

The Pennsylvania State University

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College of Education

**PRESERVICE TEACHERS' USE OF INSCRIPTIONS IN THEIR PEER  
TEACHING ACTIVITY**

A Thesis in

Curriculum and Instruction

by

Arzu Tanis Ozcelik

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The thesis of Arzu Tanis Ozcelik was reviewed and approved\* by the following:

Scott McDonald  
Associate Professor of Education  
Thesis Advisor

Gregory Kelly  
Professor of Education

Glendon W. Blume  
Professor of Education  
Chair of Graduate Program in Curriculum and Instruction

\*Signatures are on file in the Graduate School

## **ABSTRACT**

The current study investigated the preservice science teachers' uses of inscriptions in their peer teaching activities and was guided by the following research questions: 1) what kinds of inscriptions do pre-service teachers use in their peer teaching activity? 2) How and why do pre-service teachers use inscriptions in their peer teaching lessons? This study followed a multi-participant case study approach. Nine science pre-service teachers enrolled in the Secondary Science Teaching course at a large mid-Atlantic University constitute the participants of the study. Seven videos of lessons were analyzed for the inscription use. Data analysis demonstrated that preservice teachers used inscriptions in pedagogical and normative ways and the complexity of inscriptions used across different disciplines varies. Preservice teachers used inscriptions 1) to convey final form scientific knowledge, 2) to engage students in scientific practice, 3) to make thinking visible, 4) to connect multiple ideas with multiple inscriptions, and 5) to provide data or example from nature. In addition to these purposes, preservice teachers also used inscriptions for formative assessment, to engage students for the lesson, and to review the lesson with the inscriptions. It is concluded that science topics and the different sequences of the lessons could be conducive these different uses of inscriptions across different lessons. In addition, these different uses of inscriptions may impact students' understandings of how scientists use inscriptions and inscriptional practices.

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## Chapter 1

### INTRODUCTION

Science is not done, is not communicated, through verbal language alone. It *cannot* be. The ‘concepts’ of science are not solely verbal components. They are semiotic *hybrids*, simultaneously and essentially verbal, mathematical, visual graphical and actional-operational (emphasis in original, Lemke, 1998, p.87).

Visual representations constitute an important part of the culture of science. Graphs, photographs, diagrams, data tables, maps, equations, and so forth are widely used in science textbooks and scientific journals. Lemke (1998) conducted a simple survey regarding graphics use in two scientific journals. He analyzed 20 articles from two issues of *Physical Review Letters* and found the average number of graphics per page is 1.2. He also analyzed 31 technical reports from two issues of *Science* and found the average number of graphics per page is 2.5. Therefore, Lemke showed that representations comprise essential part of the science.

The term “representation” is used by researchers in cognitive science (e.g. Simon & Larkin, 1987) to refer to both internal mental structures that are the product of cognitive processing in the brain and external representations that are in an external medium such as paper, or computer screen. To avoid this dual meaning, researchers embrace the term “inscription” to refer to the externalized representations. The term “inscription” was introduced first in the sociology of science studies (Latour, 1987) to refer to graphs, signs, models and other semiotic symbols. By accepting the term “inscription,” researchers invoke a different theoretical framework from that of cognitive

psychologists, and acknowledge the mobile, immutable, sharable, and transformable nature of external representations within social context (Roth & McGinn, 1998). Following Roth and McGinn (1998) and Latour (1987), in this study I refer to external representations existing in the material form such as paper, or a smart board screen, which can be shared by many agents as inscriptions.

In the reform documents (AAAS, 1990; NRC, 1996; NCTM, 1989) there is an increasing call for authentic scientific practices. Creating, reading, and interpreting inscriptions are among the scientific practices in which students should engage in classrooms.

In their research about the roles of representations and tools in the chemistry laboratory, Kozma et al. (2000) suggested, “the kind of discourse and representation use that is desired of students would need to be modeled by teachers. As they discuss investigations with students, teachers must demonstrate how to use representations to ask questions, interpret findings, and draw conclusions.” (p.139) Also, Gabel (1999) has shown that many high school teachers tend to move between the macroscopic, submicroscopic, and symbolic representational levels without highlighting their interconnectedness. These studies demonstrated that it is important to investigate how science teachers use inscriptions in science classrooms.

Having situated learning and cognitive apprenticeship as the theoretical framework, I investigated preservice teachers’ use of inscriptions in their peer teaching activities in this study. The previous studies that investigated preservice teachers’ use of inscriptions analyzed their competencies or developments of inscription practices in long-term investigations. In the current study, preservice teachers are not in a methods course that

focuses on long-term scientific investigations. Preservice teachers are in the science teaching methods course and performing their first teaching experiences. In this manner, it is important to investigate preservice teachers' beginning teaching experiences in order to understand how and why they use inscriptions.

Drawing on the qualitative case study approach (Merriam, 2009; Yin, 2009), this study focuses on seven preservice teachers' use of inscriptions in their peer teaching lessons. Seven videos of lesson were analyzed for preservice teachers' uses of inscription.

The specific research questions that guide this study are:

1. What kinds of inscriptions do preservice teachers use in their peer teaching activity?
2. How and why do preservice teachers use inscriptions in their peer teaching activity?

## **Chapter 2**

### **THEORETICAL FRAMEWORK and LITERATURE REVIEW**

#### **Theoretical framework**

Reform documents in science and mathematics education (NCTM, 1989; American Association for the Advancement of Science, 1993) advocate creating, reading, and interpreting inscriptions as important scientific skills for the development of scientific literacy. These documents support the idea of engaging students in authentic science experiences, which is based on the notion of “authentic activity” proposed by Brown et al. (1989). Brown et al. (1989) suggested that learning is the process of acculturation to the communities of practice and the activities of these communities should be framed by its culture. The meanings and purpose of activities are socially constructed through the negotiation among the new and old members. They define authentic activity as the ordinary practices of the culture. Therefore, these reform documents advocate authentic science experiences for students in science classrooms. Brown et al. (1989) believe that all knowledge is a product of the activity and situations in which they are produced. Brown et al. (1989) stated “Learning and acting are interestingly indistinct, learning being a continuous, life-long process resulting from acting in situations” (p.33). Situated cognition suggests learning is bounded to authentic activity, context, and culture (Brown, Collins, & Duguid, 1989). Greeno and Hall (1997) suggested, “Learning to construct and interpret representations involves learning to

participate in the complex practices of communication and reasoning in which the representations are used” (p. 362). Therefore, it is important to use inscriptions in classroom discussions and have students experience these practices situated in the activities.

Cognitive apprenticeship is a model of teaching in situated cognition. Cognitive apprenticeship enables students to obtain, develop, and employ cognitive tools in domain specific activities (Brown, Collins & Duguid, 1989). According to researchers cognitive apprenticeship has four aspects -situated modeling, scaffolding, fading and coaching- that promote students’ learning in authentic activities. (Collins, Brown, & Holum, 1991) In modeling, students (apprentices) observe the teacher demonstrating how to do the task. Scaffolding is the support teachers give to the students in carrying out the task. Fading is removing the support slowly as the students get more responsibility. Finally, coaching involves observing student’s learning through wide range of activities.

Having situated learning and cognitive apprenticeship as theoretical framework, in the next section I will discuss the studies related to inscriptions and inscriptional practices.

