507). They argued against viewing professional vision as a singular, cognitive ability and claimed that professional vision is influenced by national policy context as well as social context, within which professional practice is played out. This argument is very much in line with Levin (2008), who argued for moving beyond thinking of teachers' attention as an individual skill to develop. According to Levin, what teachers attend to is similar in many ways because they are situated in particular institutional and social systems. He claimed three areas of accountability that appear to influence teacher attention: 1) the pressures of high-stakes tests and curriculum, 2) local professional communities, and 3) needs and expectations of students. I recognize the value of considering how the context that teachers' professional practice is situated in can shape teachers' attention.

Nevertheless, like Levin (2008), I believe that if the system fails to encourage teachers' paying attention to certain things, professional development should provide opportunity for the teachers to engage in these ideas and practices that are not the target of the system. For example, in his research Levin found that the system fails to amplify attention to students' productive scientific thinking and practice. This finding implied developing professional development to support teachers' attention to the substance of student thinking, which is beyond attention to the correctness of ideas and repetition of vocabulary. Moreover, within the recent science education policies (i.e., development of the Next Generation Science Standards based on the Framework for K-12 Science Education developed by the National Research Council (2012)), the system that teachers' professional practice is situated in will demand facilitation of science lessons rich in science content and scientific practices. This integration of science content and the scientific practices is very much in line with the characteristics of cognitively demanding tasks as described in the TAGS framework, which was developed based on the NRC (2012) Framework. Therefore, the conversations that took place in the Noticing-PD about the enactment of cognitively demanding science tasks were very much in line with the current science policy agenda that will start shaping the priorities of the systems that teachers' professional practice is situated in.

2.2.3 Current methodologies for studying teacher noticing

Until this point, I summarized different conceptualizations of noticing in the literature. These variations in conceptualizations of noticing necessitate variations in the methodologies that are used to study teacher noticing (Sherin et al., 2011a). In what follows, I will discuss some of these methodologies.

The majority of prior research used video clips of instruction to understand teacher noticing. There were variations in the length of the video clips, how they were selected, and whether or not they were captured from teachers' own classrooms or from other teachers' classrooms (Sherin et al., 2011b). There were also variations in how video clips were used. In most cases, teachers were shown a video clip of instruction and asked what they noticed in the video clip. In some cases, this method was used in one-on-one interviews with teachers (e.g., Colestock & Sherin, 2009; Copeland et al., 1994; van Es & Sherin, 2008) or with written analysis of teaching (e.g., Jacobs et al., 2010; Santagata, Zannoni, & Stigler, 2007). While the advantage of this method is to assess what a group of teachers noticed in a common teaching episode, it has some disadvantages as well. What teachers notice in these video clips might not be similar to what they notice in their own classrooms. This may be because of unfamiliarity with the students and the lesson in the video or having more time to think and reflect on an instance during the interview (Sherin et al., 2011b).

In some cases, teachers were asked to reflect on their own video-recorded teaching and to discuss what they noticed. For example, van Es and Sherin (2002) asked intern teachers to video record their instruction and then write a reflection by using video as the source of reflection. The goal was to assess development in interns' noticing. Similarly, Rosaen and her colleagues (2008) asked intern teachers to write a reflection on a video-recorded classroom discussion that they led and also to select excerpts from the video and write commentary about those excerpts using a multimedia editor. In some studies, teachers were asked to reflect on their own video-recorded teaching with peers in a professional development setting (e.g., Sherin & van Es, 2009). These approaches to understand teacher noticing can be easier for teachers since they were asked to reflect on their own teaching after being removed from the demands of the classroom. However, as they were removed from the demands of the classroom, their analysis might not represent their actual in-the-moment noticing (Sherin et al., 2011b).

In some studies, researchers tried to understand teachers' in-the-moment noticing. Some researchers analyzed video records of classroom instruction to assess what teachers noticed while teaching. For example, Levin (2008) studied teacher attention during teaching. He analyzed classroom discourse from videotape and transcript data by focusing on what the teacher did in response to what students say. He identified what evidence he would consider as an indicator of teacher's attention to student thinking and then coded the discourse in the classroom. Similarly, Sherin and van Es used video-records of classroom practice to examine what teachers notice during the course of instruction (Sherin & van Es, 2009; van Es& Sherin, 2009). For example, Sherin & van Es (2009) identified portions of video-recorded instruction and created analytic memos that discussed teachers' responses to students' comments, questions, and strategies. Based on these memos, they created confirming and disconfirming evidence for whether teachers noticed ideas raised by the students.

Clearly, these approaches used to capture teachers' in-the-moment noticing have the underlying assumption that visible action by the teacher provides insight for what teachers noticed while teaching (Sherin et al., 2011b). Some researchers tried more innovative techniques to capture teachers' in-the-moment noticing. In some recent studies of teacher noticing, a small camera was attached to teachers' foreheads to capture what teachers attended to while teaching (e.g., Sherin, Russ, Sherin, & Colestock, 2008; Sherin et al., 2011b). These studies provided promising evidence for using this technological innovation to capture teachers' in-the-moment noticing.

In this study, the goal is not to capture teachers' in-the-moment noticing, but instead to understand the extent to which teachers *learned* to notice salient classroom interactions during the Noticing-PD. Thus, instead of focusing teachers' in-the-moment noticing, I tried to capture teachers' *learning* through the analysis of interviews and transcripts of discussions during professional development sessions. During the in-depth one-on-one interviews with each individual teacher, I asked him or her to analyze the same two video clips and describe what they noticed in the video cases. As opposed to other studies that used interviews to investigate teachers' noticing (e.g., Colestock & Sherin, 2009; Copeland et al., 1994; van Es & Sherin, 2008), I used two video cases both in the baseline and exit interviews, the first one showing the enactment of a task related to the biology content that was the focus of the majority of the Noticing-PD sessions and the second showing the enactment of a task related to a different biology topic. I realize that teachers' analyses of the videos might be limited given that the video clip was not from their own classrooms (Sherin et al., 2011b). However, to be able to make comparison across teachers from pre to post professional development, keeping the video-clips constant across all the interviews was important.

In addition to the interviews, like some other researchers studying teacher noticing (e.g., Sherin & Han, 2004; van Es & Sherin, 2008) I used teachers' discussions during their analysis of others' video clips during the Noticing-PD as a major data source. Because I study teachers' learning within the professional development setting, it is important that I drew on data that captured what teacher said they noticed in the video cases that were discussed in the Noticing-PD. As Miles and Huberman (1984) stated, "[Qualitative data] are a source of well-grounded, rich description and explanation of processes occurring in local contexts" (p. 21). Therefore, using transcripts of the video-recorded PD sessions as a data source allowed me to explain the learning happening in that professional development context.

2.3 STUDYING TEACHERS' LEARNING TO NOTICE

In this section, I summarize prior research that has been done to examine teachers' learning to notice. I conclude this section with the analytical framework that I developed to use for examining teachers' learning to notice in this study.

2.3.1 Using video to support teachers' learning to notice

Video has become a commonly used artifact of practice to support teachers' learning to notice. One of the major goals of using video in professional development is to provide teachers access to classroom interactions in a way that is not possible during the actual act of teaching. Even though they are not in the classroom, video clips allow teachers to learn *in* practice because they are situated in the context of their work. In other words, "they could focus professional learning in materials taken from real classrooms that present salient problems of practice" (Ball & Cohen, 1999, p. 14). Using video clips in professional development also allows teachers to learn *from* practices (Ball & Cohen, 1999) because video clips are the representations of their practice. As Grossman and her colleagues (2009) stated, "The nature of the representation determines to a large extent the visibility of certain facets of practice" (p. 2066). Thus, video-clips help us to carry the closest representations of instructional practice to a professional development setting.

In the last decade, video use has increased in studies designed to support teachers' learning to notice (e.g., Santagata et al., 2007; Star & Strickland, 2008; van Es & Sherin, 2006). The majority of these studies involved video clubs—meetings in which groups of teachers view excerpts of video records from their own instruction and discuss what they noticed in the excerpt (Sherin, 2000; Sherin & Han, 2004; Sherin, 2007b). Derry (2007), who argued for setting standards for learning science research, considers Sherin and her colleagues' work around video clubs as setting "standards for developing creative methodologies that take advantage of video" (p. 314). However, she argues that there are still some aspects of this research with video clubs that can be appropriate for standardization if further developed. These aspects include a coding scheme, statistical methods for measuring change in professional vision, and frameworks for facilitation practices.

Overall, there are various advantages of video use in professional development settings, several of which are relevant for studies of teacher noticing. First, videos are powerful in capturing the richness and complexity of classroom instruction (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Colestock & Sherin, 2009; Le Fevre, 2003; Miller & Zhou, 2007). As Koc, Peker, and Osmanoglu (2009) argued, unlike written cases, video cases capture the voices, body language, and interactions of classrooms and provide a more realistic picture of the learning environment. Therefore, video cases represent the closest approximation to real classroom setting where teachers need to pay attention to certain things but not others while teaching. While communicating to viewers something of the complexity of classroom interactions, videos also allow teachers to zoom in on a particular aspect of teaching that may not be available for teachers otherwise (van Es, 2011).

Moreover, video clips are permanent records of classroom interactions. Thus, teachers are not required to rely on their memory and they can view them several times (Sherin & van Es, 2005; van Es, 2011). Rosaen and his colleagues (2008) have compared video-based reflection and memory-based written reflection on teaching. They provided strong evidence that compared to memory-based reflection, video-supported reflection supported teachers to provide more specific comments about their teaching, focus more on instruction than the classroom management, and attend to children more than themselves.

Putnam and Borko (2000) claimed that even though it is helpful to ground teachers' learning in their own classroom practice, removing them from their own classroom setting could help teachers think in new ways. They said, "The classroom is a powerful environment for shaping and constraining how practicing teachers think and act" (p. 6). The use of video removes teachers from the demands of the classroom and provides an opportunity to think about and reflect on the classroom interactions in a different environment. This opportunity enables them to observe classroom interactions without having to take an action (Sherin & van Es, 2005; van Es, 2011). As Tripp and Rich (2012) claimed, viewing videos of their classroom instruction with their colleagues allows teachers to gain a new perspective about their teaching. Findings from their recent study showed that videos helped teachers to recognize problems in their teaching and become more willing to accept that certain aspects of their teaching need to change.

While using video within a professional development context provides some advantages, there are also limitations; these should be considered in designing video-based professional development (van Es & Sherin, 2009). For example, Miller and Zhou (2007) claimed that even though video clips capture the complexity of classrooms, researchers are still limited because they record only a sample of that complexity. Thus, they recommended that researchers be systematic when recording and selecting video cases and to be transparent in their description of this process of selection. Another challenge is that participants of the professional development would consider the viewed video-clip as the representation of that teacher's practice even though that was not the case (van Es & Sherin, 2009). As Miller and Zhou (2007) underscored, "Viewers are likely to assume implicitly that the cases are representative of the larger universe of educational phenomena" (p. 332). Thus, it is important to help teachers understand the degree to which the video case is a representative of a larger instructional practice.

When used as a tool for supporting teachers' learning, the structures and tasks designed around the video clip should be considered carefully to get the most out of what the video can offer (Le Fevre, 2003; van Es & Sherin, 2009). For example, Seidel and her colleagues (2011) found that viewing their own teaching negatively influenced teachers' interpretation of classroom events; teachers were reluctant to make constructive reflection and identify consequences and alternatives. After studying the affordances and challenges of using three types of video (published video, teachers' own video versus their colleagues' video) in professional development, Zhang and his colleagues (2011) recommended that rich contextual information be provided, particularly when the video case is not from one of the PD participants' own classrooms. Moreover, their study suggests that relevance to teachers' instructional practices is an important factor that influences the usefulness of the video case. They also recommended carefully choosing discourse structures to effectively facilitate the discussions about the video cases to fit the goals of the professional development.

Research on pre-service and in-service teachers' analysis of video has provided promising results in terms of changes in teachers' approach to examining issues related to teaching and learning. As Borko and her colleagues indicated, over time teachers' discussions in the professional development meeting became more productive. Teachers' talk about the specific issues related to teaching and learning around the video clips became more focused, in-depth, and more analytical (Borko et al., 2008). In the following section, I will summarize consistent patterns in the findings of the body of research on noticing that helped me to develop the analytical framework for the current study.

2.3.2 Teachers' learning to notice from video clips of classroom instruction

Prior research provides promising evidence in terms of teachers' learning to notice by analyzing video clips of classroom instruction. In what follows, I summarize the results of these studies by organizing them in terms of changes in teachers' selective attention and in their knowledge-based reasoning.

2.3.2.1 Changes in teachers' selective attention

Consistent patterns have been observed in what teachers attend to in general when they analyzed video clips of classroom practices. According to Colestock and Sherin (2009), when teachers viewed a video clip of classroom instruction, they generally attended to issues related to pedagogy (i.e., teacher's decisions, actions, and the teaching strategies used), climate (i.e., classroom atmosphere and the way in which students and the teacher interacted), and classroom management instead of mathematical ideas discussed by the students. This indicates that teachers share a common professional vision. Along these lines, Miller and Zhou (2007) showed differences between what U.S. and Chinese elementary school teachers noticed in classroom videos. While the U.S. teachers generally paid attention to the general pedagogy issues—such as classroom management, interpersonal relations with students, presentation style, participation, classroom structure, motivational strategies, and the teachers' personalities—Chinese teachers generally commented on the mathematical content of the lesson.

There is strong evidence in the literature that what teachers attend to can be changed with either professional development or a pre-service teacher course (e.g., Hammer & Schifter, 2001; Sherin & Han, 2004; Star & Stickland, 2008). For example, Star and Stickland (2008) investigated the effect of viewing video clips of classroom instruction on pre-service teachers' ability to be observers of classroom practice. They found significant increases in pre-service teachers' ability to notice classroom events related to classroom environment, mathematical content of the lesson and communication after they attended a methods course, which focused on improving observation skills. In a replication study (Star et al., 2011), similar results were obtained regarding gains in pre-service teachers' ability to notice features of classroom environment and classroom communication, but no improvement was observed in pre-service teachers' ability to notice tasks and mathematical content; also, unlike the first study, there was an increase in teachers' attentiveness to classroom management.[7]

Similar results have been observed in video-based professional development efforts for practicing teachers. For example, van Es (2011) found that in the beginning of the professional development meetings, teachers often referred to pedagogy at a very general level and the issues that they raised about pedagogy were generally not grounded in or informed by student thinking. Moreover, teachers made very few comments related to students' conceptual thinking; they often attended to classroom organization, such as climate and classroom management. However, their focus shifted towards students' understandings of the mathematical ideas in the later professional development sessions (Sherin & Han, 2004; Sherin & van Es, 2005; van Es & Sherin, 2006). These studies showed the role of video club meetings in supporting teachers' learning to focus on students' thinking, which is underscored by others as being important as well (i.e., Hammer & Schifter, 2001; Levin, 2008; Levin et al., 2009).

In their study of teacher noticing, Sherin and Han (2004) explored further the trends that they found in increasing attention to student thinking and decreasing attention to pedagogy. Their analysis indicated that in the early professional development sessions, the majority of the discussions about the students' thinking involved simply restating what students said. However, this changed in later sessions where teachers started to analyze the meaning of students' comments or methods as well as to make generalizations and syntheses of students' thinking. There were also some changes in what teachers attended to related to pedagogy. In the later professional development sessions, teachers started to examine pedagogical issues in terms of students' thinking instead of talking about the pedagogical techniques independent of students'

[7] It should be noted that both of these studies focused on supporting pre-service teachers to develop their abilities to attend to a full range of classroom events, ranging from the mundane to important.

understandings. The current study provides an extension of these findings by systematically analyzing teachers' pedagogy-related comments in terms of two different dimensions: "link to students' ideas or actions" and "task specificity."

Professional development efforts have been also found to be effective in changing *to whom teachers look* when they analyze a video clip of classroom instruction. While analyzing the classroom videos in the beginning of the professional development meetings, teachers often referred to the class as a whole; they viewed the whole class as an undifferentiated group. They made comments such as, "I still don't think the kids understand that 1.3 is one and three-tenths" (p. 144). However, in their future analysis, they started to attend to particular students or groups of students in the classroom; they started to recognize the class as a set of individual students (van Es, 2011). These results are also consistent with what Jacobs and her colleagues (2007) found in their study about teachers' professional noticing. According to their findings, while commenting on what they learned about children's understanding, teachers who had engaged in the professional development addressed individual students or groups of students. However, teachers who had not had a professional development experience, attended exclusively to the class as a whole. Therefore, their results indicated that professional development could help teachers develop an orientation towards individual students or particular groups of students. This is important because teachers who attend to understanding individual students can differentiate instruction in a way that all students are challenged and supported (Jacobs et al., 2007). Moreover, focusing on particular students can also allow teachers to see the role of their actions in affecting student thinking.

2.3.2.2 Changes in teachers' knowledge-based reasoning

There is strong evidence in the literature that how teachers analyzed what they attended to in the video clubs can be changed through some kind of a support (i.e., professional development or pre-service teacher course). For example, van Es and Sherin (2002) investigated six science and mathematics teachers' learning to notice by using Video Analysis Support Tool (VAST) software. The software was designed to support teachers learn to notice and interpret aspects of classroom practice that are important to reform pedagogy. They found that this software helped teachers to analyze teaching in new ways, such as identifying particular events as noteworthy, providing their own interpretations of these events, as well as using evidence to discuss them. Their findings also indicated that the use of VAST resulted in teachers' making connections between specific events in the video segment and key ideas of teaching and learning.

In another study, Colestock and Sherin (2009) found that teachers were more likely to describe teaching strategies that they attended to instead of discussing why these strategies were used and helped to accomplish. Carter and her colleagues (1988) found that novice teachers were able to describe what they saw in a series of slides taken in science and mathematics classrooms but they did not appear to provide multiple and/or accurate interpretations of what they see in comparison to expert teachers. Consistent with these findings, in a study about teachers' participation in video-club meetings, Sherin and Han (2004) found that in the earlier video-club meetings, teachers were either simple restating what they saw or evaluating it (i.e., restating students' statements: "[Amy] says, 'It's not very realistic'). However, in later meetings, they started to make a detailed analysis of what they saw. For example, in the last video club, teachers spent time trying to understand what Brenda [name of a student] meant when she said that there was a "medium correlation" (p.176). Similarly, Sherin and van Es (2005) provided evidence from their study of a yearlong video-club regarding the shifts from evaluation to interpretation as well as increase in evidence-based teacher comments. Teachers started to refer to specific events in the video clips while analyzing what they saw in the video clips. As they stated, “instead of focusing immediately on the effectiveness of a particular pedagogical approach, the goal seemed now to be to understand the influence of that approach on the learning that occurred” (p. 485). Crespo (2000) provided similar evidence from her analysis of interactions between students and prospective teachers over mathematics letter exchanges in which solutions to some mathematical problems were discussed. Early on, pre-service teachers made conclusive claims about their students’ understanding. However, in the later exchanges they made more elaborate interpretations of the students’ work. These changes towards interpretative stance imply developing teacher’s expertise. This is also consistent with different orientations that teachers might have towards listening to student thinking. According to Davis (1997), teachers with an evaluative orientation listen to ideas in order to evaluate their correctness, by judging the ideas against a preconceived standard. Teachers with an interpretive orientation, on the other hand, try to get at what students are thinking.

Overall, these studies revealed changes in teachers’ analysis of teaching episodes. Particularly, teachers changed to whom and what they paid attention to in the video cases as well as their stance in analyzing the video case. Moreover, they began to refer to video as evidence to support their claims. These studies as well as the conceptualization of noticing in the literature helped me to develop the analytical framework that I used to investigate the research questions of this study. Table 4 depicts the relationship between the processes of the noticing, research questions of the current study, and the main dimensions of the analytical framework that I developed based on the literature.

Table 4: The Analytical Framework in Relation to the Research Questions

Processes of Noticing	Research Questions	Main Dimensions of the Framework
Identifying what is important in teaching situation	1) In what ways did what teachers *attended to* in the video cases change from the beginning to the end of the Noticing-PD?	**Actor** ✓ Teacher ✓ Students ✓ Particular student/group ✓ Teacher and students **Topic** ✓ Pedagogy ✓ Student Thinking ✓ Student Engagement ✓ Student Talk ✓ Classroom Climate ✓ Management ✓ Other
Using what one knows about the context to reason about a situation	2) In what ways did teachers' approach for making sense of what they attended to in the video cases change from the beginning to the end of the Noticing-PD?	**Stance** ✓ Descriptive ✓ Evaluative ✓ Interpretative **Evidence from video clip**
Making connections between specific events and broader principles of teaching and learning	3) To what extent did teachers learn to recognize video cases as an instance of a particular level or type of student thinking?	The extent to which teachers identify the level or type of student thinking based on the TAGS

3.0 METHODOLOGY

In what follows, I detail the methodology used to investigate the research questions that address the main goal of the study. I first present the guiding research questions. Secondly, a description of the context in which the study was conducted is presented, followed by a detailed description of the Noticing-PD. Lastly, I provide the details about the participants of the study, the data sources, and data analysis techniques.

3.1 RESEARCH QUESTIONS

The goal of this study is to examine science teachers' learning to notice through a video-based professional development (Noticing-PD). Specifically, the goal is to examine teachers' learning to pay attention to and reason about classroom interactions as students engage with high-level, cognitively demanding science tasks. I designed and facilitated the Noticing-PD for supporting a group of biology teachers' analyses of video cases, which depict classroom interactions during the enactment of cognitively challenging biology tasks. In this study, I examine:

1) In what ways did what teachers *attended to* in the video cases change from the beginning to the end of the Noticing-PD?

2) In what ways did teachers' approach for making sense of what they attended to in the video cases change from the beginning to the end of the Noticing-PD?

3) To what extent did teachers learn to recognize video cases as an instance of a particular level or type of student thinking?

3.2 CONTEXT OF THE STUDY

This study is situated within a larger NSF-funded project, which focused on developing a set of scalable STEM units that aim to teach rigorous mathematics tied to big ideas in biology and use engineering design in project-based activities in science classrooms. The four-week design-based unit that was used in this study is named "Modeling Genetics: The Gecko Breeder Challenge", referred to hereafter as the "Design Unit." The Design Unit was developed by a group of researchers at the University of Pittsburgh's Learning Research and Development Center. The tasks in the unit were designed to support high school students' understanding of big ideas about Mendelian inheritance with the laws of probability that Mendelian inheritance follows. While some of the tasks in the unit focused only on the big ideas associated with Mendelian inheritance, some tasks also involved mathematical ideas that are critical to understand Mendelian inheritance. The Design Unit has passed through several development and implementation cycles. The current study was conducted during the third implementation cycle of the Design Unit.

Teachers who participated in the study agreed to implement the four-week Design Unit, then attend two project-related meetings and seven Noticing-PD sessions that I specifically designed and conducted as part of this study. The project meetings were designed to introduce the Design Unit to the teachers, help them better understand the content coverage of the unit and its features, and understand the organization of the science tasks within the unit. The Noticing-PD sessions, which I will now describe in detail, are the focus of the current study.

3.3 INTERVENTION: NOTICING PROFESSIONAL DEVELOPMENT

3.3.1 Overview of the Noticing Professional Development

Noticing-PD took place once or twice a week from the first week of February 2012 to the first week of March 2012 for a total of seven meetings each of which was 3 hours in duration. The first two sessions were conducted before teachers started implementing the Design Unit in their classrooms. The remaining five sessions were conducted as teachers were implementing the unit in their classrooms. All the Noticing-PD sessions, except the first one, involved discussion of video cases of task enactment.

Noticing-PD aimed to support teachers' learning to a) distinguish science tasks at different levels of cognitive demand,[8] and b) notice classroom interactions during the enactment of cognitively challenging biology tasks. With these goals in mind, each Noticing-PD session was organized into two main parts: 1) analysis of science tasks as presented in the written materials based on the TAGS framework, and 2) discussion of a video case that illustrates the classroom enactment of a high-level task, which was usually one of the tasks that was analyzed

[8] In this dissertation study, I only focus on the teachers' analysis of video cases not the written materials. However, my current research also focuses on teachers' learning to analyze tasks as presented in the materials based on their cognitive demand. To be able to present a complete view of teachers' experiences in the Noticing-PD, however, I will describe this feature of the Noticing-PD, instead of just focusing on teachers' experiences with the analysis of the video cases.

in that session. Table 5 provides an overview of the main activities that took place in each Noticing-PD session.