### **Literature Review**

According to Roth et al (2005) inscriptions include readings from simple devices, recordings from automated devices, computer screen outputs, photographs, micrographs, data tables, graphs, and equations. Roth and McGinn (1998) emphasized, “the focus of

inscription entails a concomitant focus on the establishment and maintenance of shared practice” (p.41)

Scientists transform natural objects and phenomena into complex mathematical forms. When these complex forms are recorded, they are referred to as inscriptions. Inscriptions are crucial to the practice of science as they can be cleaned, redrawn and displayed after they are abstracted from the instrument in order to construct facts, laws, and theories (Latour, 1987). According to Latour (1987), scientists create these inscriptions to make sense the phenomena first for themselves, then for communicating science to other people in scientific journals. Lynch (1990) suggested, “Starting with an initially recalcitrant specimen, scientists work methodologically to expose, work with and perfect the specimens’ surface appearances to be congruent with graphic representation and mathematical analysis” (p.170) Lynch’s description displays the process of transforming natural phenomena to more complex mathematical forms.

Latour (1987) indicated that these transformations could be on infinite continuum. In other words, physical phenomena can be transformed into different inscriptions that are on a continuum with increasing complexity, beginning from inscriptions such as photographs that are concrete and closer to the real world to equations that are more abstract in nature. Photographs and drawings provide detailed information and examples from nature, and thus complementing and clarifying written text, but they also have an interpretative nature, which requires scientists to elucidate their meanings in their writings (Bastide, 1990).

There are many studies investigating students’, scientists’ and preservice teachers’ use of inscriptions. Kozma (2003) investigated cognitive and social affordances provide

by external, multiple representations in support of science understanding. In his study, he examined research on how scientists arrange the symbolic elements of multiple representations to construct a shared understanding of the scientific phenomena with which they are working in their labs. He compared representational skills and practices of scientists to those of students. He found that scientists arrange properties within and across multiple representations to reason about their work and confer with each other shared understandings based on underlying entities and processes. On the other hand, students have a hard time in terms of moving across or connecting multiple representations, so surface features of individual representations constrain students' understanding and discourse.

Wu and Krajcik (2006) investigated seventh graders' use of inscriptions in a teacher-designed 8-month project-based science unit. They found that throughout the unit, students used different inscriptions to exhibit significant inscriptional practices such as creating, using inscriptions to make arguments, to represent conceptual understandings, and to engage in thoughtful discussions with the support of teachers and various resources.

Carlsen's (2009) study analyzed how upper secondary students used inscriptions, both self-made as well as provided by teachers and textbooks, as tools for thinking and learning in problem solving in mathematics classrooms. He described that by using inscriptions made on the chalkboard and with paper and pencil, students externalized their thinking and at the same time engaged in mathematical reasoning. In addition, he argued that inscriptions with their material form play a conclusive role in learning mathematical reasoning.

While the previous discussed studies are concerned with students' use of inscriptions or inscriptional practices, many other studies have investigated preservice science teachers' inscriptional practices in authentic scientific investigations. Roth, McGinn and Bowen (1998) engaged preservice teachers in an authentic ecology problem that they developed. They compared the results of this study with their previous study (Roth & Bowen, 1994) examining grade eight students' results on the same ecology problem investigation. They found that "preservice teachers didn't engage to a higher degree in scientific representation practices than their younger counterparts" (p. 42). Therefore, their argument from these studies is even though preservice teachers have scientific backgrounds, since they do not engage in scientific investigations or authentic scientific problems, they are less competent on the representation practices compared to grade eight students who had experiences working with the scientific investigations.

In a similar study, researchers investigated if preservice science teachers are prepared to teach science inquiry with the purpose of transforming and analyzing data and interpreting graphical representations. Bowen and Roth (2005) worked with elementary and secondary preservice teachers and gave them data and graph interpretation tasks. They found preservice teachers do not enact the authentic practices that scientists do when asked to interpret data or graphs. They suggested that preservice teachers need more experience in engaging in data and graph interpretation practices that arise from realistic investigation activities.

In the same way, Lunsford et al. (2007) worked with graduate level preservice teachers in a 15-week course that emphasized production of inscriptions to support their claims when they are presenting their investigation results. They investigated students'

laboratory inscription notebooks and found that the number and type of representations made during the course increased as time progressed. In addition, the number of concrete, text-based inscriptions decreased as the number of graphs, tables and other complex inscriptions increased.

All these studies advocate authentic activities in the context of long-term scientific investigations. However, Forman and Ansell (2002) explored how inscriptions are used to create argumentative positions between two groups of students about the longevity of the two sets of batteries in two classroom episodes. They described the developmental process of the classroom discussions over time to show the historical evolution of both inscriptions and arguments in the classroom community. They found that the arguments in the classroom emphasize the meaning of the inscriptions and their effectiveness in supporting knowledge claims. Thus, they concluded that the classroom practices and discourses are similar to those of scientific communities.

The researchers in science education have demonstrated the importance of language in learning practices (Kelly & Chen, 1999 ; Lemke, 1990). The previous studies discussed above employed classroom discourse to investigate either students' or preservice teachers' inscription use. Thus, for this study, classroom discourse is an important source of data for understanding the use of inscriptions of preservice teachers. Discourse is defined oral, written and behavioral discourse in this study. In addition to classroom discourse, practices around inscriptions are also crucial to understand preservice teachers use of inscriptions in the lessons.

Keeping these in mind, I will follow Forman and Ansell (2002) and use the qualitative case study as the method for the current study. In the following section, I will explain the methods I used to answer the research questions of this study.

## **Chapter 3**

### **METHODOLOGY**

In this section I will explain the methods chosen to investigate my research questions:

1. What kinds of inscriptions do preservice teachers use in their peer teaching activity?
2. How and why do preservice teachers use inscriptions in their peer teaching activity?

I will first explain my research approach and method and justify my decision to choose a qualitative case study approach. Second I will describe the research context and the participants. Finally, I will describe in detail the data sources and the data analysis methods.

#### **I. Research Approach and Method**

##### **Qualitative Research**

The approach of this study is qualitative in nature. Denzin and Lincoln (2005) defined qualitative research:

Qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible. These practices transform the world...qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret phenomena in terms of the meanings people bring to them. (p. 3)

In this study, the natural setting is a secondary science teaching methods course in the teacher education program (I will describe the nature of the science methods course and teacher education program in the following section) and in particular the peer-teaching activities that take place in the course. When preservice teachers engaged in the peer teaching activity, their lessons were videotaped. I studied preservice teachers' peer-teaching practices in their natural settings within the context of their teacher preparation program. I used the video data collected in this setting in order to understand how and why preservice teachers use inscriptions in their lessons.

### **Case Study Method**

The research method for this study is qualitative case study. Merriam (2009) indicates that even though case studies have been used in other research areas for a long time, they did not gain acceptance in textbooks on research methods until 1960s and 1970s as a research method for educational problems. Merriam (2009) also describes how researchers define case studies differently in educational research. She considers a case study as a form of qualitative research and defines it as “an in depth description and analysis of a bounded system”(p. 40). However, according to Yin (2009), “A case study is an empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident” (p.18). While Yin (2009) has referred to case study as strategies of inquiry, Merriam (2009) has referred to case study as a method of qualitative research. According to Creswell (2007), “a case study research is a qualitative approach in which the investigator explores a bounded system (a *case*) or multiple bounded systems (cases)

over time, through detailed, in-depth data collection involving *multiple sources of information* (e.g., observations, interviews, audiovisual material and documents and reports), and reports a case *description* and case based themes” (p.73, emphasis in original). According to these researchers, a case should be a bounded system. In this study, the case is preservice teachers’ use of inscriptions in the peer teaching activity bounded in the course entitled SCIED 412: Secondary Science Teaching II, within the limit of one experience and including nine participants. Since the participants of this study are all bounded in the same course, this study is an embedded case study. Yin (2009) describes embedded case studies as one where a single case study includes more than one unit of analysis. Therefore, in my case each participant constitutes one unit of analysis within the larger case of the methods course peer teaching experience.