Table 5: Overview of the Noticing-PD

	Part-1: Analysis of Written Tasks	**Part-2: Analysis of Video Cases**
Session-1	→ TAGS was introduced → Tasks 1, 2 and 3 were analyzed	*No PD activity related to the video cases*
Session-2	→ Presentation and discussion about the scientific practices (NRC, 2012) → Task-4 and Task-5 were analyzed	→ Video Case-A: *Enactment* of Task-4
Session- 3	→ Task-1 was re-analyzed	→ Video Case-B (has two parts): *Enactment* of Task-1
Session-4	→ Tasks 6, 7 and 8 were analyzed → "Mathematical Task Framework" was presented.	→ Video Case-C: *Enactment* of Task-6 → Video Case-D: *Enactment* of Task-6 → Presentation on the similarities and differences between the video case-C and video case-D
Session-5	→ Tasks 9, 10, 11 and 12 were analyzed	→ Video Case-E: *Enactment* of Task-9 → Video Case-F: *Enactment* of Task-9 → Presentation on the similarities and differences between the video case-E and video case-F
Session-6	→ Tasks 13 was analyzed	→ Discussion of factors that influence maintenance or decline of cognitive demand → Video cases from the teachers' own enactment of Task-1
Session-7	→ Task-14 and Task-15 were analyzed	→ Video cases from the teachers' own enactment of Task-1 → Discussion of factors that influence maintenance or decline of cognitive demand

As Table 5 indicates, in each Noticing-PD session—except the first one—teachers analyzed biology tasks as presented in written materials as well as a video case that showed enactment of a cognitively challenging task in a biology classroom. In the second and third sessions, teachers viewed a video case that depicts the enactment of one of the science tasks that they analyzed before the video viewing.[9] In each of the fourth and the fifth sessions, they viewed two video cases (contrasting video cases). One of these video cases represented maintenance of cognitive demand of a high-level task that they analyzed before the viewing, and the second one represented decline. Finally, in the last two sessions, they viewed video clips of their own implementation of Task-1 (a task that was discussed in the first and third sessions) and generated a list of factors associated with the maintenance and decline of cognitive demand of tasks during their implementation.

3.3.2 Facilitation of the Noticing Professional Development

Two researchers participated in the sessions,[10] one as a facilitator and a second as a participant observer and co-facilitator. As the main facilitator, I prepared for each session by constructing a detailed outline to guide the facilitation of the session.[11] The outline consisted of the flow of activities involved in the session (e.g., analysis of the written tasks, providing background about the video case), a short description (or reminders) about what would be done related to each activity (e.g., "During the discussion, focus teachers' attention on the type of questions that the

[9] In the third PD session, teachers viewed two video cases from the same classroom in which Task 1 was implemented. While both of these video cases represented high-level student thinking, one video case showed the small group work and the other one showed the whole class discussion.
[10] Some members of the larger project team attended Noticing-PD sessions mostly as an observer. When they attended the sessions, they did not have any active role. They generally attended as an observer, and sometimes made comments during the discussions.
[11] These outlines were sometimes shared with the co-facilitator before the PD session.

teachers were asking"), and an approximate time allocated for each activity. I also went through the transcript of the video case that would be discussed and identified possible prompts to facilitate discussion about certain parts of the video case.

In the Noticing-PD sessions, a considerable amount of time was given to teachers for their individual analysis of the tasks and the video cases. Before having group discussions, teachers were given silent time to identify the cognitive demand of the science tasks as well as to organize their thinking in terms of what they noticed in the video case. This was done to permit teachers to organize their thinking without being influenced by others before the group discussion started. Teachers used a specially designed PD-log to record their analysis. It consisted of questions related to tasks and the video cases that would be analyzed in that session (see Appendix B for an example PD-log). Some questions included in the PD-logs are: "What level of thinking do you think Task-X demands of students?" "Please jot down what you noticed in the video-clip of implementation of Task-X in the classroom" "What do you think is the level and type of thinking that is demanded of students during the implementation of Task-X?"

3.3.3 Tasks and video cases used in the Noticing Professional Development

Each time a video case was introduced, teachers were first provided with an opportunity to analyze biology tasks that differed in terms of their potential to elicit various cognitive demand levels. During these conversations, they identified the level and type of thinking that different biology tasks had the potential to provoke. Next, they viewed a video case that showed one of these tasks being enacted in a biology classroom. In what follows, I first describe the type of tasks that were selected and then provide details about the video cases that were used in each session.

Teachers analyzed 15 biology tasks based on their cognitive demand, four of which came from the Design Unit (see Table 6). These particular tasks were selected because (a) they formed an arc of lessons that earlier implementations suggested were within the range of teachers' capacities to implement fairly well and (b) the tasks did not involve integration with mathematics (integration was proving to be very challenging for the teachers).

Table 6: Science Tasks Used in the Noticing-PD

PD Sessions	**Cognitive Demand of the Tasks**	**Tasks that were analyzed in the sessions** (*Design Unit* tasks are italicized)	**Task Content**
Session-1	High: Level-4	*Task-1: Understanding Inheritance*	Mendelian Inheritance
	Low: Level-1B	Task-2: Rules of Inheritance	
	High: Level-3B	Task-3: Using Rules of Inheritance	
Session-2	High: Level-4	*Task-4: Gecko Breeding Results*	Mendelian Inheritance
	High: Level-4	Task-5: Debate on Gecko Breeding Results	
Session-3	High: Level-4	*Task-1: Understanding Inheritance*	Mendelian Inheritance
Session-4	High: Level-4	*Task-6: Modeling Allele Combinations*	Mendelian Inheritance
	Low: Level-2B	Task-7: Punnett Square	
	High: Level-3B	Task-8: Cell City Analogy	The Cell
Session-5	High: Level-4	*Task-9: Linking Genotype-Phenotype*	Mendelian Inheritance
	Low: Level-1B	Task-10: Describing Phenotype	
	High: Level-3B	Task-11: Predicting Color of a Plant	
	High: Level-3A	Task-12: Scientific Method in Action	The Scientific method
Session-6	Low: Level-1A	Task-13: Crossword Puzzle	The Scientific method
Session-7	High: Level-5	Task-14: Factors Affecting Seed Germination	Seed germination
	Low: Level-2A	Task-15: Observing Osmosis	Osmosis

Note. Except Task-8 and Task-12, all the other tasks were first analyzed by the teachers individually in terms of their cognitive demand and then discussed as a whole group. Task-8 and Task-12 were only analyzed by teachers individually.

As shown in Table 6, in the Noticing-PD teachers were exposed to a variety of levels of cognitive demand and tasks from other topics in biology (beyond Mendelian Inheritance). I developed five additional biology tasks that were similar to the four Design Unit tasks content-wise (Mendelian Inheritance) but different in terms of the cognitive demand levels. I also incorporated tasks related to topics different from Mendelian Inheritance.

In each PD session, teachers were given time to individually answer the questions in their PD-log associated with cognitive demand of each task. After most, but not all, tasks, a group discussion was conducted about the cognitive demand of the task. The discussions typically began with each teacher stating his or her judgment of the cognitive demand level of the task (written on chart paper by the facilitator). Then each possibility was discussed generally starting with the cognitive demand level that the greatest number of teachers identified. The TAGS was used as a guide throughout.

After the written tasks were analyzed, teachers viewed a video clip that depicted either high or low-level student thinking during the enactment of one of the written tasks that had just been analyzed (which was also one of the four high-level tasks from the Design Unit). After viewing the video case, teachers were provided transcripts of the video case and then given silent time to jot down what they noticed in the video case. Then a whole group discussion commenced, during which teachers shared what they noticed in the video case. The discussions generally concluded with deciding on the level and type of student thinking that was going on in the video case.

3.3.3.1 Selection process of the video cases

The larger project had collected video records from three different teachers' classrooms in which the Design Unit was implemented in Fall 2011. The project team decided to video record these three classrooms based on the availability of resources and the goal of capturing variety in implementation of the Design Unit.

I viewed the video records of the lessons in which the four Design Unit tasks (the focus of this study) were implemented. I identified thirteen video cases, each of which represents the enactment phase of one of these tasks.[12] The selection of the video cases was guided by Stein and her colleagues' research, which indicates that the cognitive demand of tasks can change as they pass from written materials to how they are set up by the teacher in the classroom to how they are actually enacted or carried out by students and the teacher (Stein et al., 1996; 2000). I searched for video cases that represented either the *maintenance* or *decline* of high levels of cognitive demand from written materials to how the task was enacted in the classroom. I used the TAGS to differentiate the level and type of student thinking that was occurring in the video case.

These thirteen video cases were viewed with the researcher who developed the Task Analysis Guide in mathematics (Mary Kay Stein). After viewing and discussing the video cases, we identified seven to use in the Noticing-PD sessions (see Table 7 for the details about these video cases). I decided to use video cases that provided a clear window into how students were making sense of the subject matter (e.g., through memorization, no meaning making, by engaging in scientific practices). While some of the video cases were selected from a whole class discussion, others were selected from small group work.

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[12] Research suggests that how the teacher sets up a task is also important (Stein et al., 1996). However, the videos collected during the Fall 2011 implementation did not have enough variation in terms of teachers' set up of the tasks. The majority of the tasks were set up at a high-level. Therefore, teachers' learning to notice different features of the task set-up was not the focus of this study. However, teachers were shown two set-up videos and they were informed about the importance of task set-up in two of the Noticing-PD sessions. I thought this might also help them to better realize how cognitive demand of a task may change from its written version to how it is set up in the classroom to how it is implemented in the classroom.

The video cases that were used in the Noticing-PD sessions were also discussed with two graduate students who had prior knowledge about cognitive demand. They were asked to independently view the video cases and identify the level of student thinking in these video cases as being high or low. Both of them reached 100% agreement[13] with us in terms of the level of student thinking in these video cases. Lastly, all of the video cases were sent to a professional to make them ready to use in the Noticing-PD; the teacher's face was faded, her voice was changed, and subtitles that transcribed what students and teachers said were added.

Table 7: Video Cases Used in the First Five PD sessions

PD Session	Task	Video Case #	Classroom organization	Level/type of student thinking	Duration
Session-2	Task-4	Video Case-A	Whole class discussion	Low-level	7:52 min
Session-3	Task-1	Video Case-B	Group work followed with whole class discussion	High-level	15:19 min
Session-4	Task-6	Video Case-C	Group work	Low-level	5:58 min
		Video Case-D	Group work	High-level	2:54 min
Session-5	Task-9	Video Case-E	Whole class discussion	Low-level	6:30 min
		Video Case-F	Group work followed with whole class discussion	High-level	13:02 min

[13] For one of the contrasting video cases, one rater did not initially agree with us. He considered both of the videos as being high-level. However, after discussion, we came to agreement. He recommended cutting one section of one of the video cases, during which he argued the students were encouraged to think at high-level. Upon our discussion, that section was taken out from the video case. In this way, we came to an agreement.

As shown in Table 7, teachers viewed two video cases in sessions 4 and 5. These are *contrasting video cases* of task enactment. Bransford and Schwartz (1999) stated that, "Through contrasting cases, one develops the ability to notice finer and finer distinctions" (p. 92). In these two sessions, teachers discussed what they noticed as similar and different in the video cases.

In the last two Noticing-PD sessions, video cases from the teachers' own classrooms were used. These video cases were selected from the teachers' enactment of Task-1. The same procedure for selecting the video cases was used. Four of the video cases were identified as showing high-level student thinking[14] and one as indicating "unsystematic exploration," which was described by Stein and her colleagues (1996) as:

> …motivated student engagement, well-intentioned teacher goals for complex work, and well-managed work flow. The cognitive activity, however, was not at a high enough level to be characterized as engagement in complex mathematical thinking and reasoning. Students explored, discussed, and attempted to make connections, but they missed the important and central mathematical substance. (p. 478)

Table 8 provides details about the video cases selected to use in the last two Noticing-PD sessions.

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[14] I did not select video-clips that depict low-level student thinking from any of the teachers' classrooms. This was an intentional decision. First, I did not want teachers to feel bad about their practice. They might think that we considered the selected video-clip as a representation of their common practice. Moreover, this group of teachers was not used to analyzing their own teaching with their colleagues. I did not want that to be a barrier for the group discussions in the PD. This might have become a barrier, especially if we analyzed a video-clip from one of the teachers' class that showed low-level student thinking.

Table 8: Video Cases Used in the Last Two PD sessions

Task	PD Session	Videos	Teachers	Classroom organization	Level/type of student thinking	Duration
Task-1	Session-6	Video-1	Susan	Group work	High-level	07:71 min
		Video-2	Barbara	Group work	High-level	14:04 min
		Video-3	Nancy	Group work	High-level	12:45 min
	Session-7	Video-4	Carol	Whole class	High-level	10:55 min
		Video-5	Linda	Whole class	Unsystematic exploration	10:38 min

3.4 PARTICIPANTS OF THE STUDY

Recruitment for the larger project was accomplished through the outreach efforts of the project coordinator of the larger project under which this study was conducted. She personally contacted principals, science coordinators, and/or teachers. In addition, an "exposure meeting" was held at the university in which two teachers were presented with an example task from the unit and then told about the study. As a result, five high school biology teachers[15] from several school districts were recruited as part of the larger project. These teachers, who voluntarily participated in the study, were paid for their participation.

Table 9 provides information about the participants of the study. Linda and Susan were the two most experienced teachers in the Noticing-PD and they were both from the same public high school. Linda was the head of the biology department and had some prior experience

[15] In addition to these five biology teachers, there was one mathematics teacher who participated in the larger project and attended about all the Noticing-PD sessions. I did not include the mathematics teacher in the study because of his limited biology content knowledge. As I summarized in the literature, the second aspect of noticing is using what one knows about the context to reason about a situation (van Es & Sherin, 2002). This involves teachers' subject matter knowledge. Because I wanted all teachers to have subject matter knowledge in high school biology, I decided not to include the math teacher in the study.

working with the larger project team. Susan heard about the larger project from Linda. Both of them decided to implement the Design unit in their own classrooms during the Spring 2012 semester. Linda was the only teacher in the Noticing-PD who had prior experience in implementing the Design Unit; she had implemented it in Fall 2011. Thus, she was familiar with the project team's approach to teaching and learning science with a student-centered approach. Moreover, teaching the unit once in her own classroom might have equipped her with some knowledge about the major struggles that students have understanding the biology ideas communicated in the unit. Thus, it may have been easier for her to recognize some of the classroom interactions in the video cases that showed the enactment of high-level tasks from the Mendelian Inheritance unit.

Barbara and Nancy were from two different schools operating under the same charter school organization. They were both new teachers with three years of teaching experience and a master's degree. Barbara's master's degree was from the University of Pittsburgh. This charter school system pays attention to using best research-based practices in the classrooms to facilitate students' learning and encourages using project-based activities in science classrooms. Therefore, given the approach that their school system adopts about teaching and learning, Barbara and Nancy may have been familiar with and open to teaching science as more inquiry-oriented.

Lastly, Carol was from a private school. She also had experience in working with the project team; she had implemented another biology unit that was developed by the same project team. Therefore, like Linda, Carol was also familiar with the project team's approach to teaching and learning science with a student-centered approach. Moreover, both Linda and Carol previously attended some professional development sessions that were facilitated by the larger project team. Even though the nature of those professional development sessions were very different than the Noticing-PD, it is important to consider that these two teachers were exposed to more active, project-based science teaching approach though those professional development sessions. Overall, the five high school biology teachers that participated in the Noticing-PD had some knowledge and experience with teaching science in a more active, project-based manner. Thus, upon beginning the Noticing-PD, compared to many others, these teachers already had experiences with and knowledge about reform-based science instruction in which students' active involvement in the learning process plays an important role.

Table 9: Participants of the Study

Teacher Pseudonym	Grade Level	Years Teaching	Degree
Carol	12	5	Bachelor's
Linda	10	16	Master's (in Science Education)
Susan	10	13	Doctorate (Curriculum & Instruction)
Barbara	11	3	Master's (Teaching)
Nancy	11	3	Master's (Instructional Leadership)

3.5 DATA SOURCES AND ANALYSIS

Data for this study includes the transcripts of baseline and exit interviews with each individual biology teacher[16] participating in the Noticing-PD, and the transcripts of third and fourth Noticing-PD sessions. Analysis of the data was conducted in two phases. *The first phase* involved the analysis of the baseline and exit interviews to answer each of the research questions

[16] From now on, I will refer to teachers who participated in the Noticing-PD as PD-participants to prevent confusion between the teachers who participated in the Noticing-PD and the teacher in the video case.

of the study. Findings from this analysis guided the next phase, which consisted of identifying which PD sessions to analyze in order to examine what might account for the changes in teachers' noticing. In what follows, I first describe the interview data and the way it was collected and analyzed. Then, I describe the second phase of the analysis by providing details about a) the identification of the PD sessions that were used in the study, b) PD activities in these selected sessions and their underlying design rationales, and c) the analysis of these PD sessions, which generally followed the same procedure as the analysis of the interviews.

3.5.1 Baseline and exit interviews

The first data source consisted of the transcripts of the audio-recorded baseline and exit interviews in which individual PD-participants were shown video cases and asked what they noticed. The same two video cases were used for both the baseline and exit interviews. The first one showed the enactment of an osmosis task (see Appendix C) (Levin, Hammer, Elby, & Coffey, 2013); the second showed the enactment of Task-9 (Linking Genotype to Phenotype) from the Design Unit (see Appendix D). Video cases used for the interviews were identified using a procedure similar to that used to select video cases for the Noticing-PD sessions,[17] except that I only identified video clips that represented high-level student thinking because such video cases provide richer classroom interactions for PD-participants to notice. The main purpose of adding the osmosis video case to the baseline and exit interviews was to interview PD-participants about a task from a biology topic different from Mendelian Inheritance. By doing so, I was able to examine whether the Noticing-PD was effective in developing their ability to notice

[17] The procedure for selection of the video cases was described in detail in section 3.3.3.1, which is entitled "Selection process of the video cases."

significant features of a classroom, which involves enactment of a high-level task, independent of the topic that was covered in the classrooms viewed during the Noticing-PD.

A separate interview protocol was developed, piloted, and refined for the interview with each video case (see Appendix E and Appendix F for the interview protocols). The protocol for each video case was closely followed while conducting both the baseline and exit interviews. Each of the protocols was separated into four parts. *In the first part*, PD-participants were given the task and then asked what they thought about the task, particularly in terms of the potential level of thinking it demanded of students. *In the second part*, they viewed the video case that showed the enactment of this task in a high school biology classroom. After viewing the video case, they were asked to explain what they noticed. *In the third part*, participants focused on students in the video case, viewed it for the second time, and answered an accompanying set of questions about what they noticed. One of the questions towards the end of this part was about the level or type of student thinking that was going on in that video case. Lastly, *in the fourth part*, participants were asked to talk about the role of the teacher influencing the level of student thinking.

In the baseline interviews, PD-participants were first interviewed about the 11-minute osmosis video case, and then about the 11-minute inheritance video case. The baseline interviews took between 80 to 100 minutes, including the video-viewing times (40 to 60 minutes, excluding the video viewing times). Although the baseline interviews with both of the video cases were conducted at the same point in time (except in the case of one PD-participant), this was not the case for the exit interviews. Figure 2 shows the time points of the interviews within the context of the study's intervention.

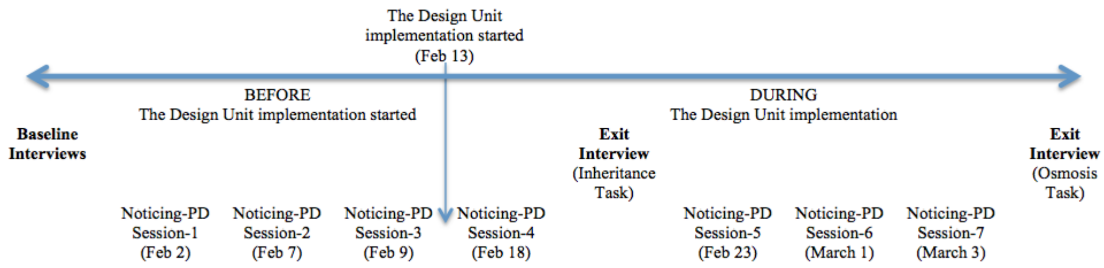


Figure 2: Timeline for the Data Collection and Intervention of the Study

As shown in the figure, the exit interviews with the inheritance video case were conducted just before the 5th Noticing-PD session in which this task was the focus.[18] These interviews took between 45 to 60 minutes, including the video-viewing time (20 to 35 minutes, excluding the video-viewing time). The purpose of the earlier time point for the exit interview was to eliminate the explanation that improvements in PD-participants' noticing was because they would be already familiar with the Mendelian Inheritance task that was covered in the 5th PD session. The exit interview with the osmosis video case was conducted after all the Noticing-PD sessions were completed. The interviews with the osmosis video took between 40 to 50 minutes, including the video-viewing time (15 to 30 minutes, excluding the video-viewing time).

In this study, I used baseline and exit interviews that were conducted with each individual PD-participant by using both of the video cases, but I did not use the entire interview transcript for the analysis. Among the four parts of the interviews that I described above, I focused on the second part and small portion of the third part of the transcripts in my analysis. The second part started with the interviewers providing some background about the video case to the teacher.

[18] Task 9 was used in the 5th Noticing-PD session and part of this task was used in the baseline and exit interviews. That said, the video case of Task-9 enactment that was used in the interviews was different from the video case of Task-9 enactment that was used in the 5th Noticing-PD session.

Right before starting to view the video case, PD-participants were told that after viewing it they would be asked to talk about what they noticed in the video case. After they viewed the video case, they were given the transcript of the video case and provided with some time (if they wanted) to organize their thinking. Then, they were asked what they noticed in the video case. This part ended after they exhausted everything they noticed in the video case. In this case, participants' talk about the video case formed the data used for the analysis. The other part of the interviews that I focused on in my analysis is the portion of the third part, which involves participants' talk in response to the question, "What level and type of student thinking is going on in this classroom?"

3.5.2 First phase of the analysis: Analysis of the interviews

Analysis of the interviews started with preparing the interview transcripts for coding. I split the transcripts of the baseline and exit interviews into two segments: 1) PD-participant's talk related to what she noticed in the video case, and 2) PD-participant's talk related to her analysis of the level or type of student thinking. Analyses of both of these segments were conducted following a systematic procedure.

I started with the analysis of the first segment. First, I divided the transcripts into idea units (Sherin & van Es, 2009), defined as "a distinct shift in focus or change in topic" (Jacobs, Yoshida, Stigler, & Fernandez, 1997, p. 13). Therefore, idea units constituted the unit of analysis of the interviews (Miles & Huberman, 1994). The second step involved coding each of the idea units with respect to three different dimensions: actor, topic of conversation, and stance (Sherin & van Es, 2009; van Es & Sherin, 2008). Each idea unit was assigned only one code for each dimension. Moreover, for each idea unit, I determined whether the PD-participant referred to a particular instance in the video case to support her explanation of what she noticed in the video case. There was not any predetermined category of codes for the analysis of the second segment of the interviews; patterns were generated from the data. Table 10 shows how coding categories are related to the each of the research questions in the study.

Table 10: Relation of the Coding Categories and the Research Questions

Aspects of Noticing (Learning to Notice Framework)	**Coding Categories**
Attending (RQ-1)	**Actor** Particular student Students in general Teacher Student(s) & Teacher **Topic** Pedagogy • Pedagogy not explicitly tied to students • Pedagogy explicitly tied to students, but at a general, non-content-specific level • Pedagogy explicitly tied to students at a specific, content-informed level Student Thinking Student Engagement Student Talk Classroom Climate Management Other
Making sense of what is attended to (RQ-2)	**Stance** Descriptive Evaluative Interpretive **Evidence from video-clip**
Linking to a broader principle (RQ-3)	Patterns generated from the data

Note. This analytical framework was developed based on the earlier work by Crespo, 2000; Jacobs et al., 2007; Sherin and van Es, 2009; van Es & Sherin, 2008; 2009, van Es, 2011 and the goals of the current study.

Addressing **the first research question**, which is about what PD-participants attended to (the first aspect of noticing), the idea units were categorized in terms of 1) to whom in the video the PD-participants directed their attention (actor), and 2) the topic of conversation. *The actor* can be a) a particular student or a group of students, b) students in general, c) the teacher, or d) both the teacher and the student(s) in the video case. *The topic of conversation* includes the categories of pedagogy, student thinking, student engagement, student talk, classroom climate, management, and other. When idea units were coded as being about the topic of pedagogy, they were categorized into one of the following sub-codes: a) pedagogy not explicitly tied to students, b) pedagogy explicitly tied to students, but at a general, non-content-specific level, or c) pedagogy explicitly tied to students at a specific, content-informed level. The purpose of this more detailed coding was to capture possible shifts in participants' capacities to notice teacher actions in relation to students' ideas and/or actions that can be associated with the maintenance or decline of high-level tasks during the enactment phase of the lesson (Henningsen & Stein, 1997; Stein et al., 1996). Table 11 and Table 12 provide details about the actor and the topic codes.

Table 11: Description of the Codes related to the "Actor"

Codes	**Definition**	**Example**
Particular student	Referring to a particular student or a group of students in the video	"… John [pseudonym of a student], said something about the male being dominant."
Students in general	Referring to students in general without seeing the class as a set of individual students	"…they [students] did struggle definitely with that concept of putting together what you see up here with the parents and the protein down below."
Teacher	Referring to the teacher in the video case	"She [the teacher] was really good with not…she just said that okay, this is a good conclusion."
Student(s) & teacher	Referring to both the teacher and the students in the video case	"…they [students] kept saying that one would be more dominant than other. She [the teacher] wasn't really correcting them…"

Table 12: Description of the Codes related to the "Topic"

Codes	Definition	Example
Student thinking	Attending to what the students are saying related to the content; what they appear to think or understand	"They said if the DNA comes from the protein or something or the protein is in the DNA and the DNA tells the trait and says what it looks like then the offspring will look more like the father"
Pedagogy		
• Pedagogy not explicitly tied to students	Attending to teacher's actions with no explicit relation to students' ideas or actions.	" She [the teacher] was doing a lot of probing questions."
• Pedagogy explicitly tied to students, but at a general, non-content specific level	Attending to teacher's actions in some relation to students' ideas or actions but at a general level without having any content-specific comments	" …when they [students] were on the right track she [the teacher] would really say 'Okay, you're right,' and more assuring things…"
• Pedagogy explicitly tied to students at a specific, content-informed level	Attending to teacher's actions that influenced or got influenced from something specific that student(s) said/did	"She [the student] said 'I don't understand why the female doesn't have a protein'… and the teacher … says, '…is there something different about her?' so she is … trying to get her to think about why might the male have that protein and not the female"
Student engagement	Attending to the level of student participation, the extent to which students were attentive to the lesson, etc.	"Any time she [the teacher] went to a group, the kids were usually the first one to say something and not her. Which is good. It shows and that's a sign of engagement."
Student talk	Attending to the process of talking about the academic content/ the way students are talking around the content.	"… in their group they were able to kind of build off of each other a little bit"
Classroom climate	Attending to the social environment of the classroom, such as the relationship between the teacher and the students or among the students.	" I noticed that the teacher was very positive, so it was very -- even if they were going down the wrong path, it was good or it was positive prompting."
Management	Issues related to student behaviors, the way the teacher deal with the disruptive behavior, effective use of classroom time, etc.	"… she [the teacher] didn't have to do a lot of the disciplinary things."

To address **the second research question,** related to how PD-participants made sense of what they attended to (the second aspect of noticing), I analyzed the *stance* they used (i.e., the position they assumed) while talking about the video case. This includes whether PD-participants 1) described which features of the activity stood out to them in the video case, 2) evaluated what they saw in the video case instead of trying to understand what was happening, or 3) interpreted what they saw in the video case. Table 13 provides the details about the stance codes. I also analyzed whether they referred to a particular classroom event as *evidence* while talking about the video case. An example for the idea unit that illustrates referring to an instance from the video case could be a comment like, "I think maybe Amy [a student pseudonym] in line 373, finally figured out that there's salt in the ocean and that makes the water have less concentration of water compared to a cell in the tree." In this comment, the PD-participant refers to a very particular instance in the video case by pointing out a specific line number from the transcript to support her explanation of what she noticed in the video case.

Table 13: Description of the Codes related to the "Stance"

Codes	Definition	Example
Descriptive	Talking about the observable features of what is seen in the video case.	"I know then the teacher directed them back up to look at the genotypes."
Evaluative	Evaluating the quality of the classroom interactions in the video; making explicit judgments about what was good or bad or should have been done differently.	" The students were able to pick out – like the one girl picked out, like, 'Well, the female doesn't have a protein,' so I thought that was good."
Interpretive	Making some inferences about what is seen; making some hypotheses about why these events could have happened.	"John [a student pseudonym], said something about the male being dominant. I think he was relating that back to the white square being dominant. Oh no no, he said that because all of them showed up except for the female because he said it overshadowed them"

I analyzed all twenty interview[19] transcripts through multiple iterations until the analytical framework was solidified. I developed a codebook that includes the description of the codes, some decision points for the analysis as well as examples for some of the codes (see Appendix G). During this process, the analytical framework related to the first segment of the interviews was discussed with a second researcher to clarify the description of the codes along the three dimensions (actor, topic, and stance) and the evidence code. To sharpen the definition of the codes and the distinction between them, a researcher and I coded the same part of an interview and then discussed the codes several times (Miles & Huberman, 1994). As a next step, the second researcher coded 20% of the transcripts by using the codebook. Four transcripts, which were used for inter-rater reliability, were randomly selected. Overall, inter-rater reliability was 81% (Kappa = .64). Differences between the two coders were discussed and resolved through consensus. The first author blindly coded the remainder of the interviews.

Displaying the analysis in an organized way allowed me to understand and draw conclusions about what has changed from baseline to exit interviews (Miles & Huberman, 1984). Based on these analyses, I created a table for the results of the baseline and exit interviews to show the number and percent of idea units relating to the various codes underneath the actor, topic, and stance dimensions as well as the evidence code. This allowed me to identify the change in the percentage of the idea units related to each code from baseline to exit interviews.

Statistical analyses were used to assess the significance of the changes in participants' analyses of the video cases from baseline to exit interviews for particular categories. Specifically, I expected to see a significant *increase* in the percentages of comments related to a) the topic code, "pedagogy explicitly tied to students at a specific, content-informed level," b) the

[19] I interviewed five PD-participants. Because each baseline and exit interview was conducted with two separate video cases, in total there were 10 baseline interviews and 10 exit interviews in this study.

stance code, "interpretative," c) the evidence code, and d) participants' interpretive stance while talking about the student thinking. In contrast, I would expect to see a significant *decrease* in a) the topic code, "pedagogy not explicitly tied to students," b) the stance code, "evaluative," and c) participants' evaluative stance while talking about the student thinking. I conducted one-tailed t-tests for dependent samples to identify the significant differences between the baseline and exit interviews in the percentages of idea units for these particular categories. Because I had *a priori* hypotheses for the direction of the expected change, I conducted a one-tailed test (van Es & Sherin, 2008). To do that, I calculated the percentages of idea units per teacher for the categories that I mentioned above and then I compared the changes in the proportions between baseline and exit interviews for all teachers.[20]

To address **the last research question,** I followed a different procedure by focusing on the second segment of the transcripts. To assess the extent to which participants started to recognize each video case as an instance of a particular level or type of student thinking, I first examined whether or not the participants identified the level of student thinking in the video cases as roughly at a "high" or "low" level. Next, I read through the sections of the transcripts in which participants were asked to describe that level of thinking and generated codes for the constructs used by participants to describe high-level student thinking (e.g., the application of knowledge, deep student engagement, etc.). I then assigned as many codes as applicable to each participant's description of student thinking. Finally, I created a table that showed the number of participants that used each construct in the baseline and the exit interviews and examined this table to determine if participants' descriptions of what constitutes high-level student thinking

[20] In these analyses, t-tests were performed on 2 out of 3 categories that comprise a dimension. Therefore, if there is significant change in one category, it is likely to observe a significant change in opposite direction for other category.

shifted from baseline to exit interviews to include more references to constructs associated with the TAGS framework.

To conclude, the above analyses allowed me to identify in detail common patterns of change in PD-participants' noticing from the beginning of the PD to after it was completed. After finishing the first phase of the analysis, the question to be asked was what happened in the Noticing-PD that could be associated with the major changes from baseline to exit interviews. Clearly, in the first phase of the analyses what happened in the Noticing-PD was a black box. Because this study is about teachers' learning to notice within a video-based professional development, it is important to examine what actually happened in the local context of the study. Thus, I used the transcripts of PD-sessions as another primary data source of the study (Miles & Huberman, 1984).

All seven PD-sessions were video recorded with two cameras. The facilitator arranged the desks in a way that the PD-participants were able to see each other during discussions and see the projector screen where the video cases were projected. The stationary camera was located at the back of where PD-participants were sitting. The roaming camera was controlled by a project manager, who assisted with the logistics of running the Noticing-PD sessions. She generally sat close to where the group was sitting. A microphone was placed on the desk and it was synchronized with the roaming camera. All of these recorded sessions were then transcribed to use in the analysis. In what follows, I provide details on the second phase of the analysis, which involved identifying the PD sessions for the analysis and analyzing transcripts of these PD sessions.

3.5.3 Second phase of the analysis

As noted in the introductory chapter, the goal of this study is not to identify the cause (in terms of the mechanism responsible) for whatever changes are observed. The goal is to identify, at a detailed level, what, if any, changes occur in PD-participants' noticing from the beginning to the end of the Noticing-PD. Thus, both in the first and second phase of analysis, I conducted detailed coding to explain teachers' learning to notice. That being said, it is very likely that the combined results of the phase-one and phase-two analyses can provide insight into what aspects of the Noticing-PD might have influenced the change in teachers' noticing. Thus, I decided to strategically identify particular PD sessions for analysis during the second phase; to do so, I was primarily guided by my knowledge of the specific design features of the Noticing-PD and the major findings from the interview analysis in terms of teachers' learning to notice.

3.5.3.1 Identifying the PD sessions for the analysis

In this study, I focused on the third and fourth Noticing-PD sessions. Session-3 was selected because it was the first session in the Noticing-PD in which the participants viewed and discussed a video case that illustrated high-level student thinking during the enactment of a high-level task.[21] Therefore, I consider PD session-3 as a baseline discussion about a video case that is similar to the ones that they viewed in the baseline and exit interviews. In the session, PD-participants viewed two video cases from the same high school biology classroom in which a high-level task was enacted. The first one was from the small group work and the second one was from the whole class discussion. In the analysis, I focused on participants' discussion of the

[21] In session 2, PD-participants viewed and discussed a video case illustrating low-level student thinking during the enactment of a high-level task; in session 1, they did not view a video case.

small group video case because 1) it is the first video case that they viewed of a high-level student thinking, and 2) PD session-4 involved a discussion about a video of small group, so focusing on small group work would be consistent across the two PD data sources used for the analysis of this study.

I selected session-4 because of my review of the majority of the video-recorded PD sessions. I viewed the portions of the video-recorded PD sessions 4, 5, 6, and part of 7 during which PD-participants talked about the video cases. At the same time, I read their transcripts. PD sessions 6 and 7 involved discussion of video cases from participants' own classrooms. The nature of the PD discussions were different in these two sessions, primarily due to the fact that teachers were now viewing lessons of a known colleague who was present in the PD session instead of an anonymous teacher. Because of this, I decided not to focus on these last two PD sessions.

My review of the PD data, my knowledge of the results of the interview analysis, and my knowledge of the design rationales of the Noticing-PD led me to conjecture that using contrasting cases may have played an important role in some of the major changes from baseline to exit interviews. Specifically, PD-participants' learning to talk about pedagogy in different ways and also participants' rising interpretive stance during the exit interviews could be associated with their experiences surrounding the use of contrasting video cases in the Noticing-PD. As mentioned earlier, PD sessions 4 and 5 involved contrasting video cases. After reviewing PD sessions 4 and 5, I determined that the discussion in PD session-5 was colored by the fact that one of the contrasting video cases was selected from one of the participants' earlier implementation of the Design Unit. This gave rise to a heated debate that was mainly influenced by one participant's strong feelings about her own video case. Even though the other participants in the PD were not told that one of the contrasting video cases was from that teacher's classroom (and her face was blurred and her voice was altered), her participation in session-5 was considerably different than the earlier sessions. Because her participation might influence the results of the analysis of this PD session and because this was an exceptional case, PD session-5 was not used for the analysis of this study.

3.5.3.2 Focus of the analysis: PD sessions 3 and 4

Earlier in the methods section, I described the Noticing-PD by providing an overall summary of what happened in each PD session. In this section, I will zoom in to PD sessions 3 and 4, and provide details for *what happened* in these sessions and *why*. Table 14 summarizes the PD activities in which participants engaged in each of these sessions and presents design rationales underlying the activities. The parts that I used for my analysis are italicized in this table.

Table 14: PD Sessions 3 and 4: Activities and Design Rationales

Activities (What happened)	Design Rationales (Why)
PD Session-3	
1. Analyzing a written task based on its potential cognitive demand (CD)	* Providing opportunity for teachers to identify the level or type of student thinking in all three phases (written materials, set up, and enactment)
2. Viewing and discussing set-up video: shows how above task was introduced to the students	
3. *Viewing and discussing enactment video: shows high-level student thinking that occurs in small groups* ▪ *Identifying the level or type of student thinking in the video case*	
4. Viewing and discussing a second enactment video: shows high-level student thinking that occurs during the whole class discussion ▪ Identifying the level or type of student thinking in the video case	
PD Session-4	
1. Analyzing three written tasks based on their potential cognitive demand	
2. Introducing "journey of a task" ▪ Summarizing PD sessions 2 and 3 ▪ Presenting the change in cognitive demand across the phases of written materials, set up and enactment	* Providing opportunity for teachers to see that cognitive demand of a task can be declined or maintained * Using contrasting cases to learn to distinguish levels of student thinking as defined in the TAGS
3. Viewing the first contrasting video case: shows low-level student thinking during the enactment of a high-level task ▪ Individual time for note-taking about what was viewed	* Using contrasting cases to support determining maintenance or decline
4. Viewing the second contrasting video case: shows high-level student thinking during the enactment of a high-level task ▪ Individual time for note-taking about what was viewed	* Using contrasting cases to reveal factors associated with maintenance or decline of the cognitive demand of the task (associated with high versus low-level student thinking)
5. *Discussion on the similarities and differences between the video cases* ▪ *Identifying the level or type of student thinking in the video cases*	

Note. In the second phase of the analysis, I focused on the transcripts of participants' talk in the PD sessions that focused on what they noticed in the video cases and how they analyzed the level or type of student thinking.

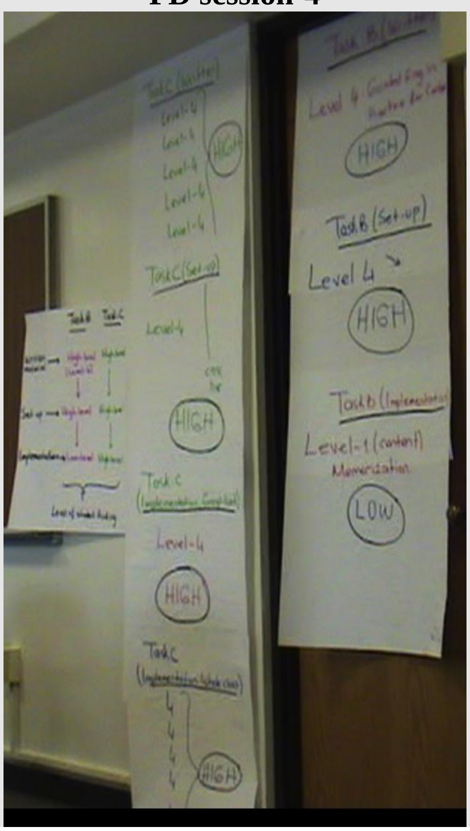
As Table 14 reveals, *in* ***PD session-3*** *the participants were engaged in a set of activities that allowed them to think about the level or type of student thinking that a task demands of students in each phase presented in the mathematical task framework (Stein et al., 1996).*[22] They were first asked to analyze a biology task as it appears in *written material* in terms of its potential cognitive demand. This was followed with viewing video cases from a classroom where this task was used. They first viewed and discussed a video case that shows how the teacher *set up* the task in the beginning of the lesson. This discussion focused on the level of thinking this kind of a set-up demanded of students. Afterwards, they viewed and discussed a video case that was from the *enactment* of the same task in the same classroom. After talking about what they noticed in the video case, they were asked to analyze the level or type of student thinking that was going on in the classroom. The same set of activities was used in session-2 as well except that the enactment video case in session-2 showed low-level student thinking during the enactment of a high-level task. In this way, in the second and third PD sessions, participants had a chance to talk about the cognitive demand of a task as it appears in written materials, how it was set up by the teacher in the classroom, and how it was actually enacted or carried out by the students.

In the beginning of the ***PD session-4****, participants were introduced to the key idea behind the mathematical task framework that is tasks can change in their level of cognitive demand as they pass from written materials to how they are set up by the teacher in the classroom to how they are actually enacted or carried out by the students (Stein et al., 1996).* Before viewing the contrasting video cases, the facilitator highlighted this key idea by re-using the sessions 2 and 3 chart papers that had PD-participants' agreement of the cognitive demand levels of the main task that was analyzed 1) as it appears in the written materials, 2) as set up by the teacher in the video

[22] The design rationales are highlighted in italics during the description of the PD activities in sessions 3 and 4.

case, and 3) as enacted by the teacher and the students during instruction. After making this summary, the facilitator made a short presentation (see Appendix H) that described the "journey of a task" as presented in the mathematical task framework (Stein et al., 1996). *The presentation of the "journey of a task" also helped to frame PD-participants' viewing of and the discussions about the contrasting video cases.* Figure 3 shows the chart papers from sessions 2 and 3 that were used in session-4 to explain the change of cognitive demand across the phases.

Chart papers used in the PD session-4



Summary of what is written on the chart papers

PD Session-2

<u>Task (Written)</u>
Level-4 (HIGH)

↓

<u>Task (Set-up)</u>
Level-4 (HIGH)

↓

Task
<u>(Implementation)</u>
Level-1 (content) (LOW)

PD Session-3

<u>Task (Written)</u>
Level-4 (HIGH)

↓

<u>Task (Set-up)</u>
Level-4 (HIGH)

↓

Task (Implementation:
<u>Small Group Work)</u>
Level-4 (HIGH)

↓

Task (Implementation:
<u>Whole Class)</u>
Level-4 (HIGH)

Figure 3: Chart Papers from the PD Session-4

The contrasting cases that were used in Session-4 were used purposely to help PD-participants recognize the difference in the level or type of student thinking at level-2A and level-4 as presented in the TAGS Framework. According to the descriptions in the TAGS framework, tasks at these levels require students to engage in a set of scientific practices to make sense of the science content, so both of these levels speak to the focus of the recent NRC Framework (2012), which emphasizes the integration of science content knowledge as well as scientific and engineering practices in students' science learning. However, what separates level-4 from level-2A is the meaning-making dimension. Tasks are categorized at level-2A when they require students to follow the procedures for the scientific practice without really understanding the content. Students engage in a set of actions because they were told to do so, mostly by the teacher. I argued that it is important for PD-participants to recognize this difference because they need to see that doing "laboratory" does not always mean that students engage in high-level thinking. The selected contrasting video cases were used to help PD-participants to notice what students think and do in these two different video cases as they were engaging in a simulation activity and in what ways the teacher's actions (i.e., questions, comments, directions) were influential in shaping students' thinking and reasoning about the biology ideas revealed in the task.

Design of the PD session-4 also involved *careful consideration of learning goals for the PD-participants*. Before the session, the facilitator prepared a presentation that described the similarities and differences between the video cases (see Appendix I). The differences outlined in this presentation were the main things that the session was designed to make salient. During the session, the facilitator, if needed, made the necessary moves that would help participants to see these main differences between the video cases. Indeed, one of the participants said of the facilitator at the end of the presentation: “She knew what we were going to say.”

Contrasting cases were used to reveal factors that are associated with maintaining or declining cognitive demand of high-level tasks during their enactment. Thus, the differences between the contrasting video cases that it was hoped that PD-participants would identify were actually a set of factors that are generally associated with maintenance or decline of task demand. Participants’ discussion of the contrasting cases was designed to help them to uncover these factors and be prepared to learn from the facilitator’s presentation about the features of classroom interactions that signal high versus low-level student thinking (Bransford & Schwartz, 1999). The presentation, which summarized the similarities and the differences between the video cases, served as a summary and refinement of what was discussed as a group. It clarified indicators of high versus low-level student thinking as well as pedagogical moves (i.e., teacher questioning, teacher moves, etc.) that are associated with high and low-level student thinking.

3.5.3.3 Analysis of the PD sessions 3 and 4

The analyses of the third and fourth PD sessions were conducted similarly to the analysis of the interviews. However, some changes were made in the analysis procedure based on my experience of the analysis of the interviews as well as some of the major patterns that were found in the interview data. In addition, analyzing multi-person discussions demanded a slightly different approach from one-on-one interviews. For example, I had to pay attention to which PD-participant made the comment during the discussions and the extent to which the facilitator was influential in PD-participants’ noticings. To record these changes, I developed an additional codebook to use during the PD analysis (see Appendix J).

One of the coding changes concerned the use of the actor dimension (whether participants focused on the student(s) and/or the teacher). I decided <u>not</u> to code the actor dimension for the PD transcripts because the first phase of the analysis revealed that, ultimately, the vast majority of PD-participants attended to <u>both</u> the teacher and/or the students in the video cases. Moreover, the pedagogy and student thinking codes are considered very related to the actor codes, so coding for student thinking and pedagogy provided enough information regarding whether PD-participants attended to the teacher, student(s), or both. The second change was about the topic dimension. I decided to use only three codes under the topic dimension: pedagogy, student thinking, and other. This was because the vast majority of the comments in the interviews were about pedagogy and student thinking. Because of the limited attention to other issues such as classroom management and student talk, I decided that detailed coding about such issues was not necessary for the analysis of the PD-sessions. Lastly, I made sight refinements in the way that I described the evidence based codes and pedagogy sub-codes.

The coding process began with reading each transcript and separating it into chunks each time a new issue was raised. At the same time, I identified what PD-participants noticed surrounding this issue. The "noticings" made by the participants during the discussions were considered as the unit of analysis of the PD sessions (Miles & Huberman, 1994). Organizing the transcripts into chunks helped me to easily follow the discussion among the PD-participants and the facilitator(s), which in turn helped with identifying the participants' noticings.

I coded each noticing in terms of: a) whose noticing (PD-participant's pseudonym); b) topic; c) stance; and d) evidence (see Table 15 for details). I also recorded the influence of the facilitator if the facilitator's prompts seemed to play a role in participants' noticings. The *topic* includes the categories of pedagogy, student thinking, and other. Some of the noticings were coded as both student thinking and pedagogy because while talking about the teacher's actions PD-participants expressed what they attended to about the students' ideas and how the teacher responded to them.

Similar to the analysis of the interviews, the *stance* PD-participants used while talking about what they attended to in the video case included descriptive, evaluative, or interpretive. However, a sub-code for "interpretive" emerged during the analysis that indicated "reasoning for maintenance or decline." Sometimes, PD-participants shared their noticings by explaining whether and how high-level thinking was maintained or declined in the video case. In most of such cases, PD-participants were trying to make to sense of what they saw in the video case that could be associated with high or low-level student thinking. Another emergent code in the PD analysis was a set of factors associated with maintaining or declining high-level student thinking in the video cases. PD-participants identified some factors, which were mostly related to the teacher's actions, associated with maintaining or declining high-level student thinking during the enactment of a task.

Finally, coding the noticing for the *evidence* code involved deciding whether the noticing a) had no evidence; b) was evidence-based, or c) had evidence provided by the context. When it is evidence-based, I specified whether the PD-participant pointed to a specific line in the transcript or referred to a specific instance in the video case without explicitly stating the line number from the transcript. The nature of the PD data necessitated an "Evidence provided by context" code because sometimes a PD-participant or the facilitator started the conversation about an issue by referring to a particular instance in the video case, which was then followed by another participant making comments about the same instance without the need to show any evidence from the video case. In such cases, I coded that noticing as "evidence provided by the context".

Table 15: Codes Used for the Analysis of the PD Sessions

Coding Categories	Codes
PD-Participant	Pseudonyms of the participants: Carol, Linda, Susan, Barbara, Nancy
Topic	▪ Pedagogy ▪ Student thinking ▪ Other
Stance	▪ Evaluative ▪ Descriptive ▪ Interpretive
Evidence	▪ No evidence ▪ Evidence based ▪ Evidence provided by context

When PD-participants' noticings were coded as pedagogy in terms of its topic, they were categorized into one of the four pedagogy-related sub-codes. These sub-codes could be considered the *refinement* of pedagogy-related sub-codes as a result of the first phase of the analysis. PD-participants' comments about pedagogy varied in terms of two different dimensions: "link to students' ideas or actions" and "task specificity." "Link to students" refers to whether or not the participant connected the teacher's actions with students' actions and ideas. "Task specificity" refers to whether or not the pedagogy comments were grounded in the biology topic and/or the scientific practice that the task requires students to engage in. Figure 4 shows the matrix that was used for categorizing PD-participants' pedagogy-related noticings.

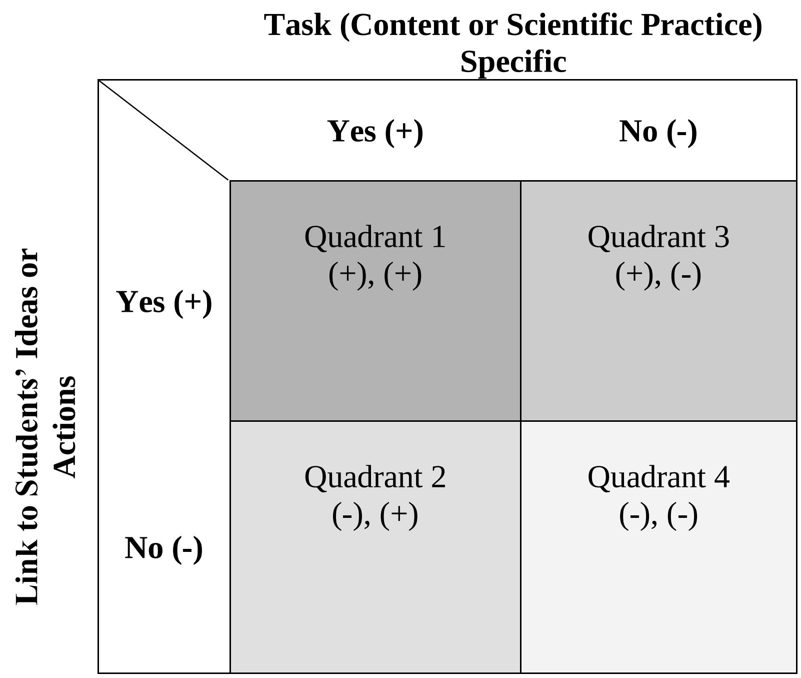


Figure 4: Pedagogy Quadrants

As shown in Figure 4, PD-participants' comments that linked teacher's actions with the students' ideas or actions at a task specific level were categorized into quadrant-1. The opposite of such comments were simply about what the teacher did. They were placed in quadrant-4. Some of the participants' pedagogy-related comments involved attention to teacher's actions in relationship to students' ideas or actions, but without being specific about the content or the practices of the task. Such comments were coded into quadrant-3. Lastly, comments in quadrant-2 grounded teacher's actions in the content or the practices of the task, but without any relation to students' ideas or actions. Table 16 provides an example for pedagogy-related noticings in each of the pedagogy quadrants.