## **II. Context and Participants**

### **Context**

The context of this study is secondary science teaching methods course (SCIED 412: Secondary Science Teaching II) in a large mid-Atlantic university’s teacher education program. This course is the science preservice teachers’ second teaching methods course in the certification program. The main focus of the course is on unit planning and the analysis of teaching. The preservice teachers are concurrently enrolled in a field experience course where they are in schools for 6 weeks in the mornings. Their prior teaching methods course (SCIED 411: Secondary Science Teaching I) focused on reform definitions of science teaching, and also asks preservice teachers to engage in

microteaching activity with middle school students coming from a local charter school. After SCIED 412 preservice teachers enroll in student teaching.

During SCIED 412, preservice teachers prepare a unit plan of a topic they choose and they select one lesson to teach in 45 minutes for an audience of their peers. There are no specific requirements for the lesson plans beyond the requirement that students are engaged in some kind of discussion. While preservice teachers are teaching to their peers, the classmates participate in the lesson and take notes on the performance of preservice teachers' teaching in order to give feedback on their teaching. The instructor of the course has a research agenda focused on preservice teachers' learning to teach, so the instructor video recorded every lesson for all preservice teachers. After preservice teachers teach the lesson, the class members (the instructor, the preservice teacher and the classmates) talk about the teaching, and what went well and what did not go well. If necessary, the instructor puts the video of teaching on the Smart board and they all watch the instances of the topic of the conversation.

### **Participants**

Nine preservice science teachers enrolled in a large mid-Atlantic university's teacher education program, leading to secondary teaching certification in scientific fields, participated in the study. There are three female and six male preservice science teachers with Caucasian origins. The participants' background information is provided in Table 3-1. The course instructor is a Science Education faculty member with a background as a Physics teacher.

**Table 3-1 Participants' background information**

<b>Name (Pseudonym)</b>	<b>Gender</b>	<b>Degree (Working on)</b>	<b>Major</b>	<b>Topic of the Lesson</b>
Alice	F	Graduate Student	Biology Bachelors	Circulation and Respiration
Andy	M	Graduate Student	Biology Bachelors	Carbohydrates, Proteins, Lipids and Nucleic Acids
Selim	M	Undergrad Student	Secondary Education with Physics option	Circular Motion
Mark	M	Undergrad Student	Secondary Education with Physics option	Physical Characteristics of Gases
Anne	F	Undergrad Student	Secondary Education with Earth and Space option	Earthquakes
Liam	M	Undergrad Student	Secondary Education with Earth and Space option	Convection Cycle and Density
Jack	M	Undergrad Student	Secondary Education with Earth and Space option	Plate Tectonics
Sam	M	Undergrad Student	Secondary Education with Chemistry option	Properties of Solids, Liquids and Gases
Tammy	F	Undergrad Student	Secondary Education with Biology option	Origins of Biological Diversity

### **III. Data Collection and Analysis of the Study**

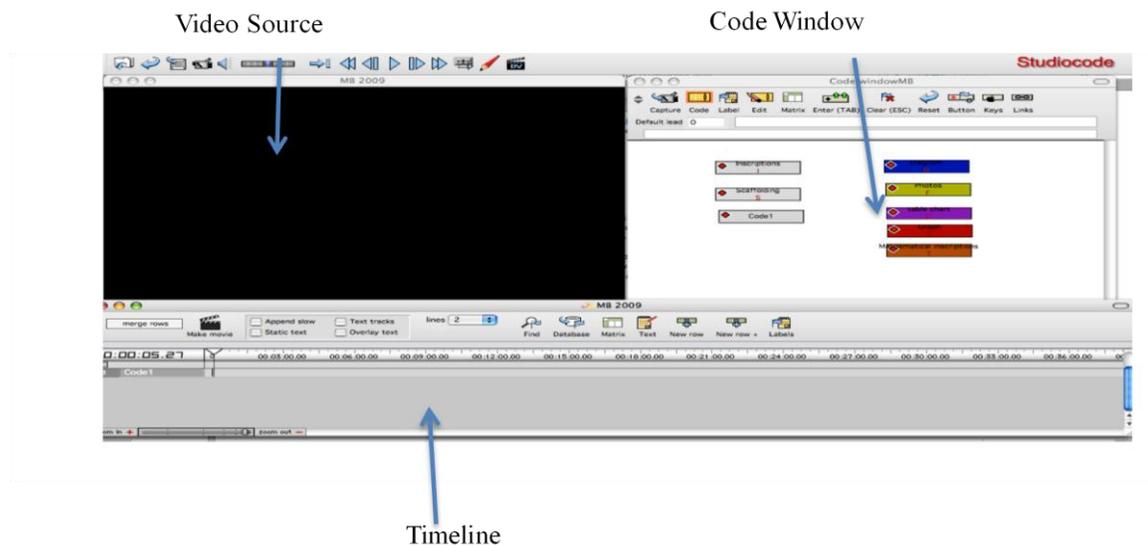
#### **Data Collection**

The data of this study comes from nine video records of lessons from the peer-teaching activity. The course instructor videotaped the lessons twice a week for five weeks in the spring semester in January and February. Two of the video records of

teaching (Andy's and Liam's Videos) were eliminated from the data set because of the poor sound quality, leaving seven lessons in the data set for analysis.

## Data Analysis

In order to prepare data for the analysis, I imported video records, which are in QuickTime® format, to Studiocode®, a Mac-based video/audio analysis software. Studiocode software consists of 3 main parts: 1) a video source, 2) a code window, and 3) a timeline. Figure 3-1 shows a snapshot of these 3 parts.

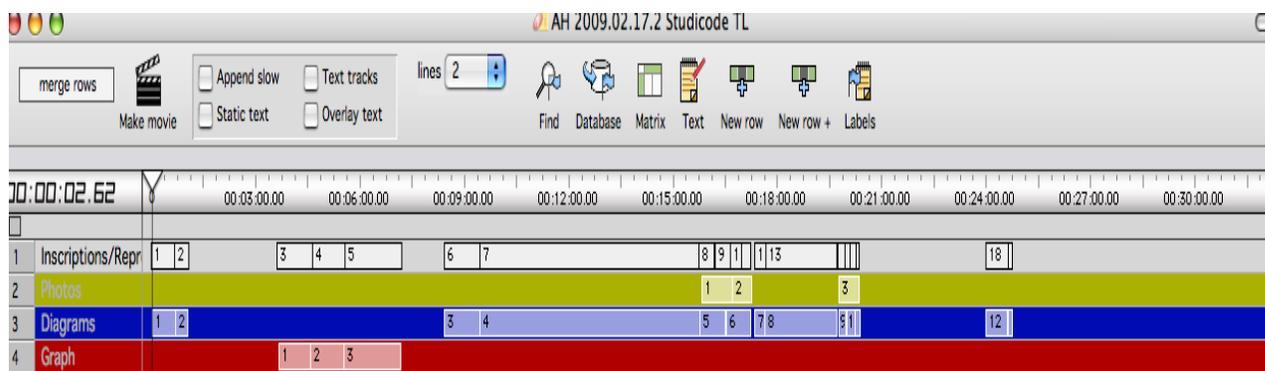


**Figure 3-1 Parts of Studiocode®**

Analysis of the data consists of several phases. The first phase of analysis involves familiarization with the data set. The second phase is analyzing data for each participant. The third phase is analyzing the data across the participants.