Table 16: Examples for Pedagogy-Related Codes

Pedagogy sub-codes	Example
(+) Link to students, (+) Task specific	"The very first group did fertilization and didn't have alleles in their egg and sperm. She [the teacher] didn't make them pull them apart. She made them add the alleles. … it went against that biological concept of the alleles don't come after or don't combine".
(-) Link to students, (+) Task specific	"I just feel like the teachers had different goals. I honestly feel like the first teacher's goal was to get all the combinations".
(+) Link to students, (-) Task specific	"… the one teacher, my evidence on line 31. She asked him a question and he [the student] goes, 'Um,' and he's thinking about it. She gives him the answer".
(-) Link to students, (-) Task specific	"She didn't guide them. It was all questions".

The sub-codes that were used during the analysis of the interviews were similar to the sub-codes described above in the pedagogy quadrants. Comments categorized into quadrant-1 would be very similar to the comments categorized as "pedagogy explicitly tied to students at a specific, content-informed level" in the interview analysis. Quadrant-2 comments were not considered as a separate category in the first phase of the analysis.[23] Pedagogy comments that were coded as "pedagogy explicitly tied to students, but at a general, non-content-specific level" would be very similar to the quadrant-3 comments. Lastly, quadrant-4 comments would be very similar to "pedagogy not explicitly tied to students."

[23] Pedagogy sub-codes were generated through the analysis of the interview data. Pedagogy quadrants were generated after interview analysis completed as I was clarifying and refining the definition of the pedagogy-related sub-codes. Not having a code like quadrant-2 (No link to students, task specific) among the pedagogy sub-codes during the interview analysis suggests that such type of comments were not an observed common pattern in participants' remarks during the interviews.

To be able to identify patterns of change from session-3 to session-4, I created a table that showed the number and percent of noticings relating to the codes within topic, stance, and evidence. Next, I grouped noticings related to student thinking and each of the pedagogy-related sub-codes separately. This allowed me to see patterns in the nature of the noticings within these groupings in terms of a) the role of the facilitator, b) stance adopted by PD-participants, and c) use of evidence. Moreover, I compiled the factors of maintenance or decline that were identified by the PD-participants. These analyses allowed me to identify patterns of change in teachers' noticings from PD session-3 to session-4 and to examine the extent to which these findings were consistent with the findings based on the first phase of analysis.

Lastly, I conducted statistical analyses to assess the significance of the changes in participants' analyses of the video cases from PD session-3 to session-4. Similar to the first phase of the analysis, I conducted a one-tailed t-test for dependent samples to identify if there were significant differences in the percentages of participants' noticings for particular aspects within each dimension. Specifically, based on the findings of the first phase of the analysis and the design rationales of the PD activities in sessions 3 and 4, I expected to see a significant *increase* in the percentages of comments related to a) the pedagogy comments in quadrant-1, b) their interpretative comments, and c) their interpretive stance while talking about the student thinking. In contrast, I expected to see a significant *decrease* in a) the percentages of pedagogy-related comments in quadrant-4, b) their evaluative comments, and c) participants' evaluative stance while talking about the student thinking. Similar to the rationale in the first phase of the analysis, because I had *a priori* hypotheses for the direction of change from session-3 to session-4, I conducted a one-tailed test (van Es & Sherin, 2008). To do that, I calculated the percentages of noticings per teacher for the categories that I mentioned above and then compared the changes in the proportions between session-3 and session-4 for all teachers. [24]

[24] Like noted above for interview analyses, in the analysis of the PD-data, t-tests were performed on two out of three categories that comprise a dimension. Therefore, if there is significant change in one category, it is likely to observe a significant change in opposite direction for other category.

4.0 RESULTS

In this chapter, I present the results based on the first and second phases of the data analysis, which showed changes in what PD-participants attended to in the video cases and how they made sense of what they attended to. In addition, there was a shift toward connecting the specifics of what they noticed to the levels and kinds of student thinking as outlined in the TAGS, especially with respect to the role that engaging in scientific practice plays in high-level thinking and reasoning. The findings are organized by research question. I start with presenting the results that address the first research question based on the analysis of interviews (phase-1 analysis) and PD sessions (phase-2 analysis). Then, I move to the second research question and present the findings as a result of the analysis of interviews (phase-1) and PD-sessions (phase-2). I conclude this chapter by summarizing the findings that answer the third research question based solely on the interview analysis.

4.1 PATTERNS OF CHANGE IN PD-PARTICIPANTS' ATTENTION

Research Question-1: In what ways did what teachers attended to in the video cases change from the beginning to the end of the Noticing-PD?

4.1.1 Findings based on the first phase of the analysis

In the first phase of the analysis for RQ-1, I examined 1) to whom, and 2) what PD participants attended to in the video cases that were shown to them in the baseline and exit interviews. Table 17 provides a summary of the percentages of participants' comments related to each category within the actor and topic dimensions in the baseline and exit interviews surrounding each video case.

Table 17: What PD-Participants Attended to in the Video Cases During the Interviews

	Inheritance Interviews		**Osmosis Interviews**	
	Baseline	Exit	Baseline	Exit
Actor				
Particular Student	(2) 5%	(5) 14%	(5) 10%	(6) 14%
Students	(23) 55%	(11) 31%	(23) 46%	(14) 33%
Teacher	(9) 21%	(6) 17%	(11) 22%	(10) 24%
Students & Teacher	(8) 19%	(13) 37%	(11) 22%	(12) 29%
Topic				
Pedagogy	(15) 36%	(19) 54%	(19) 38%	(22) 52%
Student thinking	(14) 33%	(10) 29%	(19) 38%	(13) 31%
Engagement	(2) 5%	(4) 11%	(3) 6%	(4) 10%
Student Talk	(3) 7%	(0) 0%	(3) 6%	(2) 5%
Classroom Climate	(0) 0%	(0) 0%	(3) 6%	(0) 0%
Management	(1) 2%	(0) 0%	(0) 0%	(0) 0%
Other	(7) 17%	(2) 6%	(3) 6%	(1) 2%
Total	(42) 100%	(35) 100%	(50) 100%	(42) 100%

As Table 17 indicates, in the baseline interviews there was variation in terms *to whom* PD-participants attended in the video case. They mostly attended to the students in general. The least attention, however, was devoted to particular students. When the proportions of actor codes in the baseline interviews were compared with the proportions in the exit interviews, some changes were observed. The sizes and directions of these proportional changes from baseline to exit are presented in the graph in Figure 5.

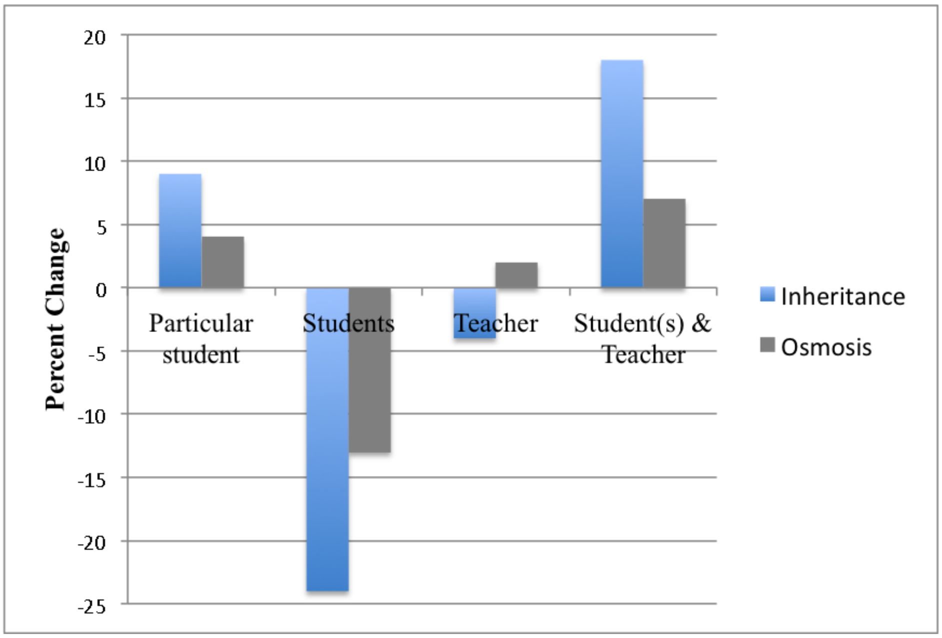


Figure 5: Change in to Whom in the Video Case PD-Participants Attended

As Figure 5 shows, in both the inheritance and osmosis interviews there was a slight increase in attention to particular students in the video cases, however there was a decline in the percentages of participants' comments that focused on the students in general (a decline of 24% for inheritance and 13% for osmosis). The extent to which participants focused on the teacher in both video cases showed very little change. Finally, compared to the earlier interviews higher percentages of participants' comments focused on *both* the teacher and the students on average.

Results regarding *what* PD participants predominantly attended to in the video cases were consistent across the inheritance and osmosis interviews. The majority of the topics on which participants focused fell under either student thinking or pedagogy in the baseline interviews compared to other issues such as climate, classroom management, or student engagement. Attention to such issues declined even more during the exit interviews. Only 17% of the comments for each video case were <u>not</u> about student thinking and pedagogy in the exit interviews.

On average, there was a moderate increase in participants' attention to pedagogy. Further analyses that focused on *exactly what about the pedagogy* the participants commented on revealed an interesting pattern (see Table 18). Analyses of the baseline idea units related to the inheritance video case indicated that 40% of the participants' comments were initially about general pedagogy not linked to students. For example, one participant said, "I noticed that she [the teacher] was doing a lot of probing questions…" Such comments focus on the teacher apart from what students appear to be doing. Moreover, they are not grounded in the content of the lesson. There were fewer of such comments in the baseline interviews related to the osmosis video case (30%).

Table 18: What PD-Participants Attended to Related to Pedagogy During the Interviews

	Inheritance Interviews		**Osmosis Interviews**	
	Baseline	Exit	Baseline	Exit
Pedagogy				
Not tied to students	(6) 40%	(0) 0%	(6) 30%	(2) 9%
Explicitly tied to students, at a general, non-content-specific level	(4) 27%	(4) 21%	(7) 35%	(9) 41%
Explicitly tied to students at a specific, content-informed level	(5) 33%	(15) 79%	(7) 35%	(11) 50%
Total	(15) 100%	(19) 100%	(20) 100%	(22) 100%

In the exit inheritance interviews, none of the participants' pedagogy-related comments was independent of students' actions and ideas. A one-tailed t-test indicated that this decline from baseline to exit interviews in participants' comments related to teachers' actions not linked to students was statistically significant [t = 2.47, p < .05]. Only 9% of the comments were in this category in exit osmosis interviews. Again, this decline from baseline to exit interviews with the osmosis video case was statistically significant (t = 2.33, p < .05). Figure 6 provides a graphical representation of the changes from baseline to exit in PD-participants' pedagogy-related comments.

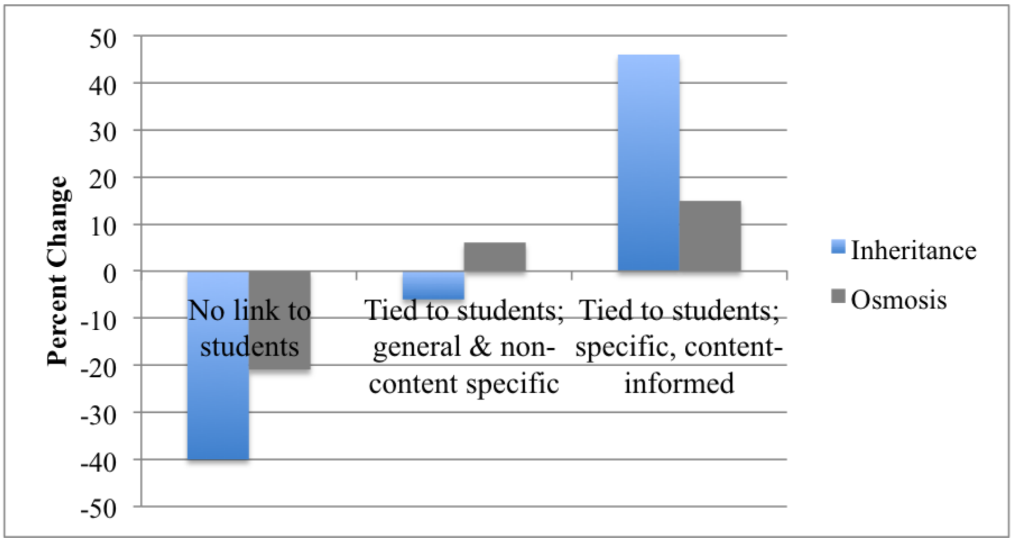


Figure 6: Change in PD-Participants' Pedagogy-related Comments in the Interviews

As opposed to the negative trends in participants' pedagogy-related comments that were independent of students' actions and ideas, there was a large increase in pedagogy-related comments that were explicitly tied to students at a specific, content-informed level. During the exit inheritance interviews, the majority of the pedagogy-related comments (79%) involved talking about the teacher's actions in relation to students' ideas and actions at a content-specific level while only 33% of their comments during the baseline interview was at that level (an increase of 46%). Once again, a one-tailed t-test indicated that this was a significant shift from baseline to exit in the inheritance interviews [$t = 6.48$, $p < .01$]. Similarly, there was a shift in participants' comments explicitly tied to students at a specific, content-informed level in the osmosis interviews, a shift that was found to be marginally statistically significant ($t = 1.83$, $p < .10$). The following statement by a PD-participant during her exit interview illustrates the nature of pedagogy-related comments explicitly tied to students at a specific, content-informed level:

> I noticed that at one point when they [students] said that it's [the offspring] going to look like the male, and the teacher said 'for this one trait', so kind of redirecting them that, again, we are only talking about one gene when organisms have tons of genes.

As this excerpt elucidates, the PD-participant focused on a teaching action specifically linked to a content-specific issue—that is, how the teacher in the video responded to students after she had listened to their interpretation of the Western Blot data and realized that they needed to understand that they were discussing the phenotype of an organism for a particular gene.

Because such large percentages of participants' comments coded for "pedagogy" included attention to student ideas, I suspected that idea units coded as pedagogy might harbor incidences of teacher "attention to student thinking" (not captured under the code "student thinking"). Thus, each time I coded an idea unit as a) pedagogy explicitly tied to students or b) pedagogy explicitly tied to students at a specific, content-informed level, I also coded whether or not there was an explicit "reference to student thinking." A new, composite code was created by combining the positive instances of attending to student thinking (under the pedagogy code) and the separate student thinking code for which we reported the percentages related to idea units in Table 17. When I analyzed the extent to which the percentage of idea units related to the composite student-thinking code changed from baseline to exit interviews, I found a 12% increase for the inheritance interviews and a 5% decrease for the osmosis interviews.

To summarize, the findings of the first phase of the analysis for the first research question revealed some changes in terms of to whom and what PD-participants attended to in the video cases. Regarding what PD participants attended to in relation to *actor*, there was not any striking changes from baseline to exit interviews. The largest change in actor, common across the inheritance and osmosis interviews, was the decline in PD participants' attention to students as a whole.

The *topic of PD-participants' comments* surrounding what they attended to in the video cases was another thing in which no striking changes were observed at the general level in the first phase of the analysis. From the beginning, the majority of the comments were about student thinking and pedagogy, and attending to these issues increased even more in the exit interviews (with an exception of a slight decline in attention to student thinking in osmosis interviews). However, when I investigated in detail *what* they attended to about pedagogy and whether this changed from baseline to exit, some striking changes were found, particularly in the inheritance interviews. What PD-participants attended to related to pedagogy changed from baseline to exit such that in the exit interviews, half or more of their comments were about the teacher's actions explicitly tied to students at a specific, content informed level.

In what follows, I summarize the findings of the second phase of the analysis addressing the first research question. In the second phase of the analysis, I explored PD-participants' attention related to pedagogy and student thinking, two major topics that they attended to in the interviews. As shown below, the results of these analyses showed consistent patterns with the findings from the interview analysis.

4.1.2 Findings based on the second phase of the analysis

To augment the interview findings related to the first research question, I examined what PD-participants attended to in the video cases that they viewed in sessions 3 and 4. To do that, I identified the number and proportion of noticings related to student thinking, pedagogy, and other issues in each PD session. Table 19 provides the summary of the percentages of what participants' noticings were about in each PD session.

Table 19: What PD-Participants Attended to in the Video Cases in Sessions 3 and 4

	PD Session-3	PD Session-4
Topic		
• Pedagogy	(33) 70%	(26) 70%
• Student Thinking	(6) 13%	(4) 11%
• Other	(8) 17%	(7) 19%
Total	(47) 100%	(37) 100%

As Table 19 indicates, there is almost no change from session-3 to session-4 in what PD-participants attended to. The majority of their noticings (70%) were about pedagogy in the session-3 and this was exactly the same in the session-4. The percentages of noticings about student thinking and other issues were also quite similar in both of the sessions. However, further analysis indicated that there were some differences in the nature of participants' pedagogy-related remarks between session-3 and session-4. When I further examined what exactly changed about pedagogy-related comments, I found consistent patterns with the findings based on the first phase of the analysis. I identified the percentages of noticings that were categorized into each of the four pedagogy quadrants. Figure 7 shows the change of participants' pedagogy-related noticings in each quadrant from session-3 to session-4.

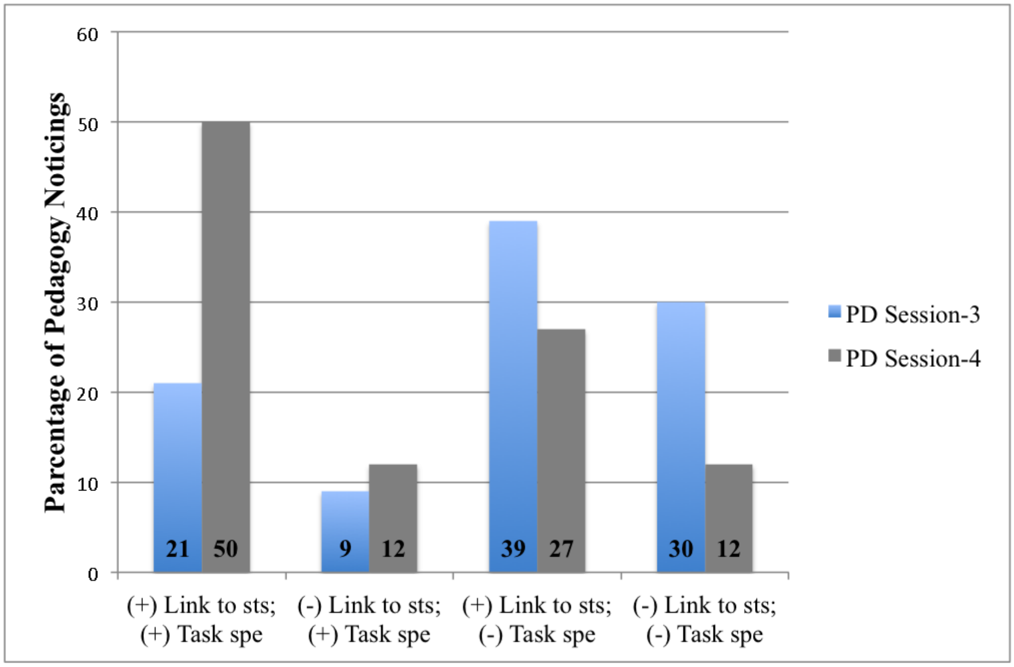


Figure 7: What PD-participants Attended to about Pedagogy in the PD sessions 3 and 4

As Figure 7 indicates, when pedagogy-related noticings were explored more deeply, it was found that there was actually a variation between session-3 and session-4 in terms of what PD-participants attended to in the video cases. The major change (an increase of 29%) was found in participants' pedagogy-related noticings in which they tied the teacher's actions to the students' ideas and actions and did so at a task-specific level (comments in quadrant-1). According to the one-tailed t-test analysis, this shift was statistically significant (t = 3.03, p < .05). The next major change was found in pedagogy-related remarks in which teachers' actions were neither tied to students' ideas or actions nor the content of the task or the practices that the students engaged in the task (comments in quadrant-4). While the percentages of such comments were 30% in session-3, it significantly dropped to 12% in session-4 (t = 2.44, p < .05). Closer to the magnitude of decline in pedagogy-related remarks in quadrant-4 was a 12% decline in participants' comments tied to students' ideas or actions at a non-task-specific level (comments in quadrant-3). Finally, there was a slight increase in pedagogy-related comments in quadrant-2. Figure 8 shows the general distribution of these pedagogy-related remarks across the four pedagogy quadrants in each PD session.

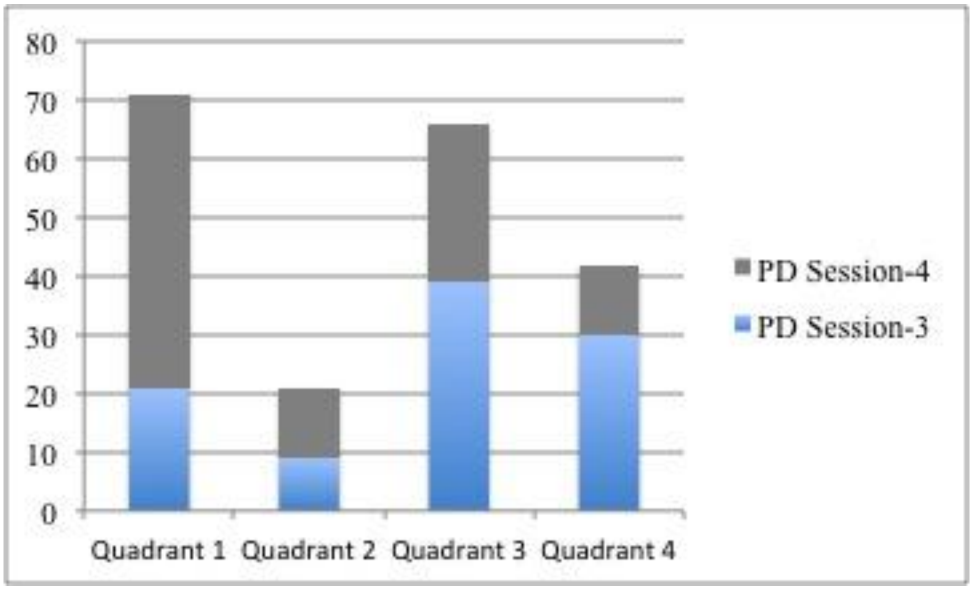


Figure 8: Distribution of Pedagogy-related Comments in Sessions 3 and 4

As shown in Figure 8, the majority of participants' pedagogy-related comments in session-4 were categorized into quadrant-1 (linked to students and task specific). Linda's comment in the following talk among the PD-participants in session-4 illustrates the nature of majority of the pedagogy-related conversations in session-4.

> **Linda:** I actually wrote that to eliminate confusion, she [the teacher] turned it into a Punnett square.
> **Nancy:** Yeah.
> **Linda:** These, those, combine. I was – a big difference, I don't know how to state this, I think I was just expanding on hers [referring to another PD participant], but I have two thoughts right now, that the first teacher kind of turned this totally into a Punnett square because there were a couple examples of this. The very first group did fertilization and didn't have alleles in their egg and sperm. She didn't make them pull them apart. She

made them add the alleles. … It went against that biological concept of the alleles don't come after or don't combine. So she didn't do the meiosis part. Second piece of evidence was once she started doing this and these with all those groups, she just kept saying, "How many combinations did you get? How many combinations did you get? How many combinations did you get?" Or, "How many combinations can you get?" And they were like, "Oh, let's do it. Okay, hurry up." And I even saw that one kid go, "Come on, let's roll with it," and he just started sticking stuff and they started combining. It was all about the combinations for her, how many combinations –
Co-Facilitator: Combinations not attached to the meaning
Linda: The biology
Co-Facilitator: The biological meaning
Linda: The meiosis that made them, the fertilization that's happening.

As this conversation illustrates, the conversation among the participants and the co-facilitator focused on the interaction of the teacher and students surrounding the task. There was close attention to how the students were positioned to work on the task through the teacher's facilitation and how they made sense of the task. Linda said the students were engaging in some procedures of the given task (e.g., sticking stuff to create the combinations) that had no connection to any biological sense making (e.g., only focusing on the number of combination, not focusing on the biological meaning such as fertilization, having alleles in egg and sperm). This is an important consideration to decide the level or type of student thinking in the classroom during the enactment of high-level tasks.

As I did with the pedagogy-related comments, I conducted further analysis with participants' noticings related to student thinking. I identified pedagogy-related comments in the first quadrant that involved attention to student thinking because noticings coded as pedagogy in the first quadrant might harbor incidences of participants' attention to student thinking. Four pedagogy-related comments in session-3 and eight pedagogy-related comments in session-4 involved attention to student thinking. When I combined these with the other noticings, which were originally coded as being related to student thinking, 21% of the noticings in the session-3 and 32% of the noticings in session-4 were related to student thinking. Thus, there was actually a moderate increase from session-3 to session-4 in participants' attention to student thinking (an increase of 11%).