In the first phase, I watched one of the videos of lessons in order to find out what is interesting in the lesson. In this phase, I watched all other participants' videos over and over again in order to be immersed in the data. (Marshall & Rossman, 2006)

In the second phase, I systematically selected and identified the instances, in which preservice teachers used representations/inscriptions, on the timeline window in order to answer the research questions. Merriam (2009) describes this as “identifying segments in the data set that are responsive to your research questions” (p. 176). She refers to these segments as “units of data”. In this study, a segment is a section of instructional time when preservice teachers are discussing around a particular inscription and inscriptional practices. When inscription changes, that is considered as a new segment. The analysis in this phase took place for each participant. For the first research question, I looked at the videos and identified what kind of inscriptions preservice teachers used in each lesson. I color-coded these segments according to the inscription types on the timeline window. Figure 3-2 is a snapshot of an example timeline window showing the color-coded segments.



**Figure 3-2 An Example timeline window showing color-coding**

Color-coding helped me with identifying inscriptions more clearly. Thus, this color-coding helped me narrow my data scope and identify more clearly which visuals are inscriptions. So, after I identified the unit of data as the segments in which the inscriptions are used, open coding was performed for each segment for each participant. During open coding process, for the types of the inscriptions I used two terms as

“pedagogical” and “normative” to classify inscriptions. “Pedagogical inscription” is used to refer to the inscriptions used mostly by teachers to help students understand scientific concepts. “Normative inscription” is used to refer to the inscriptions that scientists would use in the scientific journals to communicate with other scientists in scientific community. I used these two terms as codes for the first research question. These codes emerged out of the long observations of the data.

I tried to find evidence for the research questions throughout the open coding process. After all the codes were assigned, they were grouped into categories that addressed the research questions. Merriam (2009) calls this process of grouping into categories as “analytical coding” or “axial coding” (cited Corbin and Strauss (2007)).

During the third phase of the analysis, codes were compared and examined across participants. The codes are not mutually exclusive, so instances can be coded multiple times. A code chart organized according to the research questions is provided in Table 3-3.

In order to report the findings, I explained preservice teachers’ uses of inscriptions in their stories. Each participant’s story is developed according to his or her inscription use along with a lesson map. Lesson maps are developed according to teachers’ use of inscriptions and are provided after participants’ individual stories in the following sections. Lesson maps provide insight into the nature of each participant’s use of inscriptions in terms of its type and reasons for use of these inscriptions in their lessons. The key to read lesson maps is provided in Table 3-2.

Table 3-2 Key for the Lesson maps

Symbol	What it represents
	Triangles represents Normative Inscriptions
	Rectangles represent Pedagogical Inscriptions (The size of rectangles differ in the lesson maps, however it is just because of the amount of the text written in the rectangles, the size doesn't mean anything.)
	3D map-instructional object
	Light blue color represents when teacher uses inscription to convey final form scientific information
	Light Purple represent when teacher uses inscription to provide data or example from the nature.
	Light Green represents when teacher uses inscription to connect multiple ideas with multiple inscriptions.
	Light Orange represents when teacher uses inscription to engage students in scientific practice.
	Light red represents when teacher uses inscription to make thinking visible
	Dark red on the edges of the shapes represents when teacher uses inscriptions to engage students in the lesson. In these instances, teachers always have other purposes, so when dark red or dark blue is used with other colors, it means these inscriptions have multiple purposes.
	Dark blue on the edges of the shapes represents when teacher uses inscription for formative assessment. In these instances, teachers always have other purposes, so when dark red or dark blue is used with other colors, it means these inscriptions have multiple purposes.
	Plus represents the connection of multiple inscriptions in the same slide. If plus is not used in-between multiple inscriptions, this means the multiple inscriptions are combined or superimposed and become a layered inscription.
	Arrows represents the flow of the lesson according to inscription use.
Texts	Under the each shape and under the arrows, there are text boxes. What is happening during each inscription use or between inscriptions use in the whole lesson are explained in these text boxes.
Sequence number and time duration	Each sequence represent the inscription use instances in the lessons and time durations of each instance are also provided in the maps.

**Table 3-3 Code Chart**

Research Questions	Categories		Codes
What kinds of inscriptions do preservice teachers use in their peer teaching activities?			Maps
			Diagrams
			Photos
			Equations
			Graphs
			Pictures
			Chart
			Normative Inscription
How do preservice teachers use inscriptions in their peer teaching activities?			Through Lecturing
			Through asking students create, read, and interpret inscriptions
			Through Combining and Superimposing inscriptions
			Through gestural practices
Why do preservice teachers use inscriptions in their peer teaching activities?		To provide data about the concept being taught	To give example of fault from nature
			To give examples of different species
			To represent the process of phase change
	To assess students' understanding (Formative Assessment) Create a shared space	To make students' thinking visible	Make students draw pictures of solid, liquid and gas
			Make students use inscription to explain the blood circulation
			Draw diagrams to explain students' ideas about driving the turn

	To engage students in the lesson		Make students draw pictures of solid, liquid and gas
		To connect multiple ideas with multiple inscriptions (layered inscriptions)	To connect different scales
			Transform multiple inscriptions to create new inscription
			To represent the relationships between temperature, pressure, and volume
		To convey final form scientific knowledge	To explain the heart structures and functions, blood circulation, biological terms
			To explain the function of mitochondria, and the chemical reaction in mitochondria
			To introduce earth science terms
			To explain the structure of the plate tectonics, and evidences for plate tectonics theory
			To explain the movements of continents, and continental drift theory
	To review the lesson and assess the students	To engage students inscription practices/scientific practices	Make students interpret the pulse graph
	To Engage students for the lesson		Create chart to classify species with students
			Make students display (pulse) data on the graph
			Make students record earthquakes
			Make students read the pulse graph
	To asses students' understanding (Formative assessment)		Make students create a graph representing phase changes of water



## **Chapter 4**

### **FINDINGS**

#### **4.1 Introduction and Overview**

The current chapter is organized around research questions. The first question aims to answer the kinds of inscriptions used in the lessons. The second question is answered through stories of participants' inscription use in their peer-teaching activity. Participants' stories include how and why preservice teachers use inscriptions and the lesson maps showing the types of the inscriptions used in the teaching. Participants' stories are organized around why preservice teachers used inscriptions and how they used them is given in the explanations of why they used them. Finally, a summary for each participant is provided at the end of that story.

## 1. What kinds of inscriptions do preservice science teachers use in their peer teaching activities?

**Table 4-1 Codes for the first question according to participants**

Research Questions	Participants	Codes	
What kind of inscriptions do pre-service teachers employ/ use in their peer teaching activities?	Anne, Jack	Normative Inscriptions	Maps
	Anne, Alice, Jack, <u>Selim</u> , Mark	Pedagogical Inscriptions	Diagrams
	Anne, Sam, Tammy, Alice	Pedagogical Inscriptions	Photos
	<u>Selim</u>	Normative Inscriptions	Equations
	Alice, Sam, Mark	Normative Inscriptions	Graphs
	Sam, Mark	Pedagogical Inscriptions	Pictures
	Tammy	Normative Inscriptions	Chart

The first question of the study was asked in order to find out the types of inscriptions across different lessons. The results of this question according to participants are provided in Table 4-1. Anne and Jack are earth science major preservice teachers and they used maps, diagrams and photos in their lessons. Alice and Tammy used diagrams, photos, a graph and a chart in their biology lessons. Sam used graphs and photos in his chemistry lesson. Selim and Mark are physics major preservice teachers and they used diagrams, graphs and equations in their lessons. The pattern about the types of inscriptions in different lessons is consistent with Lemke's (1998) study. He described the preliminary survey he did with 20 articles from two issues of *Physical Review Letters* and 31 technical reports from two issues of *Science*. He stated that *Physical Review Letters* is one of the most respected journals in the physical sciences and *Science* is the corresponding journal for the biological and earth and space sciences. He found that mathematical expressions were less frequent in *Science*, but visual representations except tables such as photographs, molecular diagrams are more common. Therefore, the

pattern of kinds of inscriptions in the journals for the disciplines in Lemke's study is consistent with the inscription use of the teachers' trying to teach the scientific disciplines in the lessons.

The other result from this part of the analysis was the division of inscriptions into normative and pedagogical categories. This division emerged out of my coding of the inscriptions used by preservice teachers and I categorized inscriptions into these two groups broadly by the type of inscription. Maps used in the lessons are normative inscriptions because scientists created these maps out of data as a result of extensive measurements or observations. Diagrams are mostly pedagogical; teachers use them in order to explain concepts in a basic style to support students' understanding. Photos are pedagogical inscriptions and they are more direct and straightforward in terms of understanding. Equations are normative inscriptions and are used by scientists to represent the underlying principles of phenomena in a mathematical form. The graphs and charts used in the lessons are normative since scientists would use them in the same way used in the lessons. These are my attempt to organize inscriptions used in the classrooms in terms of the use in school and disciplinary communities. Preservice teachers used pedagogical inscriptions to help students bridge everyday concepts to scientific concepts. Preservice teachers also used normative inscriptions, which are the ones that scientists would use in their theory development or to communicate scientific theories, facts, and laws in scientific communities. Details about how teachers use these inscriptions can be seen in the participants' stories in the next part.

## **2. How and why do preservice teachers use inscriptions in their peer teaching activities?**

In this section, I provided the participants' stories regarding detailed inscription use in the lessons.

### **Anne's Story**

Anne is an earth science major preservice teacher. The title of her lesson for the peer-teaching event was earthquake mechanisms. She taught why earthquakes occur, where they occur, and what mechanisms prompt them. She mostly used PowerPoint slides to lecture the lesson. Her lesson map is provided in Figure 4-1. Her lesson map represents inscriptions used during the lesson along with some details about the structure of the lesson. She used one normative inscription and four pedagogical inscriptions. In Sequence 1, 3 and 4, she used inscriptions to convey final form scientific information. In sequence 2, she used the inscription to provide data or an example from nature about the concept being taught. She explained inscriptions through lecturing and using gestural practices, however in sequence 3 she did not attend to explaining the inscription. The excerpts of these instances are provided in the following sections.

### **To convey final form scientific knowledge**

In Sequence 1 and sequence 4 Anne used inscriptions to convey final form scientific knowledge (Duschl, 1988; Schwab, 1960). Sequence 1 is represented in the following section as a representation of conveying final form scientific knowledge.

Anne began her lesson by taking students' ideas about earthquakes, and wrote them on the board. Then, she moved to present her slides with the PowerPoint she prepared. She showed the plate tectonics map and explained the plate boundaries on the map. This map is a normative inscription that scientists created as a result of extensive data collection. The following excerpt conveys her explanation about the map:

The earth is comprised of all these [pointing to the plates on the map with her both hands] lithospheric plates and they are in motion. They don't move very fast but they are in motion. Where two plates meet right here [drawing 3 different boundaries between plates on the map with her finger] is called a plate boundary. And Earthquakes generally occur at plate boundaries. And somebody mentioned that [pointing to the board where she put student' ideas] and they do have occurred in plate boundaries but not always, which is pretty common. (04:42-05:10)

As it is apparent in this excerpt, Anne is using the map by pointing, touching, and drawing on the map to explain the plate boundaries and where earthquakes occur. She uses the map as a platform to show and introduce these scientific concepts (plates and plate boundaries) to the students. Notice how she purposefully draws on the map several times in order to show where plate boundaries are. In this instance, Anne introduces canonical earth science concepts to the students. In addition, it is important to notice how she explains these concepts by lecturing to the students, even though she connects her explanation to students' ideas at the end, she prefers to explain the map in an authoritative way.

### **To provide data or example from nature**

After she explained the plate tectonics map, she moved to another slide in which she explained the motion types and associated faults for each motion. In this slide, she

also showed a photo. The following excerpt is from her explanation of the slide in sequence 2:

Each plate boundary is associated with a specific plate motion, which creates a fault that can produce earthquakes. You guys know about this. Transform motion is associated with strike-slip faults. Divergent motion is associated with normal faults. Convergent motion is associated with reverse faults. And so when this happens, the two plates slip with respect to one another. And this over here [pointing to the photo on the slide] is San Andreas Fault. And it is called earthquake zone because it has a lot of fault lines along with it. (05:10-05:46)

In this instance, the photo is a pedagogical inscription. Anne explains this inscription after she explained the motion types and fault types. This photo is an example of fault from nature, which gives an opportunity to show an actual fault that earth science teachers cannot bring to the classroom. Therefore, this pedagogical inscription enables Anne to show what a fault looks like and serves as a data function. Anne uses this pedagogical inscription to provide an example from nature about the faults through pointing to the inscription.

### **No attention to the explanation of the inscription**

Anne moved to explain breaking point of rocks in the new slide. In this slide, she used a diagram showing the breaking point of rocks, and a picture of a plastic fork. The diagram is a pedagogical inscription, which models the breaking point of rock segments, but the picture of plastic fork is not an inscription, she used the plastic fork to make an analogy. While she was explaining this slide she re-presented the breaking of plastic fork by bending motion, and then she said, “Rocks have a breaking point as well. When a rock reaches its breaking point an earthquake occurs.” However, she did not make a connection to the diagram representing the breaking point of rocks. In this slide, Anne did