To summarize, the second phase of the analysis revealed that the proportion of PD-participants' comments about student thinking increased from session-3 to session-4 but the proportion of comments about pedagogy did not change. However, when explored further, it was found that what participants attended to in the video cases about pedagogy (related to quadrant-1 and quadrant-4) changed significantly between session-3 and session-4. In session-4, participants' comments about the teacher's actions became more tied to students' ideas and actions. Comments were also more grounded in the content (or the practices) of the task. Clearly, this major change from session-3 to session-4 was very consistent with the findings based on the first phase of the analysis, which indicated that the proportion of comments about teacher actions that are explicitly tied to students at a specific, content informed level was higher in the exit interviews. Similarly, consistent findings were found in participants' pedagogy-related comments that were only about what the teacher did. In both sets of analysis, there was a significant decline in such comments. Finally, there was a general decline in comments in which PD-participants talked about the teachers' actions in relation to students' ideas or actions without grounding their comments to the content of the task. Only in the osmosis interviews was there a slight increase in such comments. These consistent patterns in the findings—particularly about pedagogy-related noticings—suggest that PD-participants learned to attend to pedagogy in different ways than they did before the Noticing-PD.

4.2 PATTERNS OF CHANGE IN PD-PARTICIPANTS' SENSE MAKING

Research Question-2:

In what ways did teachers' approach for making sense of what they attended to in the video cases change from the beginning to the end of the Noticing-PD?

4.2.1 Findings based on the first phase of the analysis

To address the second research question, I examined the *stance* participants took while analyzing the video cases during the interviews. The analysis also focused on whether participants referred to evidence from the video while talking about what they saw in the video case.

Table 20: PD-Participants' Stance While Analyzing Video Cases During the Interviews

	Inheritance Interviews		**Osmosis Interviews**	
	Baseline	Exit	Baseline	Exit
Stance				
Descriptive	(14) 33%	(6) 17%	(18) 36%	(13) 31%
Evaluative	(12) 29%	(3) %9	(13) 26%	(4) 10%
Interpretive	(16) 38%	(26) %74	(19) 38%	(25) 60%
Total	(42) 100%	(35) 100%	(50) 100%	(42) 100%

As shown in Table 20, participants' comments were fairly evenly distributed among descriptive, evaluative, and interpretive stances in the both inheritance and osmosis baseline interviews. Interestingly, unlike findings from earlier studies, in both the baseline inheritance and osmosis interviews 38% of participants' comments were coded as interpretive, slightly higher than the evaluative comments and the descriptive comments. In the exit interviews, however, the distribution of the descriptive, evaluative, and interpretive comments was different. Figure 9 shows the changes from baseline to exit interviews in the percentages of PD-participants' stance while talking about what they attended to in the video cases.

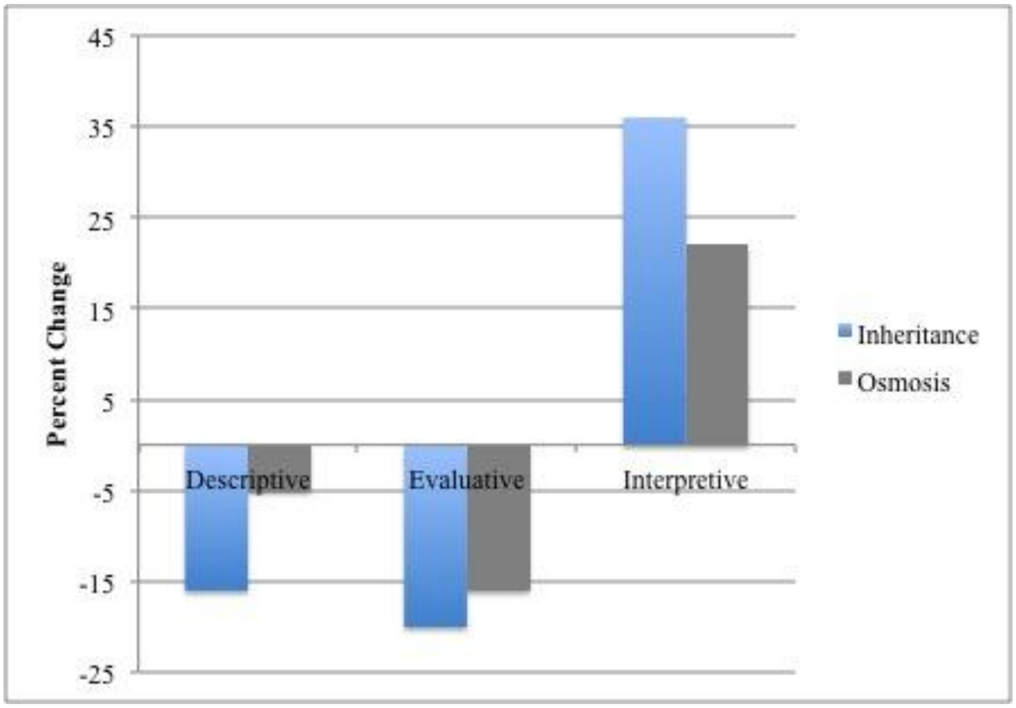


Figure 9: Change in PD-Participants' Stance from Baseline to Exit

As shown in the Figure 9, participants made fewer descriptive comments in both exit interviews. Moreover, there was a decline in participants' evaluative comments from baseline to exit, and this decline was found to be marginally significant in both the inheritance interviews ($t = 2.07$, $p < .10$) and the osmosis interviews ($t = 1.75$, $p < .10$). The following quote from a baseline interview with one of the PD-participants illustrates the nature of evaluative comments. She makes some explicit judgments about what was good about the teacher's actions.

> I thought it was really nice that when that one group was struggling, she said, she was really good with not—you want so bad to just correct them or tell them—and she just said 'okay, this is a good conclusion'.

In this evaluative comment, the PD-participant expressed that she found teacher's actions "good." She did <u>not,</u> however, explain her reasoning about why she found the teacher's actions "good."

In contrast, there was a marginally statistically significant increase from baseline to exit in the percentages of interpretive comments in the inheritance interviews ($t = 1.90$, $p < .10$) and a statistically significant increase in the percentages of interpretive comments in the osmosis interviews ($t = 4.54$, $p < .01$). The majority of the comments both in the exit osmosis and inheritance interview were categorized as reflecting PD participants' interpretive stance (74% in inheritance, 60% in osmosis). The following comment illustrates the nature of interpretive comments that were made by participants frequently in the exit interviews:

> … then she [the teacher] put back a question to them, 'Can you relate this to the genotypes you saw?', they were able to understand that the bottom part [the bottom of the worksheet that showed Western Blot data] . . . like why all those offspring looked – because it was because of the male, but they couldn't relate it back right away to the top part [the top of the worksheet that showed PCR data] until she asked them, can you relate this [Western Blot data] back to the genotypes that you saw [in the PCR data] and that got them all thinking again.

As this comment by one of the PD-participants' comments demonstrates, their interpretive remarks showed their intent to make sense of what was happening in the video case. In this comment, she first tried to understand which parts of the task students seemed to understand (i.e., interpreting Western Blot data) and then she reasoned about how the teacher's move influenced students' thinking.

I conducted further analysis on stance within comments coded as student thinking (i.e., the composite code). Despite not having found striking differences in overall attention to student thinking, I suspected that there might be significant changes in *the way* in which participants commented on students' thinking. Specifically, I expected that early on, participants would mostly take on an evaluative stance when commenting on student thinking, but during the exit interviews would mostly adopt an interpretive stance. The analysis indicated that there was a significant increase in participants' *interpretive* comments related to student thinking from baseline to exit interviews (t = 2.51, p < .05) (based on combined inheritance and osmosis interview data).[25] However, even though there was a decreasing trend in participants' evaluative comments about student thinking, this decline was not a statistically significant (t = .85, p > .05). Moreover, these findings also revealed a decline in participants' descriptive comments (a decline of 27%). Overall, it is possible to say that in the exit interviews when PD-participants talked about student thinking, there was a growing tendency to make interpretive remarks but a decreasing tendency to make evaluative and descriptive remarks.

Apart from the stance PD-participants adopted, the first phase of the analysis also examined change in participants' use of evidence from the video case in their comments. A significant increase from baseline to exit was expected in participants' comments that involved a reference to evidence from the video case. Although participants referred to the video as evidence in 26% of the comments in the baseline inheritance interviews, 34% of the comments in exit interviews involved evidence from the video case, a change that was not significant (t = 1.26, p > .05). On the other hand, evidence-based comments were marginally significantly higher in the exit osmosis interviews in comparison to baseline interviews (t = 2.05, p < .10). In short, even though there was a growing tendency among the PD-participants to refer to the video case

[25] Because there is a small number of student thinking comments, I was unable to conduct separate analysis for inheritance and osmosis interviews to examine the change in the stance participants adopted while they were commenting on student thinking. Thus, I merged two data sets to test for the statistical significance of the change.

as evidence of what they talked about, this shift was not statistically significant in the inheritance interviews.

4.2.2 Findings based on the second phase of the analysis

To augment the above findings from the interviews with information from the PD, I conducted a similar analysis on PD sessions 3 and 4 in the second phase of the analysis. I examined whether the PD participants took descriptive, evaluative, or interpretive stance in each PD-session while talking about what they attended to in the video case. Table 21 provides the summary of the percentages of participants' comments that were categorized into different categories of stance.

Table 21: Change in PD-participants' Stance from Session-3 to Session-4

	PD Session-3	**PD Session-4**	**Change**
Stance			
• Descriptive	(23) 49%	(8) 22%	(-) 27%
• Interpretive	(17) 36%	(28) 76%	40%
• Evaluative	(7) 15%	(1) 3%	(-) 12%
Total	(47) 100%	(37) 100%	

Table 21 reveals similar patterns to what was found in the interview analysis in terms of the change in participants' stance while analyzing what they attended to in the video cases. The largest change from session-3 to session-4 was found in the percentages of participants' interpretive comments (a increase of 40%). While 36% of noticings in session-3 were categorized as interpretive, this value increased to 76% in session-4. This change was found to be statistically significant (t = 4.69, p < .01). In addition, there was a large decline from session-3 to session-4 in descriptive comments (a decline of 27%). Moreover, as expected, there was a statistically significantly decline in participants' evaluative comments ($t = 3.06$, $p < .05$).

Analysis of the noticings in the PD sessions revealed that participants were sometimes trying to make sense of what they attended to in the video case to decide whether there was a high or low-level student thinking. They were reasoning about whether and why the level of student thinking changed during the enactment phase. The following conversation between one of the PD-participants and the facilitator during the PD session-4 illustrates participants' reasoning regarding the kind or level of student thinking in the classroom viewed in the video case. During this discussion in session-4, participants were sharing what they noticed in the video case that helped them to decide on whether there was high or low-level student thinking in the classroom (during the enactment phase of the task).

> **Linda:** I did level 1-A [one of the lowest levels in the TAGS]. I just said they [students] were repeating a procedure that she [the teacher] showed them. It's true 'cause she did go through and show them. She was like, yeah, stick that on there and tell me how many combinations or if they have their combinations, 'No, you only have one combination,' so then they start resticking them. So it was like, 'Oh, this procedure, I should have made all my different combinations.' I didn't know if there was any science content at that point for a lot of the groups.
> **Facilitator:** So, but you are saying that there is a procedure.
> **Linda:** There's some sort of procedure. She's telling them, 'You need one of these squares in each gamete.' I'm not even using those words, but you need one square to join with another square. That's the procedure.
> **Facilitator:** Okay. So you are saying that there is a procedure, but they do not understand the meaning behind the procedure.
> **Linda:** Yeah.

As shown in this example, Linda explained what she saw in the video case that led to her categorize the level of student thinking as 1A, which is one of the lowest levels of student thinking according to the TAGS Framework.

There were also instances when PD-participants commented explicitly on how the cognitive demand of the task changed during the task enactment. For example, one of the PD-participants made the following argument in session-4 while sharing her noticings about the contrasting video cases:

> I said both teachers were kind of lowering the cognitive demand through their implementation because even though they were asking kids questions, sometimes they would answer their own question or say, "What do you, look at this," you know, or direct them to the answer, point to how many alleles are in this gamete. You know what I mean? Like directly showing them the answer and the first one's actually doing for them.

As this participant's comment illustrated, while PD-participants were interpreting what they saw in the video case, their comments revealed their reasoning for why (or how) they thought the cognitive demand of the task was changed during the task enactment phase.

I compared session-3 and session-4 in terms of the proportion of interpretive comments that involved reasoning for maintenance or decline when PD-participants talked about pedagogy and student thinking. Four out of 17 interpretive comments in session-3 (24% of interpretive comments) and 11 out of 23 interpretive comments in session-4 (48% of interpretive comments) involved reasoning to decide whether there was a high or low-level student thinking in the video case. Therefore, there were more of the interpretive comments (which involved reasoning for maintenance or decline) in session-4 in comparison to session-3. Moreover, the analysis indicated that the majority of such comments (75%) were influenced by the facilitator's prompting in session-3. In contrast, only 18% of these interpretive comments were influenced by the facilitator's prompting in session-4. In other words, in session-4, PD-participants were able to reason more independently of the facilitator regarding whether and why there was a high or low-level student thinking in the video case.

PD analysis also revealed that participants started to identify factors associated with facilitating high and low-level student thinking during the task enactment phase. These factors were mostly related to the video teacher's pedagogical moves such as guiding, questioning, or scaffolding students' engagement in the task. Table 22 provides the summary of these factors that were identified by the PD-participants in sessions 3 and 4.

Table 22: Factors associated with High and Low-Level Student Thinking

	PD Session-3	PD Session-4
Maintenance	✓ Revoicing what students said and making them work through it ✓ Not telling students where to go but providing hints for not to go in the wrong direction	✓ Helping students make sense of the meaning behind procedures ✓ Making students work though the problem/task ✓ Using appropriate terminology while guiding students' engagement in procedures
Decline		✓ Focusing on procedures without connection to underlying biological meaning ✓ Nature of teacher's questioning ✓ Fast, non-elaborate implementation ✓ Providing knowledge instead of making students work through it ✓ No scientific practice to engage in

As Table 22 indicates, the majority of these factors were identified in session-4 during the discussions on the contrasting cases. For example, one of the PD-participants identified a factor associated with high-level student thinking while sharing what she noticed in the video case:

> But I also think in the second task, like in the last group that we watched, which is like line 46 there, 48. I know there are two alleles for each gene, so, I mean, is it separate two? And so she [the teacher] says, "Right, it could be black or white." But she's just helping clarify. But then she lets them go through that whole process of putting two and two. She doesn't tell them, "Just go ahead and try it." So I feel like that's not learning the task 'cause they're still having to work through it and figure out why they were wrong, whereas I feel like the first teacher would have just said, "No, _______." You know

> what I mean? So it’s a different process. I said for the second teacher video two, she redirected the students’ question back to them or tried to get them to work through it.

In this comment, the PD-participant shared what she saw as differences in the contrasting video cases in terms of the teacher’s facilitation of students’ learning. According to her comment, she considered “redirecting students’ questions back to them and making them work through it” as associated with maintaining high-level student thinking.

I also conducted additional analyses on stance within comments coded as student thinking (including the pedagogy comments that were coded as student thinking). I identified the proportion of comments that involved attention to students thinking and adopted an interpretive stance. The first phase of the analysis found a significant increase in participants’ interpretive comments related to student thinking from baseline to exit interviews. Similarly, PD analysis revealed an increase in participants’ comments that involved attention to student thinking and took an interpretive stance. While 70% of the comments that involved attention to student thinking were interpretive in session-3, all of the comments that involved attention to student thinking were interpretive in session-4. None of the comments about student thinking was evaluative in both of the sessions. Because the number of interpretive comments about student thinking was very low in the baseline interviews, I did not conduct a statistical analysis to test the significance of change from baseline to exit in participants’ interpretive stance while talking about the student thinking.

Finally, like in the first phase of the analysis, I examined whether participants referred to evidence from the video case while talking about what they saw in the video case. Analysis revealed a small decrease from session-3 to session-4 in the percentages of noticings that did not involve evidence from the video case (a decline of 5%) and a moderate increase in evidence-based noticings (an increase of 9%). In 9% of the noticings in session-4 and 5% of the noticings in session-4, evidence was provided by the context, which means that the participants continued to comment on the same instance that was referenced by another PD-participant or the facilitator. Evidence provided by the context did not apply to the interview analysis because the facilitator did not scaffold participants' noticing during the interviews. However, the direction of the findings regarding the use of evidence was consistent with the findings based on the interview analysis, which showed that there was a growing tendency among the PD-participants to refer to the video case as evidence of what they talked about in the exit interviews.

4.3 LEARNING TO RECOGNIZE EACH VIDEO CASE AS AN INSTANCE OF A LEVEL OF STUDENT THINKING

Research Question-3: To what extent did teachers learn to recognize video cases as an instance of a particular level or type of student thinking?

To assess the extent to which participants started to recognize each video case as an instance of a particular level or type of student thinking, I began by examining whether or not the participants identified the level of student thinking in the video cases as roughly "high" or "low" level. In 19 out of 20 interviews (both baseline and exit), participants correctly identified the level of thinking as "high." Even at baseline**,** the nature of the interview question (How would you describe the level and type of student thinking?) invites PD-participants to connect what they saw on the videotape to larger, more general ideas. Because they had not yet been introduced to the TAGS, participants in the baseline interview needed to rely on their own knowledge base for larger ideas with which to connect.

All participants (with one exception) called the level of student thinking “high”[26] in both of the video cases shown in the baseline and exit interviews. When pressed to provide a reason for identifying student thinking as high-level, they reached for a range of constructs or ideas. As shown in Table 23, all participants connected students’ actions with “thinking or sense making.” This covered a range of thinking processes including reasoning, making connections, and trying to deeply understand something. For example, after viewing the inheritance video one participant stated, "They’re [the students] trying to get those connections that I’d mentioned, those relationships, and it’s not—it only comes from you *thinking* (emphasis added) it through and interpreting data. It’s not like you can read it and highlight it."

Three participants talked about the students’ *engagement* with the task; however, engagement tended to be associated with the “look” of focused work without additional details regarding the kind of thinking students appeared to be doing. The *application* of what one knows to a new situation was another way of describing the high-level thinking in which they said students were engaging in the videos (n = 3 PD-participants). For example, while discussing the osmosis video, one participant said:

> Again, I think it's that application piece. I mean the first -- I'm trying to think of that tier you have, like your first tier of level of understanding is, you know, repetition or identification, and your second tier is maybe like applying or creating.

This participant went on to identify Bloom’s taxonomy as the framework she was using to describe what constitutes high-level thinking (One additional participant used Bloom’s taxonomy in the baseline interview as well.).

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[26] The interviewer asked the participants, “On a scale from 1-5 (with five being the highest) at what level would you place the level of student thinking going on in this video?”

Table 23: Ideas/Constructs Used to Describe High-Level Student Thinking

Idea/Construct	# of participants who cited this construct	
	Baseline	Exit
Recall of and building on prior knowledge	2	2
Student application of what they know	3	0
Student engagement (without mentioning anything about their thinking)	3	2
Student thinking or making sense of something	5	5
Defined in terms of what it is not or what is not happening	3	4
Some reference to scientific practices	0	5
Other	2	2

Three participants found it helpful to explain students' high-level thinking in terms of *what was <u>not</u> going on*. One participant stated, "High-level thinking requires more than just memorizing given information" while another said, "It's more than knowing a definition of a scientific concept but understanding it more deeply." The two participants who used constructs coded as *other* talked about high-level student thinking as encompassing a multitude of different skills and the level of thinking one needs to engage in in order to teach.

After the Noticing-PD, participants were expected to reach for and use ideas embedded in the TAGS to describe student high-level thinking. As shown in the final column in Table 23, all participants did refer to scientific practices in some way when describing students' levels of thinking. Two additional things are noteworthy about Table 23. First, participants' use of other constructs to describe high-level thinking lessened somewhat, but not entirely. In particular, participants still talked about *thinking* (in a general sense) as a key aspect of higher-level cognition and they still defined high-level thinking in terms of *what it is <u>not</u> or what did <u>not</u> happen.* Whereas the baseline descriptions of what high-level thinking tended to point toward memorization and definitions, the exit descriptions were different. They tended to point to what the teacher and/or task did not do that defined the work as high level. For example, several participants noted that the teacher did not provide extra help and that she made students do the thinking. One participant referred to the non-scripted nature of the instructional task:

> There is no set procedure. She [the teacher] is not telling every group to do the same thing, to come up with this answer. So that's another indicator [of high-level thinking] that they're not using some procedure that you have to use. You can get to this answer anyway that your brain is allowing you to get there.

Although all five PD-participants referred to scientific practices at some point in their description of high-level thinking, their use of the term did not reveal a fully developed understanding of scientific practice. Most common was the idea that doing scientific practices necessarily involved engaging in investigation or data analysis. For example, in discussing the osmosis task, one participant noted that there was no scientific practice going on because:

> They're not performing an experiment. They're not analyzing control groups versus experimental groups. They're not analyzing a graph or a data table. They're not observing a natural phenomenon. So I think anything that I would think of as a scientific practice, actually doing science is kind of missing from this.

Another PD-participant noted: "They weren't looking at data or looking at an analysis of the board before and after or something like that or looking at pictures of salt water concentrations or something. You know what I mean? They weren't looking at data." Similarly, another PD-participant commented regarding how the teacher in the osmosis video might include scientific practices in the lesson: "Afterwards she might say something like, 'Now I want you to find some materials and do this example like show me this example hands on in real life, full time.'" Finally, some participants incorrectly stated that the lack of engagement in scientific practices meant that a task could not be high level. This, however, is actually not the only requirement for high-level thinking in the TAGS.

4.4 SUMMARY OF THE FINDINGS

To conclude, the goal of the first and second phase of the analyses was to identify, at a detailed level, what (if any) changes occurred in PD-participants' noticings. Table 24 summarizes all the main findings in terms of the changes from the baseline to exit interviews and from PD session-3 to session-4.

Table 24: Summary of Findings from the First and Second Phase of Analyses

	Interviews				PD	
	Inheritance		Osmosis		Sessions	
Actor						
Particular Student	9%		4%		*NA*	
Students	(-) 24%		(-) 13%		*NA*	
Teacher	(-) 4%		2%		*NA*	
Students & Teacher	18%		7%		*NA*	
Topic						
Pedagogy	18%		14%		0%	
→ (+) Link to students; (+)Task specific	46%	**	15%	~	29%	*
→ (-) Link to students; (+) Task specific	*NA*		*NA*		3%	
→ (+) Link to students; (-) Task specific	(-) 6%		6%		(-) 12%	
→ (-) Link to students; (-) Task specific	(-) 40%	*	(-) 21%	*	(-) 18%	*
(Composite) student thinking	12%		(-) 5%		11%	
Other	(-) 14%		(-) 7%		2%	
Stance						
Evaluative	(-) 20%	~	(-) 16%	~	(-) 12%	*
Descriptive	(-) 16%		(-) 5%		(-) 27%	
Interpretive	36%	~	22%	**	40%	**
Use of evidence from the video case	8%		24%	~	9%	
Recognizing as an instance of a particular level/type of student thinking	A shift toward connecting the specifics of student thinking to the levels of thinking as outlined in the TAGS					

Note. ~ $p < .10$; * $p < .05$; ** $p < .01$

Addressing the first research question, analyses revealed that the majority of the topics on which participants focused fell under either student thinking or pedagogy. As Table 24 indicates, the major consistent changes across the two phases of the analysis were found in *what* PD-participants attended to related to pedagogy in the video cases. Overall, there was a significant shift in participants' pedagogy-related comments in which they tied the teacher's actions to the students' ideas and actions and they did so at a task-specific level. In contrast, there was a significant decline in pedagogy-related comments in which teachers' actions were tied to neither students' ideas or actions nor the content of the task or the practices in which the students engaged in the task. These findings suggest that PD-participants learned to attend to teachers' actions in the video case in a different way than they did before the Noticing-PD—that is, they attended to the interactions of the teacher with the students surrounding the task (*the instructional triangle* that was discussed in the literature review).

As shown in Table 24, both phases of the analysis for the second research question also revealed consistent findings. There was a significant increase in participants' interpretive comments as opposed to a significant decrease in evaluative comments and some decline in their descriptive comments. Moreover, further detailed analysis revealed that there was a change in *the way* in which participants commented on students' thinking. Specifically, both phase of the analysis indicated an increase in participants' *interpretive* comments related to student thinking. Therefore, the findings suggest that PD discussions can support teachers' learning to adopt an interpretive stance while talking about what they attended to in the video cases. Apart from that, analysis also revealed that there was a growing tendency among the PD-participants to refer to the video case as evidence of what they talked about.

Finally, to answer the last research question, I focused on PD-participants' answers to the question in the interviews about the level or type of student thinking in the video case. Analysis of their answers revealed that how they described what constitutes a high-level thinking changed from the beginning to the end of the Noticing-PD. They began to reach for and use ideas embedded in the TAGS Framework to describe the level or type of student thinking and TAGS provided them with a language to describe the level or kind of student thinking.

5.0 DISCUSSION AND CONCLUSIONS

This study focused on developing science teachers' professional vision. Members of a profession develop a *professional vision* that enables them to see and understand complex situations in particular ways (Goodwin, 1994; Sherin, 2001). Like Sherin and her colleagues (2011b), in this study I considered "noticing as professional vision in which teachers selectively attend to events that take place and then draw on their exiting knowledge to interpret these noticed events" (p. 80). Thus, I conducted detailed analyses of changes in science teachers' learning to notice through video-based professional development (the Noticing-PD).

In the Noticing-PD, teachers were shown video cases that illustrated complex classroom interactions during the enactments of cognitively demanding tasks in high school biology classrooms. Prior research has revealed the complexity of such interactions during the enactment of high-level tasks, in particular their tendency to unintentionally turn high-level, cognitively demanding tasks into classroom activities in which students simply reproduce previous knowledge without making sense of the disciplinary ideas (Doyle, 1983; Stein et al., 1996). Therefore, the video cases that were used in the Noticing-PD presented participants with examples of these kinds of classroom interactions that may enable them to develop their professional vision to see and understand teacher-student interactions in particular ways.

I investigated the development of teachers' professional vision by focusing on two sub-processes of professional vision: selective attention and knowledge-based reasoning (Sherin, 2001). To answer the first research question, I investigated what changes occurred in ***what PD-participants attended to in the video cases***. Previous research has demonstrated consistent patterns regarding what teachers notice in general when they analyze video clips of classroom instruction. Teachers generally attend to issues related to pedagogy (i.e., teacher's decisions and actions and the teaching strategies used), climate (i.e., classroom atmosphere and the way in which students and the teacher interacts), and classroom management instead of the disciplinary ideas discussed by the students (Colestock & Sherin, 2009; Sherin & van Es, 2005; Sherin & Han, 2004).

In contrast to the majority of prior research findings, the first phase of this analysis indicated that PD-participants' comments were mostly about student thinking and pedagogy even before professional development started (during the baseline interviews). Only a very small proportion of their comments during the baseline interviews involved issues such as classroom management or climate. During the exit interviews, the majority of teachers' comments were still about pedagogy and student thinking. Participants' attention to pedagogy increased even more in comparison to baseline interviews. Their focus on pedagogy in the video cases was also more prevalent during the PD-sessions. The second phase of the analysis revealed that during the third and the fourth PD sessions, the majority of their comments were about pedagogy (70% in each of the sessions).

On the other hand, detailed analysis regarding *what about pedagogy participants attended to in the video cases* revealed some interesting patterns of change in both phases of analysis. In the baseline interviews, participants' comments about pedagogy varied. Some of the pedagogy-related comments in the baseline interviews involved attention *only* to what the teacher does. Such pedagogy comments were independent of the students and just focused on the teacher. This is consistent with van Es (2011)'s findings, which showed that in the beginning of the professional development meetings, teachers often referred to pedagogy at a very general level and the issues that they raised about pedagogy were generally not grounded in or informed by student thinking. My analysis revealed a large decline in such remarks by the participants in both sets of interview analysis as well as the PD sessions. None of the teachers' comments in the exit inheritance interviews were simply about what the teacher does and this decline was statistically significant. Only 9% of their comments in exit osmosis interviews involved solely attending to the teacher's actions that were not linked to students. Similarly, participants' pedagogy-related comments that were categorized into pedagogy quadrant-4 (no link to students; not task specific) were only 12% in PD session-4.

On the contrary, there was a significant increase in participants' pedagogy-related comments that were grounded in the content (or the scientific practices) of the task and that were tightly linked to students' ideas and actions. This shift in such comments is consistent with the findings of Sherin and Han (2004), which showed that video club participants started to examine pedagogical issues in terms of students' thinking instead of talking about pedagogical techniques independent of students' understandings. This study further elaborates on the findings of Sherin and Han (2004) by refining the nature of comments that examine pedagogical issues. In the second phase of the analysis, participants' pedagogy-related comments were analyzed in terms of their tie to the content (or the scientific practices) of the task as well as students' ideas and actions.

Seventy-nine percent of the pedagogy-related comments in the inheritance exit interviews and half of them in osmosis exit interviews involved talking about teacher's actions in relation to students' ideas and actions *at a content-specific level*. Similarly, half of the pedagogy-related comments in session-4 were categorized into the first pedagogy quadrant (link to students; task specific). These findings suggested that participants were shifting their understanding of pedagogy from a solo act to a view of teaching as the “assistance-of-student-learning” (Tharp & Gallimore, 1988). According to these findings, Noticing-PD may advance participants’ attention to what the students said or did while engaging in the science task to make sense of the scientific ideas, and how the teacher responded to students’ ideas or actions to advance their understanding. In other words, participants’ pedagogy-related comments became more about the interaction of the teacher with the students surrounding the task (Cohen & Ball, 1999; 2000).

To examine the development of teachers’ professional vision, the second sub-process of professional vision that I explored was their knowledge-based reasoning (Sherin, 2001). To answer the second research question, I investigated what changes occurred in ***PD-participants’ stance*** as they talked about what they attended to in the video cases. In both the first and the second phase of the analysis, I investigated whether PD-participants adopted a descriptive, evaluative, or interpretive stance during their analysis of the video cases. There is strong evidence in the literature that how teachers analyze what they saw in the video cases can become more interpretive and evidence-based because of professional development efforts (Sherin & Han, 2004; Sherin & van Es, 2005; van Es & Sherin, 2002). Results of the current study echo these findings. Across the analysis of the PD sessions and the interviews, there was consistently a significant increase in participants’ interpretive comments. It is indicated in the literature that it is important for teachers to develop an interpretive stance, which means that they analyze a teaching situation for the purpose of making sense of what happened (Hammer, 2000; Putnam & Borko, 2000; van Es & Sherin, 2002). These findings suggest that Noticing-PD was effective in supporting participants’ adopting an interpretive stance. Moreover, even though it was not a striking shift, there was a growing tendency among the PD-participants to refer to the video case as evidence of what they noticed.

In the current study, it is important to recall that the teachers developed an interpretive stance to make sense of particular kinds of classroom interactions, those in which cognitively demanding tasks were enacted in science classrooms and in which teachers were instrumental in maintaining or declining the cognitive demand of the high-level tasks. Adopting an interpretive stance could support PD-participants' understanding of the extent to which the students make sense of the task and the ways in which the teacher facilitated their sense making. By engaging in such reasoning, PD-participants learned how to determine the extent to which the cognitive demand of high-level tasks were maintained in the video cases. In fact, analysis of the PD sessions revealed that about half of participants' interpretive comments in session-4 involved reasoning for maintenance or decline of the cognitive demand. These findings suggest that Noticing-PD may be be instrumental in facilitating PD-participants' reasoning about the level or type of student thinking, and also the teacher's role in maintenance or decline of the cognitive demand as they were viewing and discussing video cases.

The findings, overall, did not reveal prominent increases in the quantity of participants' comments about student thinking. This is not consistent with the findings of previous studies on teacher noticing (e.g., Sherin & Han, 2004; Sherin & van Es, 2005). However, I found consistent results with Levin and Richards' (2011) study of teacher attention. They found that teacher candidates in a graduate-level science teacher preparation course were able to attend to students' ideas and understandings from the beginning. However, after the course there were differences in the nature of candidates' talk related to student thinking. Similar to the findings of current study, Levin and Richards (2011) found that the candidates were trying to make sense of students' ideas during the exit interviews. Similarly, Sherin and Han (2004) found that in the early professional development sessions, the majority of the discussions about the students' thinking involved simply restating what students said. However, in the later sessions teachers started to analyze the meaning of students' comments and began to make generalizations and syntheses of students' thinking. Similarly, participants' comments about students thinking in the current study were both descriptive and interpretive in session-3. However, all of such comments in session-4 were interpretive.

Finally, to address the last research question, I investigated ***the extent to which PD-participants could recognize each video case as representing a particular level or type of student thinking***. This research question is directly linked to a particular aspect of noticing: making connections between the specifics of classroom interactions and the broader principles of teaching and learning they represent (van Es & Sherin, 2002; 2008). Making connections between specific events and broader principles of teaching and learning has been considered part of teachers' reasoning processes (Sherin, 2007a). In this study, the TAGS Framework was used to facilitate teachers' making connections between the specifics of what they noticed in the video cases to the larger set of ideas about students' thinking as represented in the TAGS. As Goodwin (1994) would say, TAGS functioned as a "coding scheme" to analyze the events in the video cases; it helped to "transform phenomena observed in a specific setting into objects of knowledge that animate the discourse of a profession" (p. 606).

Using the levels of student thinking that are described in TAGS framework to identify the level or kind of student thinking based on what was noticed in the video cases was one of the goals of the Noticing-PD. Thus, I investigated the extent to which PD-participants learned to identify each video case as representing a particular level or type of thinking as represented in the TAGS. Before the TAGS framework was introduced, participants' descriptions regarding what constitutes high-level thinking were diverse. After being introduced to the TAGS, they began to reach for and use ideas embedded in the TAGS, such as students' engagement in some set of procedures without really understanding the disciplinary ideas, students' engagement in particular scientific practices, and the amount of scaffolding provided to the students through the task or the teacher. However, participants were not always able to successfully articulate the connection between what they see in the video case and the big ideas related to the level or type of student thinking presented in the TAGS framework. This may be because they had not developed a full understanding of the features of the TAGS framework (i.e., what the scientific practices are, what constitutes procedures in a task, what it means for students to meaningfully engage in the procedures of the task).

5.1 IMPLICATIONS FOR PRACTICE: DESIGNING EFFECTIVE PROFESSIONAL DEVELOPMENT PROGRAMS

As the interpretation of the findings reveal, this study provides a comprehensive explanation about the changes in PD-participants' selective attention and knowledge-based reasoning from the beginning to the end of the Noticing-PD. The findings also provide some insight into what aspects of the Noticing-PD may have influenced these changes in teachers' noticing. The analyses were focused on specific PD sessions in which participants were deliberately engaged in particular activities to facilitate their noticing classroom interactions during the enactment of high-level tasks presented in the video cases. Findings of the study suggest that some of the design features of the Noticing-PD may have shaped what teachers paid attention to and how they made sense of what they saw in the video cases. Future professional development designs could incorporate these features to support teachers' learning to notice from the video cases.

To start with, the change in the nature of PD-participants' pedagogy-related comments may be associated with the unique features of the Noticing-PD in comparison to previous video club designs. Focusing participants' attention on classroom interactions during students' engagement with cognitively demanding tasks and expecting them to decide whether the cognitive demand was maintained or declined during the enactment may have shaped participants' view of the video cases. In particular, at the end of the discussions about each video case, participants were asked to identify the level or type of student thinking that was going on in the video case. In other words, they were asked to decide whether the cognitive demand of a high-level task was maintained or declined during the enactment of the task. Making this decision requires PD-participants to attend to the ways students interact with the ideas and scientific practices required by the task through the facilitation of the teacher (e.g., what students say or do surrounding the task in response to what the teacher said, what kind of questions students asked to the teacher about the task and how the teacher responded to these questions). Ultimately, it is this interaction of the task by the teacher and students that is critical for engaging students at high-level thinking and reasoning about the subject matter. The increase in PD-participants' comments tied to students' ideas and actions *and* grounded in the task suggests that Noticing-PD supports teachers' learning to recognize the teacher as part of this interaction.

The second phase of the analysis revealed that PD-participants' interpretive comments involved reasoning about the maintenance or decline of high-level student thinking during the enactment of the task. There were more of the interpretive comments (which involved reasoning for maintenance or decline) in session-4 in comparison to session-3. Moreover, while the majority of such comments (75%) were influenced by the facilitator's prompting in session-3, session-4 PD-participants were able to reason more independent of the facilitator regarding whether and why there was high or low-level student thinking in the video case. This may be associated with the way their view of the video cases was set up in session-4. In the beginning of the session, PD-participants were introduced to the key idea behind the mathematical task framework—that is, that tasks can change in their level of cognitive demand as they pass from written materials to how they are set up by the teacher in the classroom to how they are actually enacted or carried out by the students (Stein et al., 1996). Right after this introduction of the "journey of a task," participants were asked to view contrasting video cases. Knowing the possibility of decline in cognitive demand while viewing these two video cases may have facilitated PD-participants' reasoning about the maintenance or decline in the video cases without needing to be prompted by the facilitator.

Another feature of the Noticing-PD that may have supported the findings was the use of the contrasting cases. As mentioned earlier, Noticing-PD was unique in that it focused PD-participants on a particular type of classroom environment, one in which cognitively demanding tasks were enacted. In such classroom environments, maintaining the level of student thinking demanded by a cognitively demanding task is found to be challenging and mostly associated with the teacher's instructional guidance (Stein et al., 1996). Thus, one of the reasons that I used contrasting cases was to reveal factors that are associated with maintaining or declining cognitive demand of high-level tasks during their enactment. Participants' discussion of the contrasting cases was designed to help them to uncover these factors. As anticipated, in session-4 PD-participants identified various factors that they thought were related to why there was a high-level thinking in one of the video cases but the opposite in the second one. These factors were mostly related to the video teacher's pedagogical moves such as guiding, questioning, or scaffolding students' engagement in the task.

Teachers' view of the contrasting cases in session-4 had a second purpose: to support teachers' learning to differentiate between the level or type of student thinking associated with level-2A and level-4 as presented in the TAGS Framework. What separates level-4 from level-2A is the students' meaning-making dimension. The level of student thinking in the classroom should be categorized at level-2A when students engage in the task by following the procedures for the scientific practice without really understanding the content. Students engage in a set of actions because they were told to do so, mostly by the teacher. In session-4, PD-participants identified "helping students make sense of the meaning behind procedures" as a factor related to high-level student thinking and "focusing on procedures without connection to underlying biological meaning" as another factor related to low-level student thinking. PD participants' recognition of these factors implies that session-4 was influential in helping teachers to see the importance of "meaning making" to the identification of whether or not students are engaging at a high level thinking. For example, one the video cases in the Noticing-PD showed students' engagement in a simulation task. They were modeling producing offspring geckos by using rules of Mendelian Inheritance. After viewing the video case (in which the cognitive demand declined) one of the PD-participants said:

> She [the teacher] is like 'Okay, take allele out and say combination and then take the gene out [teacher did not facilitate the use of appropriate terminology]… Yeah, she removed the biology from it. At the end, they [students] weren't even making geckos. They were making combinations.

This comment shows that the PD-participant was attending to how the teacher-guided students' engagement in the simulation task and how this was consequential for the way students engaged in the task. According to what she noticed, students ended up following teacher-given procedures without really making sense of their underlying biological meaning. Such comments were also generally coded as pedagogy in the first quadrant that is linked to students' ideas and actions and grounded in the task. Therefore, it can be argued that PD-participants' learning to talk about pedagogy in different ways may be associated with their experiences surrounding the use of contrasting video cases in the Noticing-PD.

Last but not least, participants' experiences in the Noticing-PD were grounded very tightly in their actual practice in the classroom. As Zhang and his colleagues (2011) underscored, relevance to teachers' instructional practices is an important factor that influences the usefulness of a video case. In the Noticing-PD, participants viewed video cases of enactments of cognitively demanding tasks that they used in their own classrooms. As mentioned earlier, Noticing-PD sessions were conducted during teachers' implementation of the Design Unit in their own classrooms. The video cases were selected from prior implementations of the tasks in the Design Unit in different high school science classrooms. In that respect, what PD-participants viewed and discussed about in the video case paralleled what they would experience or had recently experienced in their own classrooms. Moreover, as recommended in the literature, the Noticing-PD was content-specific (Kennedy, 1999; Scher & O'Reilly, 2009). The artifacts of practice used in the PD (i.e., instructional tasks and video clips of classroom instruction) helped to focus discussions on biology concepts and ideas that PD-participants deal with each day in the context of their own classroom settings with their students.

5.2 LIMITATIONS AND IMPLICATIONS FOR FUTURE RESEARCH

The study has some limitations, most of which shed light on recommendations for future research. To start with, even though the findings of the study allowed me to develop a set of propositions regarding the design features of the intervention that may have shaped what teachers noticed, I was not able to make causal claims for why these changes happened. Thus, future research should aim to test these propositions through more rigorous research designs to examine the extent to which the conjectured features of the Noticing-PD are effective in supporting teachers' learning to notice classroom interactions during the enactment of high-level tasks in new ways.

It is important to consider the participants of the study while interpreting the findings. As mentioned earlier, participants of the Noticing-PD were composed of teachers who had previously been exposed to student-centered approaches to teaching and learning science. Some of them had some prior experience with teaching innovative biology units such as the Mendelian Inheritance Unit that involves the use of project-based activities in which students are positioned as the active participants of the teaching and learning process. Some of them work in a school system in which project-based science teaching and learning is encouraged. Therefore, they may have been especially well-suited for professional development that focused on noticing in high-cognitive demand classrooms in which both teachers and students play important, interconnected roles. They might have had some expertise in noticing important features of classroom interactions during the instruction that involves using student-centered activities some of which could potentially be designed at high cognitive demand levels.

There were also some caveats that are important to point out regarding the analysis of the interview and professional development data. First, one was about the categories within the actor dimension. According to the first phase of the analysis, there was a slight increase in the percentages of participants' comments that focused on particular students. I had hoped that this increase would be more pronounced because, as noted in prior studies, it is important that teachers learn to recognize the class as a set of individual students (van Es, 2011). This is important because teachers who could attend to the understanding of individual students were able to differentiate instruction in a way that all students are challenged and supported (Jacobs et al., 2007). It is important to be cautious during the interpretation of my findings because some of the participants' comments that were coded for "teacher and students" under actor did not differentiate whether it was "particular students" or "students in general." In other words, participants' comments that were coded as "teacher and students" might have harbored incidences of "attention to particular students" and thus my findings may underestimate teachers' attention to particular students.

The second caveat regarding the data analysis is about the pedagogy-related sub-codes that were used in the first and the second phase of the analysis. As mentioned earlier, the pedagogy quadrant that was used in the second phase of the analysis is a *refinement* of pedagogy-related sub-codes that were used in the first phase of the analysis. Definitions of these categories indicate that comments categorized into quadrant-1 would be very similar to the comments categorized as "pedagogy explicitly tied to students at a specific, content-informed level" in the interview analysis. Pedagogy comments coded as "pedagogy explicitly tied to students, but at a general, non-content-specific level" in the interview analysis would be very similar to the quadrant-3 comments. Lastly, quadrant-1 comments would be very similar to "pedagogy not explicitly tied to students." Quadrant-2 comments were not considered as a separate category in the first phase of the analysis. Such comments might have been categorized into any of the other three categories during the first phase of the analysis. However, because the pedagogy sub-categories emerged through the analysis of the interview data, not having a category like quadrant-2 during the analysis of the interviews indicates that the frequency of such comments was small in the interviews and so they were not recognized during the analysis. Having only a few comments in the PD-sessions categorized into quadrant-2 is also consistent with the rarity of such pedagogy-related remarks in the interviews.

The first phase of the analysis revealed some differences between the interviews that were conducted with two different video cases. In the initial design of the study, the main purpose of using the osmosis video case in addition to the inheritance video case during the baseline and exit interviews was to interview PD-participants about a task from a biology topic different from Mendelian Inheritance. By doing so, I was able to examine whether the Noticing-PD was effective in developing their ability to notice significant features of a classroom, which involves enactment of a high-level task, independent of the topic that was covered in the classrooms viewed during the Noticing-PD. While identifying the video case that would be used in the interviews, I mainly focused on the enactment of a cognitively demanding task in a high school biology classroom. However, the findings of the study revealed that the two video cases present different types of classroom interaction during the enactment of a high-level task. According to the first phase of the analysis, there were mostly consistent trends in terms of the changes from baseline to exit interviews in what PD-participants attended to and how they made sense of what they attended to in both types of video cases. However, some of the changes in pedagogy-related comments were larger with the inheritance video case. I conjecture that the *nature of the task* that is enacted in the classroom creates differences in the way that the teacher and students interact surrounding the task (see Stein & Kim, 2009, for a discussion of how “doing mathematics” tasks open up the discourse space in ways that are very different from “procedures-with-connections-to-meaning” tasks). For example, the osmosis video case was not as rich as the inheritance video case in terms of how the teacher facilitated particular students’ understanding of the scientific ideas that the task requires students to engage in. The video depicted a whole class discussion during which the teacher in the video case was repeating similar teaching moves to facilitate a whole-class discussion, such as constantly asking student “why.” On the other hand, this video case mostly made students’ thinking available to notice. Further research should explore how the affordances of the task might influence differences in the video case in terms of what participants were able to attend to regarding the classroom interactions during the enactment of instructional tasks.

The ultimate goal of professional development programs is to change teachers’ instructional practices. That being said, this study did not explore the effects of teachers’ learning to notice on their instructional practice. However, the findings are promising in that teachers identified a set of factors that are associated with maintaining or declining the cognitive demand of high-level tasks during their enactment. Discussions of the video cases generally involved consideration of what specific teacher practice facilitated high-level student thinking. According to Mason (2002; 2011), possible actions can be accumulated through noticing other people or yourself doing them so that one can remember these actions in a particular situation. In that respect, PD-participants recognizing the factors that are associated with maintenance and decline is a promising finding of this study. Considering Mason’s claim, it is possible to argue that identifying these factors in their analysis of the video cases could support PD-participants’ future actions that are necessary for maintaining high-level thinking during the enactment of cognitively demanding tasks in their own classrooms. Future research should investigate whether PD-participants' identification of these factors influenced their own instructional practices in their own classroom in terms of maintaining or declining high-level student thinking. Specifically, future research should explore whether the PD-participants employed the factors that they identified during the Noticing-PD in their own instructional practices as they were enacting similar cognitively demanding tasks analyzed in the Noticing-PD. An important question for future research concerns the extent to which PD-participants who were able to identify the factors of maintenance and decline and who learned to attend to pedagogy in quadrant-1 (linked to students and task specific) are able to maintain the cognitive demand of high-level tasks in their own classrooms.

The TAGS framework was central in the Noticing-PD in terms of guiding PD-participants identification of the level or type of students thinking in the video cases. It provided scaffolding for the teachers' interpretation of what they attended to in the video cases. However, it also demanded learning. For example, to identify the level of student thinking, PD-participants needed to identify the scientific practices in which students engaged in the classroom. However, they often struggled with identifying the scientific practices that the students were exposed to in the task. Recent work on teachers' analysis of the cognitive demand of instructional tasks as they appear in the written materials showed that teachers struggle with identifying the scientific practices in an instructional task. Consequently, this creates challenges in their identifying the levels of cognitive demand as presented in the TAGS (Tekkumru Kisa, Stein, & Schunn, 2013). The same struggle was also observed during the discussions about the PD-participants' analysis of the level or type of student thinking in the video cases. Moreover, teachers also grappled with some of the language used in the TAGS framework, such as "scripted procedures." Thus, even though PD-participants started to reach for and use ideas embedded in the TAGS framework to recognize each video case as an instance of a particular level or type of student thinking, their reasoning was not fully developed. Future work regarding the development and use of TAGS framework in research and practice (e.g., professional development programs) should focus on the improvement of the clarity of the language used in the TAGS framework to help to distinguish the hallmarks of the cognitive demand levels (Tekkumru Kisa et al., in preparation).

In addition to the role of the TAGS framework in facilitating PD-participants' view and analysis of the video cases, the *transcripts* of the video cases played a different role during the PD-discussions. Right after viewing the video case in each PD-session (as well as the interviews), teachers were handed transcripts of the video cases. During the discussions, transcripts became an important tool. Teachers were frequently pointing out particular instances in the transcripts that they noticed in the video case. Sometimes, they were reading to remind themselves what happened during a particular instance. Like van Es and Sherin (2006), I believe that future research should investigate the role of transcripts in teachers' analysis of the classroom interactions that they viewed in the video cases. For example, Rosaen and his colleagues (2008) compared video-based reflection and memory-based written reflection on teaching and found that video-based reflection supported teachers in providing more specific comments about their teaching. I consider transcripts as an additional memory support within the contexts in which video is used to discuss instruction. Future research should examine the ways in which transcripts support teachers' learning from the video cases.

5.3 CONCLUSIONS AND CONTRIBUTIONS TO CURRENT KNOWLEDGE BASE

This study provides evidence for developing science teachers' professional vision of classroom events that happen during the enactment of cognitively demanding science tasks. Teachers who participated in the Noticing-PD started to attend to noteworthy classroom interactions during the enactment of high-level tasks in new ways and their stance in analyzing these events became more oriented towards sense making.

These findings contribute to the current knowledge base on teacher learning in several ways. First, this study combines two important bodies of research: teachers' learning to notice and the enactment of cognitively demanding tasks in the classroom, and, in so doing, extends each, both of which are grounded in the mathematics education literature. In particular, the study provides evidence that video-based professional development can be effective in directing teachers' attention to aspects of the classroom environments (e.g., pedagogy in response to student thinking) that often conspire to lower the demands of cognitively complex tasks.

I started my argument about the goal of this study by using Goodwin's (1994) discussion about the jury trail of Rodney King to illustrate how members of a profession (in this case, the police) were able to see and understand the actions of both police officers and Rodney King (as recorded on a videotape of the beating) through a common, professionally trained, perceptional lens. In that case, analysis by expert police officers focused on whether or not King's body movements in the videotape should be coded as aggressive or cooperative and how the police officers responded to him. Along similar lines, this study showed that PD-participants' expertise in analyzing *teaching* during the enactment of cognitively demanding tasks changed. Like the expert who was able to see and make sense of the actions of both police officers and Rodney King, PD-participants attended to and reasoned about the actions of the students and the teacher in the video cases. They started to attend to teacher's actions in different ways and began to interpret what they saw in the video cases. In other words, their professional vision of classroom environments in which teacher orchestrates students' engagement with cognitively challenging tasks changed.