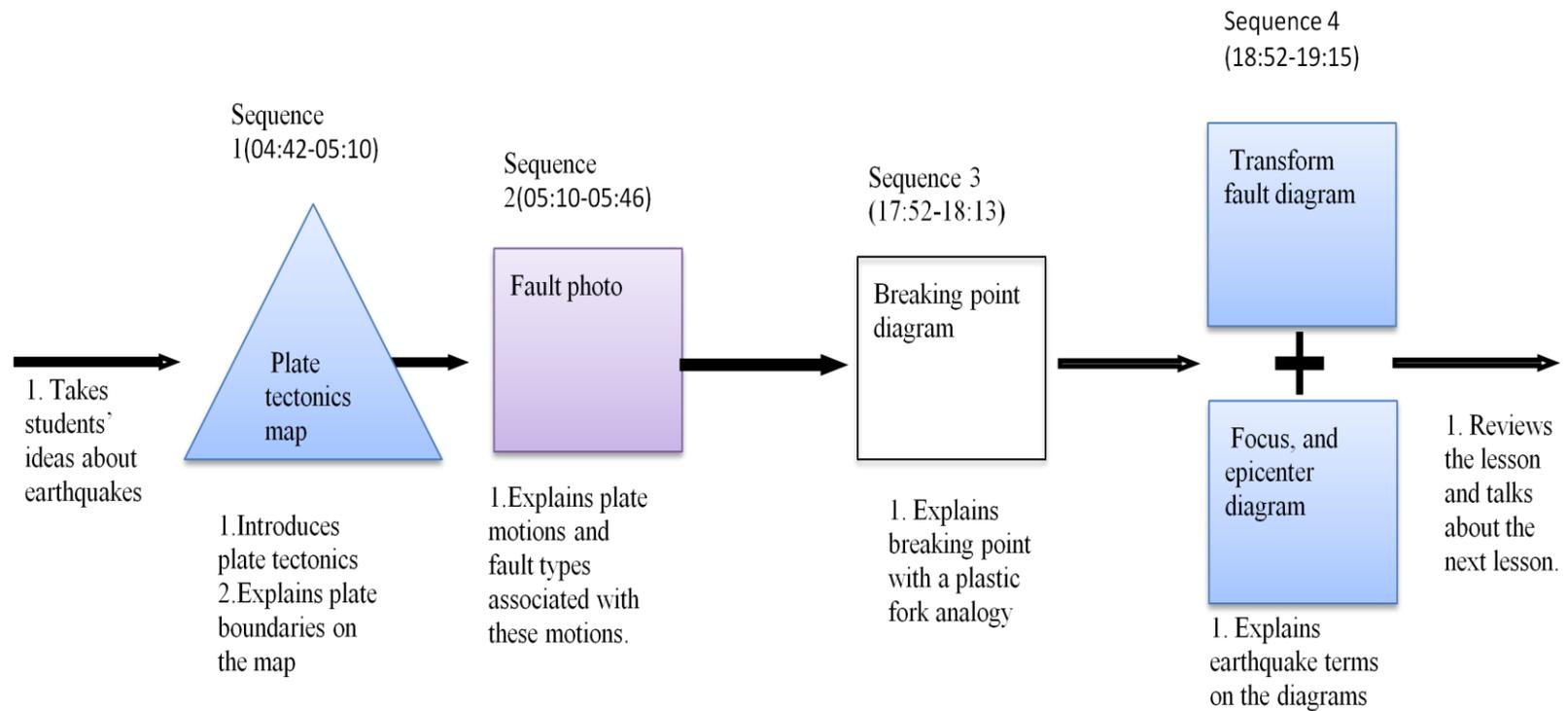
not attend to explain or even refer to the inscription she put in her slide. She may think that with the explanation she made students would understand the inscription or make a connection to the inscription, however the inscription was very detailed and included many scientific concepts and the geographic context of mountains and valleys. In a real classroom situation, students may try to link what is shown to them to the concept they are being taught, and if they cannot establish a healthy connection between the two, they may not direct their attention fully to the next concept. This could prevent students from following the lesson with the teacher, and the effectiveness of teaching along with the attention of students could fade away. Therefore, preservice teachers should explain what they present to the students.

### **Summary of Anne's Story**

Throughout Anne's lesson, she used a map as normative inscription, a photo and 3 diagrams as pedagogical inscriptions. She used the plate tectonics map and the last two diagrams as a platform to convey final form scientific information. She made her explanations on the inscriptions by using gestural practices. In these sequences, Anne used inscriptions to convey and introduce the earth science concepts to the students. She did all explanations about these inscriptions by lecturing. She used the photo as data to give an example of a fault from nature, which is a different purpose from using an inscription as a platform to convey final form scientific information. The last pedagogical inscription is the diagram representing the breaking point of rocks. Anne put this diagram in the slides; however, she did not attend to explaining or refer to it during the slide explanation. Overall, Anne used inscriptions for two purposes, one is to convey final

form scientific knowledge and the other one is as data or example from nature to the phenomenon that is being discussed in the lesson.

## Anne's Earthquake Lesson



**Figure 4-1 Anne's Lesson Map**

## **Alice's Story**

Alice is a biology major preservice teacher. Alice's lesson is on circulation and respiration. Her lesson is very rich in terms of the use of inscriptions compared to those of some other participants. Her lesson map is provided in Figure 4-3. I organized the lesson map from the beginning of the lesson to the end of the lesson in a linear format representing the inscriptions used. As it is seen in the map, she used two normative inscriptions, one at the beginning and one at the end of the lesson and nine pedagogical inscriptions in between these two normative inscriptions. Two normative inscriptions (Sequence 1 and Sequence 11) are the same inscriptions but used in different times for different purposes in the lesson, so I represented them two times in the lesson map. In the lesson, she used inscriptions for multiple purposes. These purposes (or ways) are to engage students in scientific practice, to convey final form scientific information, to make student thinking visible and formative assessment, and to connect multiple ideas and concepts using multiple inscriptions. The excerpts of these instances are provided in the following sections.

### **To engage students in scientific practice**

To engage students in scientific practice is one way that Alice used inscriptions. Sequence 1 and 11 are interrelated instances and representations of this situation. The following excerpt represents the sequence 1 and also refers to the sequence 11 at the end. She began her lesson with an activity and wanted students to take their pulses and record

them for resting, walking, and doing jumping jacks for one minute. After they gathered their data and recorded them, she wanted students to graph their results. The following excerpt represents how she engaged students in scientific practice.

Alice: Okay, So, the next thing I want you guys to do is work in groups and I want you to take number of beats you felt for resting versus walking versus doing jumping jacks and make a graph showing these...

[Students are talking to each other and drawing their graphs on their notebooks, and one student from each group (there are three groups) is drawing their graphs on the board.]

[While students are drawing] Alice: okay, while these guys are drawing up here, without explaining why, what is going on, you guys describe me what exactly we are seeing on these graphs. So, what are these showing us just by looking at what they are drawing [students are still drawing on the board]?

A student: A little increase.

Alice: A little Increase for?

A student: [Inaudible]

Alice: You guys more active then.

A student: Yeah

Alice: So, basically, as you go from resting to jumping jack because of greatest amount of activity, you see an increase on the speed for a minute.

[After students finished drawing on the board, she approached to the board]

Alice: You see across all the groups here, increase [she is pointing and making a increase movement with her finger on the first student's activity graph], increase [she is pointing and making a increase movement with her finger on the second student's activity graph], and increase [she is pointing and making a increase movement with her finger on the third student's activity graph], for a minute as we increase the activity [pointing to the axial line of the graph]. Basically, we can see our results, now what we want to do is explain exactly why we see this increase for a minute, so I want you guys to be thinking about this as I gave you more information about circulation and respiration because at the end of the class I want you be working in groups and try to explain what is going on [pointing to the graphs on the board], why we see this increase. (00:46-07:08)

This excerpt shows how Alice engaged students in creating a normative inscription out of the data they collected. In this instance, she let students display this data with the graph, which is a normative inscription. After students created the graph, she asked them to read the graph, which is an important scientific practice. She scaffolded students while students were reading the graph through asking questions. After

students' finished reading, she also read the graphs and explained what they drew. However, she did not ask students to interpret the graph, which is also an important inscription practice. She purposefully connected the graph interpretation to the rest of the lesson. Therefore, she achieved multiple purposes with this normative inscription. She engaged students in scientific practice by letting them create an inscription and read the inscription. Thus, engaging students in scientific practices gives them opportunities to get close to and experience the practices of scientists. Alice also used this graph as an engagement tool for the lesson by connecting the graph interpretation to the rest of the lesson. In addition, at the end of the lesson (in sequence 11), she used this graph as a review or assessment tool of the lesson by asking students to interpret the graph.

### **To convey final form scientific information**

To convey final form scientific information is another way Alice used inscriptions. In Alice's lesson map, the pedagogical inscriptions in Sequence 2, 3, 6, 7, 9, and 10 are used to convey final form scientific information. In these sequences, she used inscriptions as a platform to talk about a scientific concept, a process, or a phenomenon. Sequence 2 is provided in the following excerpt as a representation of conveying final form science. In sequence 2, after she talked about the definition of pulse, she presented the skeleton diagram. The following excerpt is her explanation about the skeleton diagram:

Alice: You can also feel pulse from rest of your body; you can even get pulse from behind your knee, also in your neck. What indicates we actually have these vessels, arteries going throughout the entire [touching and pointing on the skeleton diagram] body, so it is not just in your wrist [touching her wrist], it is whole thing [pointing to her own body], and you got blood circulating through

these vessels [pointing and drawing on the diagram to the vessels] all the way through. And you can see on this diagram here [touching on the diagram] one's [pointing on the diagram] color blue and one's [pointing on the diagram] color red, but Jack was mentioning before we had veins versus arteries, so who can tell me what an artery is?

Jack: Carries blood away from heart.

Alice: Yeap, so an artery carries blood away from the heart. So who can tell me what a vein is then?

Selim: It brings it back.

Alice: Yeap, it brings back, arteries stay away and veins bring blood back to the heart. So, one thing I wanna show right here [pointing to the heart on the skeleton diagram] is to bring your focus right on the heart and exist a pump [touching and making moving motions on the diagram] that sends blood rest of your body. (08:28-09:27)

In this instance, she used this pedagogical inscription to explain from which parts of the body they can take pulses, and the scientific concepts (artery, vein) and processes (heart pumping). She made scientific explanations on the pedagogical inscription with extensive use of gestural practices to emphasize the parts of the body. She used the inscription as a platform to convey final form scientific information. This inscription is a mediating device that Alice used to introduce scientific terms to the students. While conveying scientific information, she tried to involve students through asking questions.

### **Making student thinking visible and formative assessment**

Making student thinking visible and formative assessment is another way Alice used inscriptions. Sequence 4 is a representative of this situation. After she explained the structure of the heart, the functions of these structures, and the blood circulation on the heart diagram in sequence 3, she engaged students in an activity. The following excerpt shows how she introduced the activity in sequence 4.

I have a quick activity for you guys just to make sure that you understand the diagram and how blood flows through. You'll see that at each table there is diagram of the heart [showing the diagram printed on the paper] and I am giving you two different colors of string, you got red and blue. Red represents [showing the red string] oxygenated blood and blue represents [showing the blue string] unoxygenated blood. I just want you to kind of wrap the string on top of the diagram [pointing and showing the diagram on the paper to the class] where there be a certain type of blood model, so red would be rivers oxygen and also I want you to draw joint arrows the blood path through. [Students are drawing with the strings on the diagram and Alice is visiting each table and looking at the diagrams' accuracy.] Okay, you guys have a pretty good understanding of oxygen levels and blood. This is actually going to be important for respiration, kind of think about this [pointing to the blood circulation diagram] as we were doing jumping jacks versus walking, what exactly is going on with circulation of blood why is that important in the whole process. (12:48-15:43)

In this excerpt, Alice engaged students in the activity with a diagram wanting them to draw the circulation of the blood on the diagram. So, in this activity Alice is trying to get students' understanding of the circulation of blood by engaging them this drawing. She uses the diagram to make students' ideas (about the blood circulation) visible and for formative assessment purposes. Therefore, Alice used this pedagogical inscription for multiple purposes.

### **Using multiple inscriptions to connect multiple ideas**

Using multiple inscriptions to connect multiple ideas and concepts is another way Alice used inscriptions. Alice used the pedagogical inscriptions in sequence 5 and 8 differently than all other inscriptions. Alice combined and superimposed 4 different inscriptions (2 photos and 2 diagrams) and made them a layered inscription. In these instances, she combined inscriptions in a way to connect multiple scales and concepts. After the heart diagram activity (sequence 4), she showed this layered inscription (two

photos and two diagrams). The following excerpt is her explanation of sequence 5 representing this situation.

Alice: So, if we talk about respiration, okay, so if we talk about respiration a little bit, notice that when you are doing your dumping jacks, something else is going on, so yeah your pulse is increasing but what else comes with that, you notice anything else change?

A student: Breathing

Alice: So, You are breathing a little bit more heavily or?

A student: Yeah [inaudible]

Alice: Okay, you are breathing heavily, this means that you have this greater demand for oxygen. And it is easiest to explain this by kind of going all the way down through the cell level. So start of with there [Number 1 in the Figure 4-2] and then we look behind the other picture then we go on to the tissue level your muscles are also demanding more oxygen [Number 2 in the Figure 4-2], moving through the down we are looking a little bit closely within the tissue that still demanding more oxygen [Number 3 in the Figure 4-2], if we go into the cell, we can see mitochondria here [Number 4 in the Figure 4-2], what are the mitochondria responsible for? This might help us understand.

Liam: Breaking glucose to ATP.

Alice: [nodding to student's response] breaking glucose to ATP. So, who can tell me what exactly ATP does? Or what does it supply for cell.

Andy: Energy

Alice: Energy yeah, so ATP supplies energy. (15:46-17:06)



**Figure 4-2 Explanation of a layered inscription**

In this excerpt, Alice shows two pictures and two diagrams in order to explain the demand of oxygen from body muscle level to tissue and cell level. So, she combined and superimposed photos and diagrams consecutively in order to explain the phenomena and concepts in different scales. She also involved students in explanation of the concepts through asking questions.

### **Summary of Alice's Story**

Alice used many inscriptions in her lesson on circulation and respiration. She engaged students in scientific practice through making them create and read normative inscriptions. She used the interpretation of this inscription as an engagement activity for the rest of the lesson. Therefore, she used the first normative inscription to engage students in scientific practice and to engage for the rest of the lesson. She used same normative inscription at the end of the lesson as a review and assessment of the whole lesson by means of asking the interpretation of the normative inscription. Alice used most of the pedagogical inscriptions in between these two normative inscriptions in order to explain the meaning of the first normative inscription (graph). So, Alice helped students co-construct the meaning of the inscription through the lesson situated in the multiple inscription practices. While Alice was helping students co-construct the meaning of the inscription, she used many pedagogical inscriptions along the process for different purposes. She used inscriptions to convey final form scientific information and she tried to integrate students through asking questions in these situations. In these instances when Alice conveys final form science, these inscriptions serve as mediating devices, which

help Alice to explain the scientific concepts to the students who are new to the scientific community. In the other instance when she used pedagogical inscription, she used them to make students' thinking visible and for formative assessment purposes. And last but not least, she used multiple inscriptions (layered inscriptions) to connect multiple ideas and concepts by combining and superimposing pedagogical inscriptions.