The study introduced a new "coding scheme" (Goodwin, 1994) that can be used to facilitate teachers' learning to notice important classroom interactions in science classrooms. By using the TAGS framework to orient teachers' noticing during the professional development, this study demonstrates a more guided approach than has been used in most studies of teachers' noticing. Moreover, the TAGS framework allowed more systematicity in the selection of the video cases that would be used in the professional development. In this study, the video clips were specifically selected to show a cognitively demanding task unfolding during a science lesson by using the TAGS framework to differentiate the level or type of student thinking during the enactment of instructional tasks.

Finally, once again applying Goodwin's example to science teachers' professional vision suggests one additional contribution of this study. Goodwin's archeologist and farmer most likely had clear ideas of *what they were looking for* before actually observing the spot of sand. The archeologist might be looking for remnants from an ancient ruin, while the farmer for the type of the soil or the nutrient profile of the soil for growing good plants. Following this logic, I argue that developing teachers' professional vision demands specification of what teachers should be looking for. In my study, teachers were looking for teacher-student interactions that occur in a particular type of classroom environment, one in which high-level tasks are enacted. Because of this, I was able to support them to be prepared to look for specific things during the enactment of high-level tasks, things that past research suggests are critical. When teachers are committed to students learning to think and reason in cognitively rich ways in their own classrooms, the teacher can now ask themselves: “Am I paying attention to students’ following the right procedure or making sense of the ideas?” “Am I automatically answering any question that students ask when they struggle or am I providing the right amount of support so that the actual thinking remains the responsibility of the student?” “Am I prompting students to make sure they are moving towards making sense of the disciplinary ideas without being more directive?” “What do students mean when they say the offspring will look like the male and, if needed, how can I ask the right question to challenge their thinking?” These are all important factors that cause either the maintenance or decline of high-level tasks during their enactment.

APPENDIX A

TASK ANALYSIS GUIDE IN SCIENCE (TAGS)

LOW-LEVEL TASKS

Level-1: Memorization

Scientific Practices without Science Content

SCIENTIFIC PRACTICES

- Does not require engagement in scientific practice to make conceptual links with the science concepts and ideas.
- Requires memorization of the definition of any scientific practice.
- Involves repeating previously learned steps of a "scientific method"
- Requires "memorizing the doing science"

Examples

1. *Students are required to define what a model means and describe why it is used.*
2. *Students are required to memorize the definition of what hypothesis means, and they are asked to write one or two hypothesis using "if...then" statement.*

Science Content without Scientific Practices

SCIENCE CONTENT

- Does not require engagement in the scientific practices by which body of science knowledge is established, extended, refined or revised.
- Involves reproducing previously learned "body of knowledge" or committing facts, formulas, and definitions to memory.
- Although it involves reproducing previously learned "body of knowledge", task does not require conceptual understanding.

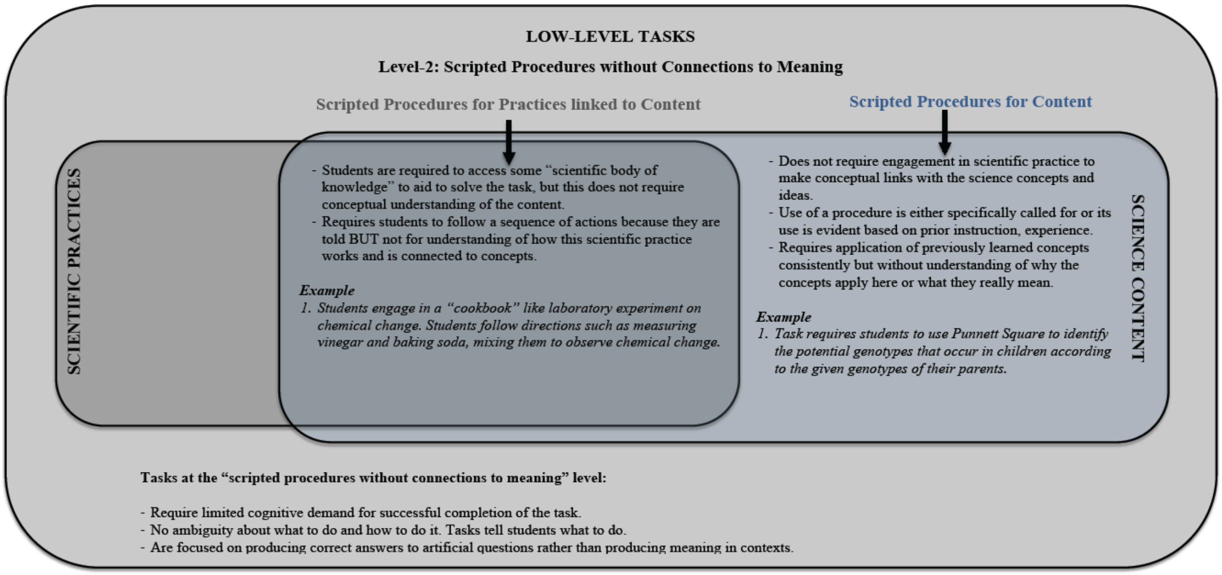
Examples

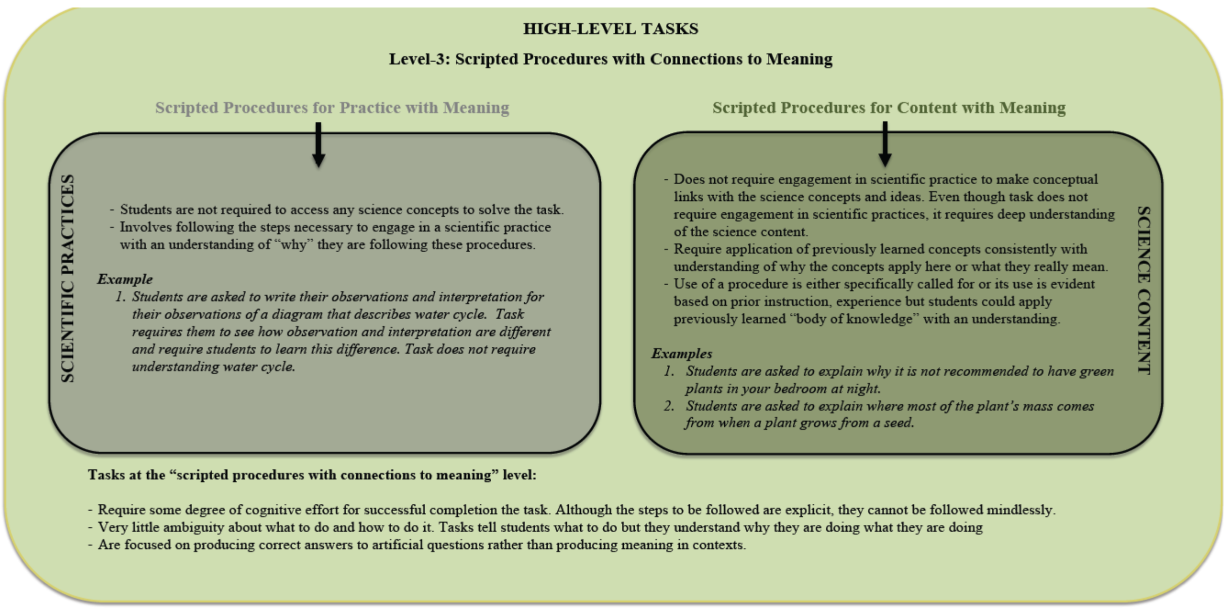
1. *Students are asked to write the differences between plant and animal cell.*
2. *Students are asked to draw arrows on the diagram of a eukaryotic plant cell matching the organelle to its appropriate name using the given list of organelles.*

Tasks at the "memorization" level:

- Are not ambiguous: Such tasks involve exact reproduction of previously seen materials and what is to be produced is clearly and directly stated.
- Cannot be solved using procedures[1] because a procedure does not exist or because time frame is too short to use a procedure.

[1] Procedure is a sequence of actions to take or similar steps to follow. Procedure involves repeating a same course of action to produce the right answer. Engaging in scientific practice may involve following a set of procedures. Similarly, science content can be presented with a sequence of procedures that can be used to produce the right answer.


LOW-LEVEL TASKS
Level-2: Scripted Procedures without Connections to Meaning
Scripted Procedures for Practices linked to Content
Scripted Procedures for Content
SCIENTIFIC PRACTICES
- Students are required to access some "scientific body of knowledge" to aid to solve the task, but this does not require conceptual understanding of the content.
- Requires students to follow a sequence of actions because they are told BUT not for understanding of how this scientific practice works and is connected to concepts.
Example
1. Students engage in a "cookbook" like laboratory experiment on chemical change. Students follow directions such as measuring vinegar and baking soda, mixing them to observe chemical change.
- Does not require engagement in scientific practice to make conceptual links with the science concepts and ideas.
- Use of a procedure is either specifically called for or its use is evident based on prior instruction, experience.
- Requires application of previously learned concepts consistently but without understanding of why the concepts apply here or what they really mean.
Example
1. Task requires students to use Punnett Square to identify the potential genotypes that occur in children according to the given genotypes of their parents.
SCIENCE CONTENT
Tasks at the "scripted procedures without connections to meaning" level:
- Require limited cognitive demand for successful completion of the task.
- No ambiguity about what to do and how to do it. Tasks tell students what to do.
- Are focused on producing correct answers to artificial questions rather than producing meaning in contexts.


HIGH-LEVEL TASKS
Level-3: Scripted Procedures with Connections to Meaning
Scripted Procedures for Practice with Meaning
Scripted Procedures for Content with Meaning
SCIENTIFIC PRACTICES
- Students are not required to access any science concepts to solve the task.
- Involves following the steps necessary to engage in a scientific practice with an understanding of "why" they are following these procedures.
Example
1. Students are asked to write their observations and interpretation for their observations of a diagram that describes water cycle. Task requires them to see how observation and interpretation are different and require students to learn this difference. Task does not require understanding water cycle.
- Does not require engagement in scientific practice to make conceptual links with the science concepts and ideas. Even though task does not require engagement in scientific practices, it requires deep understanding of the science content.
- Require application of previously learned concepts consistently with understanding of why the concepts apply here or what they really mean.
- Use of a procedure is either specifically called for or its use is evident based on prior instruction, experience but students could apply previously learned "body of knowledge" with an understanding.
Examples
1. Students are asked to explain why it is not recommended to have green plants in your bedroom at night.
2. Students are asked to explain where most of the plant's mass comes from when a plant grows from a seed.
SCIENCE CONTENT
Tasks at the "scripted procedures with connections to meaning" level:
- Require some degree of cognitive effort for successful completion the task. Although the steps to be followed are explicit, they cannot be followed mindlessly.
- Very little ambiguity about what to do and how to do it. Tasks tell students what to do but they understand why they are doing what they are doing
- Are focused on producing correct answers to artificial questions rather than producing meaning in contexts.

HIGH-LEVEL TASKS

Level-4: Guided Engagement in "Scientific Practices" with Understanding of the "Science Content"

- Focus students' attention to the use of practices for the purpose of developing deeper levels of understanding of "body of scientific knowledge".
- Require guided engagement in a set of scientific practices and students develop a sense of why they are engaging in these practices.
- Require some degree of cognitive effort. Students need to engage with the conceptual ideas that underlie the scientific practice in order to develop understanding and make scientific reasoning.

Examples

1. *Students are asked to write their observations and interpretation for their observations of a diagram that describes water cycle. Task requires them to see how observation and interpretation are different and require students to learn this difference and at the same time make sense of the water cycle.*

HIGH-LEVEL TASKS

Level-5: Engagement in "Scientific Practices" with Understanding of the "Science Content"

Doing Science: Scientific Practices & Science Content

- Require engaging in scientific practices to understand "body of knowledge".
- Require complex thinking; there is not a predictable, well-rehearsed approach or pathway.
- Require students to explore and understand a natural phenomenon.
- Require considerable cognitive effort and may involve some level of anxiety for the student due to unpredictable nature of process.
- Require students to access relevant knowledge and experiences and make appropriate use of them in working through the task.
- There is no single solution and correctness of solution depends upon consistency with available evidence.
- Develop a better understanding of how scientific knowledge is produced.
- Involve engagement in important scientific practices such as modeling, developing explanations, and argumentation to develop deeper understanding of the science content.

Also

- Demand self-monitoring or self-regulation of one's own cognitive processes.

Examples

1. *Students are asked to design a robot that warns people about the air quality in different parts of their neighborhood.*

APPENDIX B

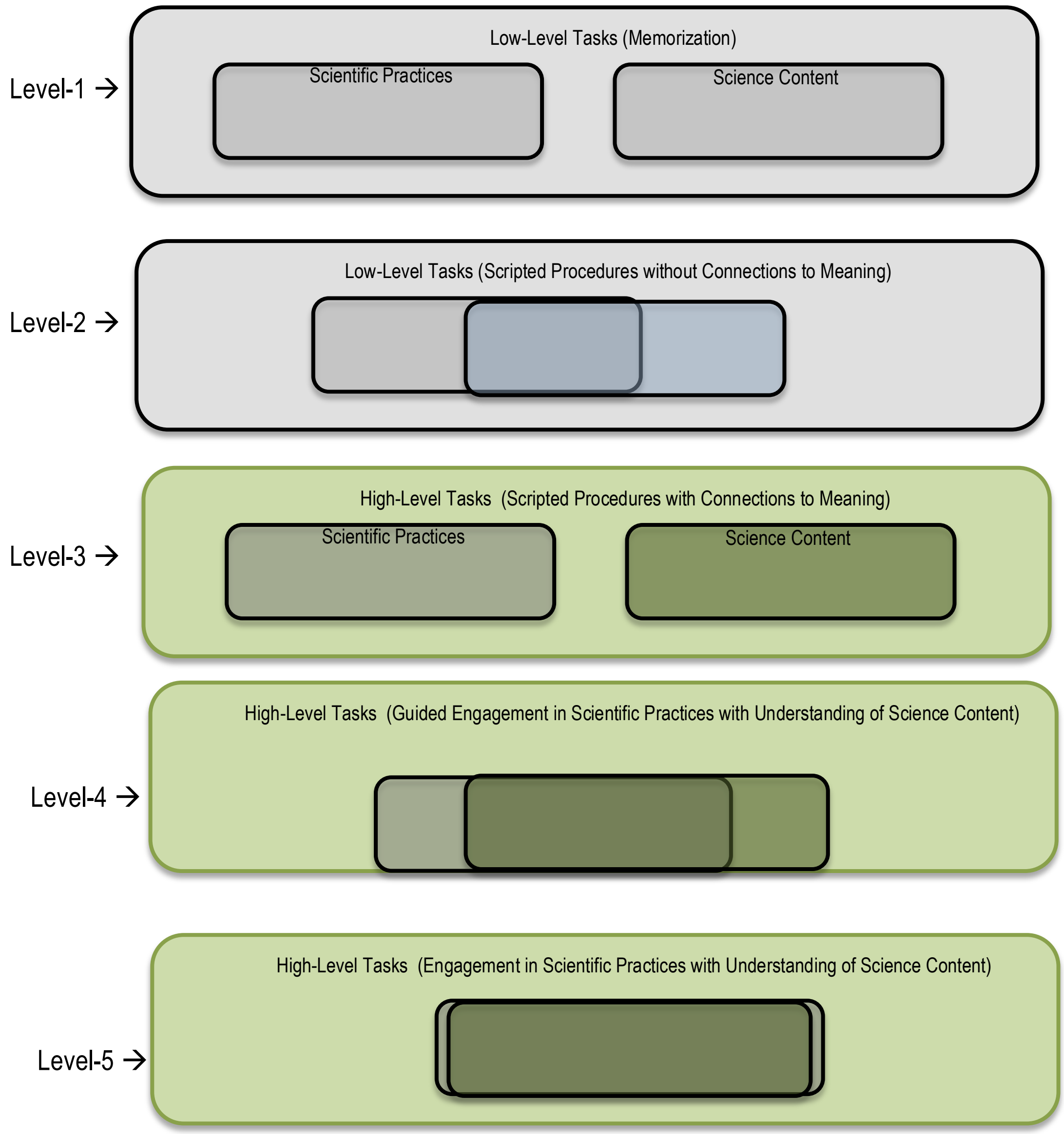
AN EXAMPLE PD-LOG

This is an example PD-log that was handed to the Noticing-PD participants in the third PD session, held on February 9, 2012.

Name:________________________

PD Log
Part-I
(February 9, 2012)

1. What level of thinking do you think **TASK-C** demands of students? Please mark the category in the TAGS that you think **Task-C** is in:



Please jot down why you thought so:

PD Log
Part-II
(February 9, 2012)

Please jot down what you noticed in the video-clip in which the teacher introduced the Task C to the students:

Please jot down what you noticed in the video-clip of implementation of Task C in the classroom:

Group Work	Whole Class Discussion

PD Log
Part-III
(February 9, 2012)

1. What do you think is the level and type of thinking that is demanded of students during the implementation of Task C (**during the group work**)?

Do you consider it as high or low level thinking?

Please jot down why you thought so:

PD Log
Part-IV
(February 9, 2012)

1. What do you think is the level and type of thinking that is demanded of students during the implementation of Task C (**during the whole class discussion**)?

Do you consider it as high or low level thinking?

Please jot down why you thought so:

APPENDIX C

THE OSMOSIS TASK

The task about osmosis used in the baseline and inheritance interviews was entitled, "The Rime of the Ancient Mariner." It was a stanza from Samuel Taylor Coleridge's poem "The Rime of the Ancient Mariner," and asked students to explain what they thought the stanza was describing (Levin et al., 2013). The task was:

> Please read the stanza, think about what the poem means in scientific terms and write your interpretations.
>
> *Water, water everywhere and all the boards did shrink*
> *Water, water everywhere, nor any drop to drink*

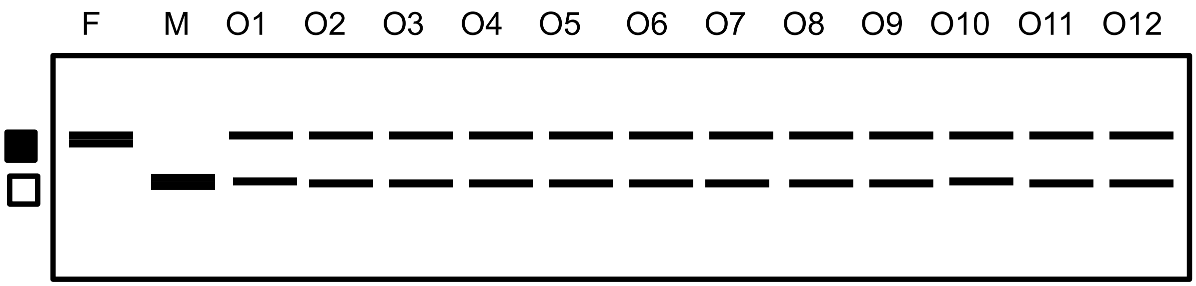
APPENDIX D

THE INHERITANCE TASK

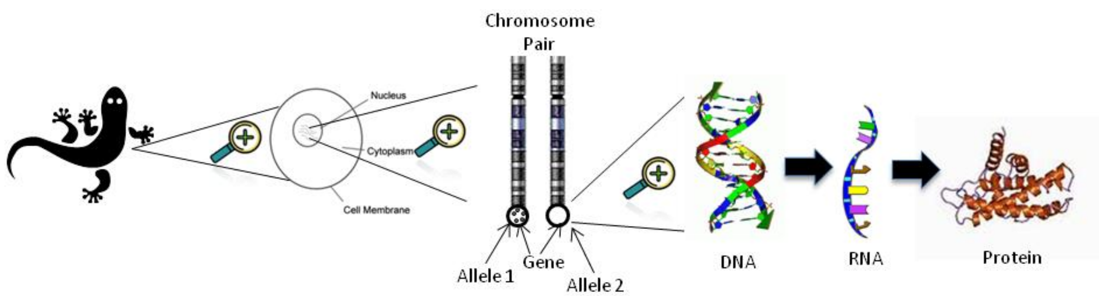
The task about the Mendelian Inheritance used in the baseline and inheritance interviews was entitled, “Connecting Genotype to Phenotype”. It asked students to interpret PCR and Western Blot data to recognize that the Western Blot shows protein variants of a particular gene and understand that it is the interaction of proteins that determine the phenotype. The task shown to the teachers during the interviews is included on the following two pages.

Results of the mating:

PCR



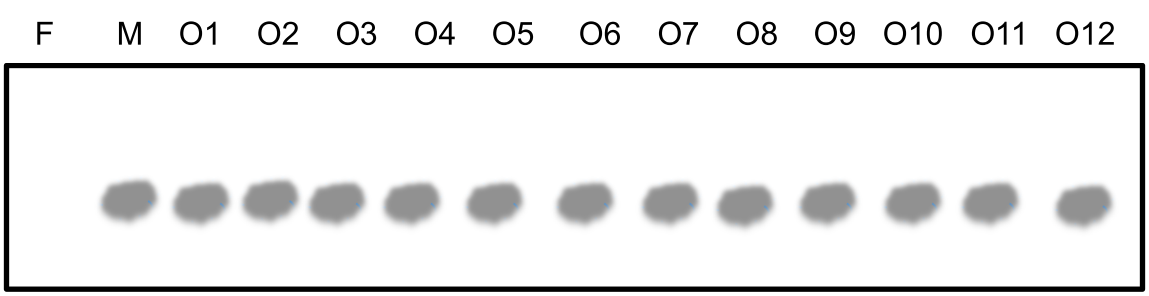
a. You are looking at the DNA level here. The information in the DNA is transferred into a molecule called RNA and the cell uses that information to make a particular protein. The interaction of the proteins determines what an organism looks like. In terms of the picture, we have been using:



b. Not only can scientists look at the DNA variants of a particular gene, they can use another technique called Western blot to look at the protein variants.

c. This is the Western Blot for this mating:

Western Blot



d. What are your observations?

e. What conclusions can you draw?

Conclusion	Evidence/observations

APPENDIX E

INTERVIEW PROTOCOL ABOUT OSMOSIS

Part-I: Task

15 min

Give background about the video to help teachers understand the context:

- 10th grade biology class. Students were introduced to diffusion and membrane semi-permeability in the prior lesson. They hadn't yet studied osmosis. They were given homework to read about osmosis in the textbook. In the beginning of the class, teacher projected this poem and asked a student to read it aloud. Then, she asked students to think about what the poem meant in scientific terms and to write their interpretations down in their notebook. She gave students a few minutes to write and then she asked them to share their interpretations with the rest of the class. The video that we will view captures one part of this whole class discussion. This video doesn't show the beginning of the discussion during which students shared their ideas without building on each other's thoughts. It is 11 minutes long.

I would like you to take a look at this task and try to solve it by yourself.

Ask:

1. What do you think about the task? What level of thinking do you think it demands of students?
    a. IN NEEDED: If students were to try to think about the poem from a scientific point of view, what kind of thinking would they have to engage in?

(In order to answer this question, you might reflect on your own thinking as you tried to make meaning of the poem through a scientific lens.)

    b. IF NEEDED: If you would like to rank this task in terms of the level of thinking it demands of students, let's say from 1 to 5, how would you rank it? Why?

Part-II: Viewing the Video & General Discussion

15 min

I would like you to view this video and then we will talk about what you noticed in the video.

Let teacher view the video.

Feel free to take some time to organize your thoughts. You can use this paper to jot down your thoughts. I will give you the transcript in case you will need to refer back to it.

15 min:

To capture kinds of issues teacher pays attention to in the video, start with a general question:

1. What did you notice in the video?

IF NEEDED:

a. What stood out to you in the video?

2. Is there anything else that you noticed? [Repeat this question until the teacher says she/he did not notice anything else]

Do not push if the teacher does not say anything about the students, their thinking, or their understanding.

Part-III: Viewing the Video & Targeted Discussion on Student Thinking

Now, I would like you to view the video again. This time, I would like you to focus on students, what they are doing, what they are saying, how are they thinking!

15 min:

Let teacher view the video.

Fell free to take some time to organize your thoughts.

15 min:

To capture the extent to which the teacher could interpret the level or type of thinking that is going on in the video as task is implemented in the classroom, ASK:

1. What did you notice about the students, anything about what they are doing, saying, or thinking?
2. How do you think they are interpreting the teacher's request to think about the poem from a scientific point of view?
3. What level and type of student thinking that is going on in this class discussion?

a. Probe: *What kind of thinking students are engaging in this task*?

b. Probe: What ideas, if any, are they wrestling with? *How* are they wrestling with those ideas?

c. Probe: How deeply are they thinking about the task?

If teacher says:	Ask (IF NEEDED)
Students are drawing on their prior knowledge	1. Can you point to a specific instance where you hear a student drawing on their prior knowledge? 2. What do you mean by prior knowledge? Is all prior knowledge the same? Is it all productive for working on this problem?
Students use the wrong term: density instead of concentration	3. Why do you think they did that? Did they keep using the term density until the end of the discussion? (this is particularly interesting because students are familiar with the term concentration because of their earlier discussion about diffusion; they actually used concentration when asked about diffusion.)
Brian was … (towards the end of the discussion)	4. What did you like about what Brian is doing? (lines 373-374; he understood the concentration difference)
Students were using sinking instead of shrinking	5. Where does this idea of boards "sinking" come from rather than shrinking? (line 245) Why would the students be thinking about the boards sinking?
Brian's comment about what osmosis is (lines 312, 313 & 322) after this term is brought into the discussion by Tilson (line 295)?	6. What does Brian think what osmosis? How does he think about it?
Rachel is confused (lines 345, 347)	7. Why? What doesn't make sense to her?

Part-IV: Discussion on Your Own Practice

What about the teacher?

What was she doing or not doing that might have influenced the students were thinking?

APPENDIX F

INTERVIEW PROTOCOL ABOUT INHERITANCE

Part-I: Task

10 min:

Give background about the video to help teachers understand the context:

- 11th grade biology class. They hadn't yet studied phenotype; so, they did not know what dominance and recessive means. They were introduced to genotype and had experience of making sense of genotype data presented with the PCR results.
- In the beginning of the class, teacher handed out this worksheet to the students. She first went over what is given in the worksheet, i.e., what the zooming picture shows, what the Western Blot shows. After that conversation, she asked students to individually make some observations of the PCR and Western Blot data and to try to make sense of it and make some conclusions about it. After that, she told students to move to their small group to share their observations and conclusions.

The video that we will view captures some part of this group work (about 9 minutes) and the whole class discussion (about 2 minutes). Because the class ended at the end of the group work, teacher had to hold the class discussion in their next science lesson, which was a couple of days later.

(NOTE: Students describe alleles of a gene as white and black. In the previous task, they used “square” representing a gene, and “white and black” as alleles for that gene. In this task, students continue to use this language.)

I would like you to take a look at this task and try to solve it by yourself. To help them start the task, explain them what PCR shows. It will be okay to give this information to the teachers because the students would know this (or had opportunities to study it) in the previous lessons.

Help teacher understand the task.

Ask:

1. What do you think about the task? What level of thinking do you think it demands of students?
   a. Probe: If a student were to try to solve the task (make observations and draw conclusions), what kind of thinking would they have to engage in?

(In order to answer this question, you might reflect on your own thinking as you tried to solve the task.)

   b. IF NEEDED: If you would like to rank this task in terms of the level of thinking it demands of students, let’s say from 1 to 5, how would you rank it? Why?

Part-II: Viewing the Video & General Discussion

15 min:

I would like you to view this video and then we will talk about what you noticed in the video.

Let teacher view the video.

Feel free to take some time to organize your thoughts. You can use this paper to jot down your thoughts. I will give you the transcript in case you will need to refer back to it.

15 min:

To capture kinds of issues teacher pays attention to in the video, start with a general question:

1. What did you notice in the video?

   IF NEEDED:

   a. What stood out to you in the video?

2. Is there anything else that you noticed? [Repeat this question until the teacher says she/he did not notice anything else]

Do not push if the teacher does not say anything about the students, their thinking, or their understanding.

Part-III: Viewing the Video & Targeted Discussion on Student Thinking

Now, I would like you to view the video again. This time, I would like you to focus on the students, what they are doing, what they are saying, how are they thinking!

15 min:

Let teacher view the video.

Tell teacher “Fell free to take some time to organize your thoughts. You can use this paper to jot down your thoughts”.

15 min:

To capture the extent to which the teacher could interpret the level or type of thinking that is going on in the video as task is implemented in the classroom, ASK:

1. What did you notice about the students, anything about what they are doing, saying or thinking?
2. How do you think the students are interpreting the data presented in the PCR and Western Blot?
3. What level and type of student thinking is going on in this class.
    a. Probe: *What kind of thinking students are engaging in this task*?
    b. Probe: What ideas, if any, are they wrestling with? *How* are they wrestling with those ideas?
    c. Probe: How deeply are they thinking about the task?
4. Do you think there were differences in student thinking in group work versus whole class?

If teacher says:	Ask (IF NEEDED)
Keegan’s analysis was interesting.	1. Why do you think so? What did you think Keegan meant when he said “males are superior to females” (p.7-line 32) How did he change his thinking?
Commonality in students’ thinking in second and third group	2. What is common in students thinking?

Second group had difficulty relating Western Blot data with the PCR data (line 99)	3. What did it reveal about their thinking? To what extent could these students connect PCR and Western Blot data? What was hard for them to see?
Students in the second group did not understand dominance and recessive. (line.120 to line.139)	4. Say more
Kegan's comment about two white and two black (line 148)	5. What did he mean?

Part-IV: Discussion on Your Own Practice

What about the teacher?

What was she doing or not doing that might have influenced the students were thinking?

APPENDIX G

CODEBOOK

Each idea unit will be coded <u>for each dimension</u>:

1) ACTOR

2) TOPIC OF CONVERSATION

3) STANCE

4) EVIDENCE-BASED REASONING

** NOTE: While coding I bolded the part in the idea unit that gives me the clue about the topic of the conversation. I <u>underlined</u> the part in the idea unit that gives me the clue about the stance. There are sections that I underline and bold!

ACTOR

Actor is the main subject of the idea unit. Who in the video-clip the interviewee is mainly talking about in that particular idea unit.

Each idea unit will be coded into <u>one of the following</u>:

1. **Particular student(s):** If the interviewee talks about a particular student(s) or group(s) of students in the video

Example:

"*… John [name of the student], said something about the male being dominant*."

** When the interviewee gives an example about a particular student but talks about students in the video case in general, then I DO NOT code this as "particular students".

Example (coded as "students"):

"I remember that girl saying, "Well, what is this, the genotypes?" So they are remembering what they are doing."

2. **Students:** If the interviewee talks about students in general. From the idea unit, you should see that interviewee views the class as undifferentiated group instead of a set of individual students.

Example

"*I think they struggled definitely with that concept of putting together what you see up here with the parents and the protein down below."*

** If you pick "students", please pick something other than pedagogy from the topic codes.

3. **Teacher:** If the interviewee talks about the teacher in the video-clip

** If you pick "teacher", please pick something other than student thinking from the topic codes.

4. **Students and the teacher:** If the interviewee talks about both the teacher and the students in the video-clip

** For the actor codes,

- If you choose "teacher", it's the "teacher in the video clip". If the interviewee talks about herself as a teacher, don't consider this as "teacher" actor.

- If you chose “students and the teacher”, it’s the “teacher in the video” and “students in the video”.

** If you pick “students and the teacher”, you have to pick pedagogy from the topic codes. Then, choose one of the subcodes under pedagogy based on the directions provided below.

TOPIC OF CONVERSATION

Topic of the conversation indicates what the idea unit is about.

Each idea unit will be coded into <u>one of the following</u>:

1. **Pedagogy:** What is the teacher in the video-clip is doing to facilitate sts’ learning.

Techniques and strategies for teaching the subject matter in the lesson (Sherin & Han, 2004; Es & Sherin, 2009)

If you code the idea unit as “pedagogy”, you should code it under <u>one of the following</u> sub-codes.

The logic underlying the difference among the sub-codes is that (a) is differentiated from (b) & (c) by the explicitness of the tie to students (were students’ ideas and actions mentioned or not?); (b) is differentiated from (c) by *the nature of* the teacher-student tie. Was it a general level or was it at a specific content level?

a) **Pedagogy: Pedagogy not explicitly tied to students.**

Example:

The teacher was asking a lot of guiding questions.

b) **Pedagogy explicitly tied to students, but at a general, non-content-specific level:**

→ What the teacher did in response to students’ ideas or actions

→ How the teacher’s actions influenced students’ actions or ideas

c) **Pedagogy explicitly tied to students at a specific, content-informed level:** To code the idea unit under this sub-code, the interviewee needs to explain concretely

→ how *specific* teacher actions influenced or got influenced by something specific that a student(s) said

→ how specific teacher actions influenced or got influenced by something specific that a student(s) did

Example:

When that girl in the first group interpreted the PW diagram, teacher asked her to link it to PCR data. This prompt by the teacher allowed this group to recognize the relationship between the protein and the white allele.

** There is a possibility that idea units coded under sub-code (b) or (c) [most like (c)] include interviewee's comments related to student thinking. While coding, I want to be able to capture that. If you coded the idea unit under sub-code (b) or (c), please indicate when the interviewee refers to student thinking explicitly.

Example:

I did notice that she would leave each group with kind of a thought, you know, get them so far and say, "Okay, think about that question." Or someone would say, you know, "Well, why doesn't" – that <u>one girl again said, "Why doesn't the female have a protein on that allele?"</u> And so she would say, "Well, you know, maybe that's something you need to discuss with your group," kind of getting them to talk more about it.

2. **Student Thinking:** What the students are saying related to the content; what they appear to think or understand

Examples for students thinking in each stance:

Describe

"but even in their conclusion of the group, he had said that one trait is more dominant over the other"

Evaluate

"All three of the groups, by the end of that day one, were on the right track"

Interpret

they did struggle definitely with that concept of putting together what you see up here with the parents and the protein down below

----

> *Teacher (continues): And they kept saying this idea, like, it's going to look like the male. I think one thing, you know, students think of traits, they only think of eye color, hair color – you know, your outside. They don't think of – you know, proteins could be – I don't know. Does it even tell you what this protein codes for? No, it just says it's a protein, so they don't know that it's gonna make the male look different. It might be a hormone that's produced by the male, so they don't really make that connection, you know?*
> *Interviewer: Oh, okay.*
> *Teacher: Students automatically think, like, "If I inherit this protein, that means I look like the male."*
> *Interviewer: Oh, okay.*
> *Teacher: Did you – I mean, I don't know. I felt like that was – they kept making that –*
> *Interviewer: Is it like you look like either male or female, or –*
> *Teacher: Yeah, or like you're gonna look exactly like your dad 'cause you inherit this one protein. Like, it seemed like they kept saying, you know, "You're gonna look like the dad.*

3. **Student Engagement:** The level of student participation, the extent to which students were attentive to the lesson, etc.

4. **Student Talk:** Process of talking about the academic content/ the way students are talking around the content (i.e., students were listening to each other, building on each other's ideas). (One way to think this code is "accountable talk")
5. **Classroom Climate:** Social environment of the classroom, such as the relationship between the teacher and the students or among the students.

** If you need to decide between student talk and climate, then please choose "student talk".

6. **Management:** Issues related to student behaviors, the way the teacher deal with the disruptive behavior, effective use of classroom time, etc.
7. **Other**

STANCE

The way interviewee tries to make sense of what he/she pays attention to

Idea unit will be coded into <u>one of the following:</u>

1. **Descriptive:** The interviewee talks<u> about observable features</u> of what is seen in the video.

****** Please code as **evaluative** when the teacher makes judgments about the teacher's content knowledge or skills of teaching: (i.e., mistake in the vocabulary that the teacher uses).

****** Based on the idea unit, if it seems like: if two people looking at the same classroom episode could come to the same conclusion, code as **describe**. (Low-level inference).

Example:

That the students had lots of different explanations at the beginning. They were willing to try and take a stab at it and explain what was going on.

2. **Evaluative:** The interviewee evaluates the quality of the classroom interactions (either specific for the teacher or the students) in the video

    - Interviewee comments on what was good or bad
    - Interviewee comments on how things could have been done

    ** Below are some decision points to distinguish "evaluative" and "interpretive":

    - If the interviewee makes comments like "if I was the teacher of that class, I would…" or "If I would go back and do that again, I would…" WITHOUT trying to make sense of what was happening, then please code it as **evaluative**.
    - If the interviewee provides alternative pedagogical solutions informed by her interpretation and analysis, DO NOT consider it as **evaluation**. In other words, if the interviewee provided alternative pedagogical approaches by making it clear that she/he tried to make sense of the video clip and then identified the problem, and then provided a solution, then please code it as **interpretive**.
    - If an evaluative phrase is located in an idea unit that is interpretive, please code it as **interpretive**.
    - If an idea unit is coded as "student thinking" for topic dimension, the interpretative stance could involve interviewee's explaining "what kid say/does" which may suggest "what they appear to understand or know" by assessing students' proximity to the "target conceptual goal" that the interviewee seems to have in mind based on what she says. Therefore,
        - If what is described (in terms of what students sad and appear to understand) is content specific and then there is an evaluative phrase, then code it as **interpretive.**

Example:

The students were able to pick out – like the one girl picked out, like, "Well, the female doesn't have a protein," so I thought that was good

- If what is described (in terms of what students said and appear to understand) is NOT content specific and then there is an evaluative phrase, then code it as **evaluative**

Example:

All three of the groups, by the end of that day one, were on the right track.

3. **Interpretative:** The interviewee makes some inferences about what is seen.

- The interviewee makes some hypotheses about why these events were taking place
- The interviewee tried to make sense of a situation

EVIDENCE-BASED REASONING

While interpreting what they see in the video clip, interviewees sometimes used a particular instance in the video clip to support what they say.

- **Refer to specific events and interactions from the video as evidence:** The interviewee grounds her comments to the specific instances in the video.

****** These instances can be indicated either by referring to particular line numbers or a particular specific interaction.

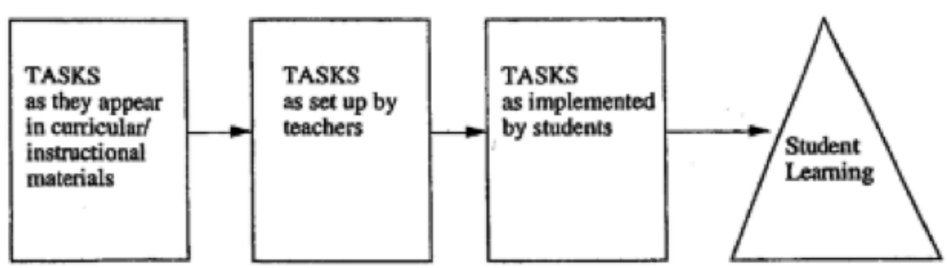
APPENDIX H

PRESENTATION: JOURNEY OF AN INSTRUCTIONAL TASK

In the beginning of Noticing-PD session-4, teachers were introduced to the key idea of the Mathematical Task Framework (tasks can change in their level of cognitive demand as they pass from written materials to how they are set up by the teacher in the classroom to how they are actually enacted or carried out by the students) (Stein et al., 1996) through a presentation, entitled "Journey of an Instructional Task". The following slides provide the details of this presentation.

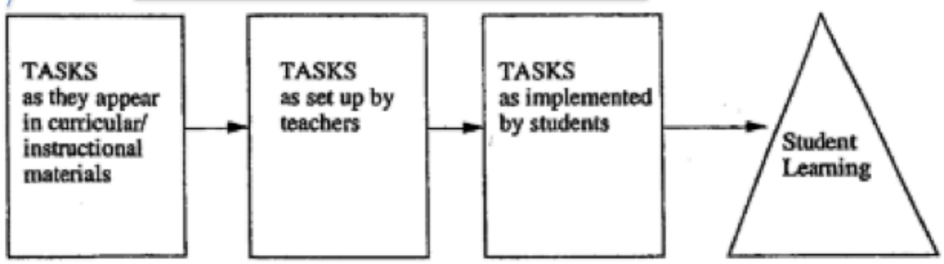
Journey of an Instructional Task

A representation of how instructional tasks unfold during classroom instruction



A representation of how instructional tasks unfold during classroom instruction

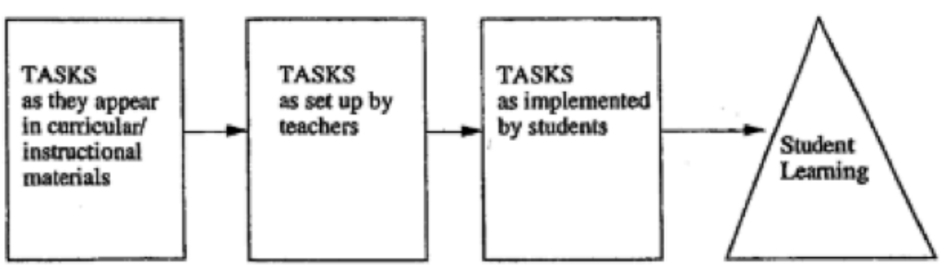
What is the level or type of thinking that the task demands of students?
What is the **cognitive demand** of the task?

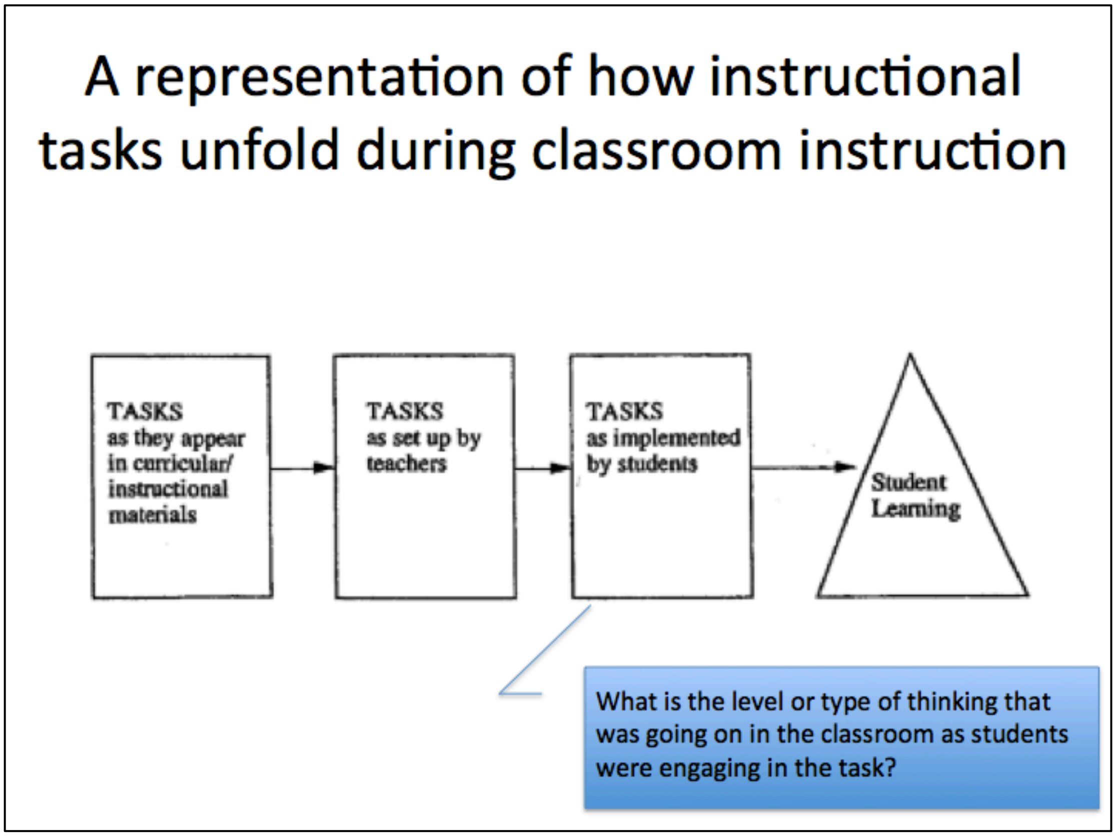


<u>Cognitive demand:</u> the kind and level of thinking required of students in order to successfully engage with the task.

A representation of how instructional tasks unfold during classroom instruction

What level of thinking this kind of a set-up will demand of students?




A representation of how instructional tasks unfold during classroom instruction
TASKS
as they appear
in curricular/
instructional
materials
TASKS
as set up by
teachers
TASKS
as implemented
by students
Student
Learning
What is the level or type of thinking that was going on in the classroom as students were engaging in the task?

APPENDIX I

PRESENTATION: SIMILARITIES & DIFFERENCES BETWEEN THE VIDEO CASES

At the end of the Noticing-PD session-4, the facilitator made a presentation that summarized the similarities and the differences between the contrasting video cases discussed in that session. The following slides provide details about this presentation.

Similarities & Differences
(Video-1 vs Video-2)

Similarities…

- Students worked in groups
- About all the students were engaging in the task
- Students were following the procedures for building a model that represents offspring formation.
- The teacher was walking around the groups
- The teacher was asking questions to the students and answering their questions.
- Students were engaging in "developing & using models" scientific practice (one of the scientific practices).

Similarities…

- Students worked in groups
- **About all the students were engaging in the task**
- Students were following the proc [illegible] a model that represents offspring formation.
- The teacher was walking around the groups
- The teacher was asking questions to the students and answering their questions.
- Students were engaging in “developing & using models” scientific practice (one of the scientific practices).

Differences….

Video-1	Video-2
• Students were engaging in procedures to make all possible combinations of a white and a black square	• Students were engaging in thinking about the meaning behind procedures of modeling offspring formation

Similarities…

- Students worked in groups
- About all the students were engaging in the task
- Students were following the procedures for building a model that represents offspring formation.
- The teacher was walking around the groups
- The teacher was asking questions to the students and answering their questions.
- Students were engaging in “developing & using models” scientific practice (one of the scientific practices).

Similarities…

- Students worked in groups
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Differences....

Video-1

- Students were following a sequence of actions because they were told but not for understanding the conceptual meaning behind them.

Video-2

- Procedures and the materials that they use were meaningful to students
- Students would evaluate whether they followed right or wrong procedure based on what they know scientifically (rules of inheritance)

Similarities...

- Students worked in groups
- About all the students were engaging in the task
- Students were following the procedures for building a model that represents offspring formation.
- The teacher was walking around the groups
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Similarities…

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Differences….

Video-1

- Teacher was asking questions to make students' thinking visible
- Teacher helped students clarify their thinking
- Teacher helped students to draw conceptual connections

Video-2

- Teacher was not waiting enough for students giving answer to her questions
- Teacher was sometimes providing the answer for the question she asked
- The questions where about 'what to do" but not about "why to do so".

APPENDIX J

CODEBOOK (SPECIFIC FOR THE ANALYSIS OF THE PD SESSIONS)

Teacher Comments

- Chunked based on the shift in the focus of the comments made by the teacher(s)
- One chunk could include more than one teacher's comment and more than one noticing by the same or different teachers

Individual Teacher Noticings

- What did the teacher notice?
- I do not code for the math teacher
- I do not code teacher's who just showed an agreement or repeated what was said
- I code for the teacher who made the main point and who clearly made a point
- For each noticing, I identify:

Teacher: ….

Topic:

- Pedagogy: (..) Link to Sts, (..) Task Spe
- Student thinking: …
- Other: …

Stance:

- Describe
- Evaluate
- Interpret
    - Reasoning for maintenance or decline (*when there is a clear reference to whether it is maintenance or decline, of so why*)
    - Reasoning by comparison

Evidence:

- No evidence
- Evidence-based
    - Evidence points to a line
    - Evidence points to a specific instance/student(s)
- Evidence provided by context (*when they are already talking about a particular line*)

Note: Teacher X provided evidence from the video

Note: Focused discussion on a line because the facilitator said so

Pedagogy

Link to Students' Ideas or Actions

Task (Content or Practice) Specificity		**Yes (+)**	**No (-)**
	Yes (+)	1	3
	No (-)	2	4

Examples for Pedagogy Codes:

(+) Link to Sts, (+) Task Spe

Interview: *You know, repeatedly a bunch of them said, "You're gonna look like the dad." And I think that the teacher at one point even said, "You're gonna have the trait of the dad," you know, kind of – not correct them, but they kept – you know, with that misconception that – you know, yes, some alleles, that means you're gonna look like the dad, but it depends on what that allele is coding for. I mean, it might be types of hormones you produce or the types of proteins that you're making obviously. I'm trying to find where they said that. Yeah, so like she said, you know, "I don't understand why the female doesn't have a protein," and she said, "Well, that's a good question." And she's like, "Yeah," and the student says they don't know why, and the teacher goes on to say, "Well, what is she? Is there something different about her?" So she's really trying to get her to think about why might the male have that protein and not the female, which is a good observation.*

(+) Link to Sts, (-) Task Spe

Interview: *I did notice that she would leave each group with kind of a thought, you know, get them so far and say, "Okay, think about that question." Or someone would say, you know, "Well, why doesn't" – that one girl again said, "Why doesn't the female have a protein on that allele?" And so she would say, "Well, you know, maybe that's something you need to discuss with your group," kind of getting them to talk more about it, which was good.*

Interview: *She didn't get hung up on their words they were using like. She didn't correct and say density or concentration. She just let it go, and I thought that was interesting.*

(-) Link to Sts, (+) Task Spe

PD-Session-4:
Linda: My similarity is neither teacher referenced the rules. I didn't understand why they didn't use what they just worked on for the whole week.
Facilitator: Teachers did not use the rules?
Linda: No. So it goes right along with what Carol is saying, but the similarity as a– if we're comparing teachers, yeah, they had all those questions, yeah, they were redirecting them, but neither teacher referenced the rules
Co-facilitator: The rules of inheritance
Linda: that they should only have one. That would have clarified it.

PD-Session-6:
Barbara: Yeah, later in that lesson we talked about why a line was thicker – But in that part of the lesson, I was really focused on how they get – like why the offspring look like that.

(-) Link to Sts, (-) Task Spe

Interview: *I noticed that she was doing a lot of, you know, probing questions, I think a little more so than the last – I think the first activity was a little more inquiry-based.*

* To code (+) for the task specificity, the teacher's comment should be really related to the task. Just giving example student or teacher statements to talk about something more general is not enough to categorize it as task specific.

Student Thinking

If the teacher's comment is categorized as "student thinking", then explain the nature of the comment:

1. Students' interpretation of the task (i.e., how they made sense of the task, what ways they use to make sense of the task)
2. Students' getting ideas revealed in the task
3. Students' need for support for sense making

4. What students said
5. Students’ use of terms (to explain something)

Emergent Codes

1. Associating with classroom events/practice
2. Thinking about applying to your own practice
3. Identifying the level or type of student thinking in the video clip
4. Factors/ Reasons associated with maintaining high-level thinking
5. Questioning whether "X" is a factor that could cause declining the cognitive demand (in her own practice)
6. Factors/Reasons associated with declining high-level thinking

Teacher Facilitation

Did the facilitator’s prompts play a role in teacher’s comments? If did, how?

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