### Alice's Circulation and Respiration Lesson

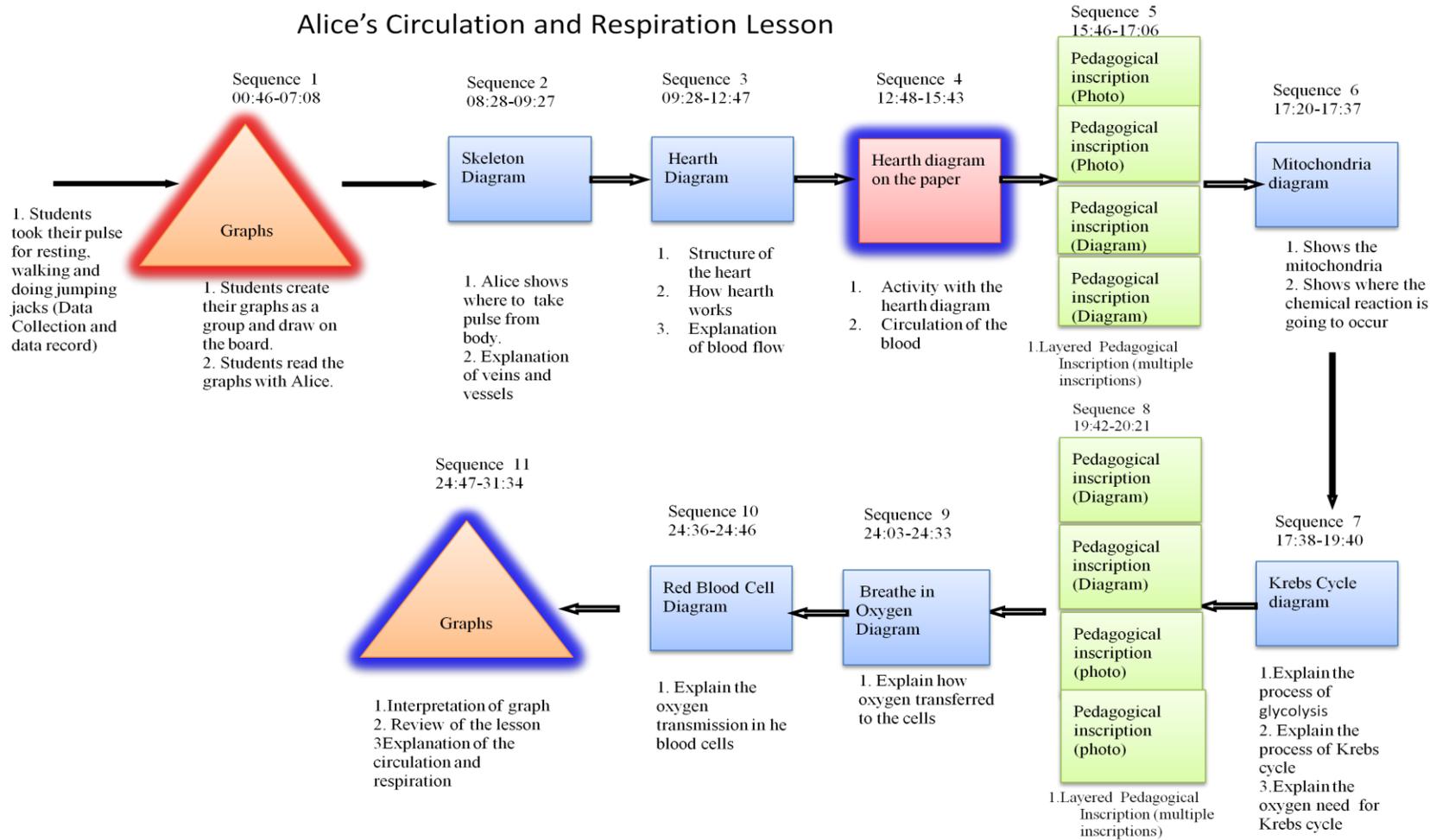


Figure 4-3 Alice's Lesson map

## **Jack's Story**

Jack is a Secondary education major with an Earth and Space option. His lesson is on plate tectonics targeting students in grades 9-12. He mostly used PowerPoint slides to lecture the lesson along with the activities he made students work on. He taught how, why, who, and when the theory of Continental Drift came about, and why this theory was put down and criticized by other scientists and how it sparked the theory of Plate Tectonics, and the evidence of plate tectonics theory, ocean floor mapping, magnetic striping and polar reversals, seafloor spreading and concentration of earthquakes.

Jack's lesson map is provided in Figure 4-4. As it is apparent in his lesson map, he used many pedagogical and normative inscriptions in nine sequences. He used inscriptions to convey final form scientific information in Sequence 1, 2, 3, 4, 5, 6, 7, and 9. He used the inscription in sequence 8 to engage students in scientific practice. To represent these instances, I provide the explanations in Sequence 1, and 8 as the example of these two situations in the following excerpts.

### **To convey final form scientific information**

After Jack elicited students' ideas regarding how Wegener's idea of continental drift theory is different from the theory of plate tectonics, he presented the continental drift map in the slide. The following excerpt is his explanation of the map in the Sequence 1.

Jack: Wegener proposed a lot of ideas. What he claimed was about 300 million years ago supercontinent was formed and has since been rifting apart. Does anybody know what supercontinent was called?

[There is no answer from the students.]

Jack: Pretty stuff [pointing to the supercontinent on the map], Pangaea [labeling the part and pointing on the map], that's awesome. Like we said before, Wegener's explanation was continents moved through the earth's crust, they almost like, he said, flown through imagine like a iceberg flown through sheets of iceberg (...) So, a lot of people like, how is that happen, is it just one forms of for example, Eurasia here [pointing on the map], this [pointing and emphasizing with his hands on the map] whole piece is connected down all the way from the earth and moved up north [pointing and making moving motion to show its drift to illustrate how the continent moved to other side]. So, a lot of people were confuses how could that happen, there is no real life evidence to show that can happen. He also said that a lot of this responsible for centripetal tidal (...) and he claimed that north America and Europe are moving apart at two hundred fifty centimeters in a year, you can imagine that 's really fast in a year relatively. (12:11-13:41)

In this instance, the map representing the supercontinent is a normative inscription, which represents the continental drift theory. Jack uses this map as a platform to explain how continents move apart from each other by making moving apart motions with his hands and to convey Wegener's explanation of the theory. He uses this inscription as a mediating device to explain final form scientific information regarding Wegener's explanation of the continental drift. During his explanation, he uses many gestural practices (pointing, labeling and emphasizing) and tries to involve students through asking questions.

### **To engage students in scientific practice**

In this instance he gave maps of the world on the papers and also recorded earthquake locations and wanted students to map these earthquakes. The following excerpt is his explanation of the activity in Sequence 8.

Jack: I want you to do this activity real quick. So mentioned before, you said [referring to Mark] earthquakes would be a class. These [he is distributing papers to the students] are maps of the world. And I have [he is bringing a container in which there are papers in which earthquake locations are given.] earthquakes that have happened, recorded earthquakes.

Just pick one. [He is handing the container to the students and wanting them to pick one paper] Pause it out, just take a marker or pencil and mark that, that's fine.

Mark: just want me to say it.

Jack: yeah, just say it out loud.

Mark: J8 [Mark is reading the earthquake location and other students are recording them on the map.]

Andy: K8 [Andy is reading the earthquake location and other students are recording them on the map.]

Selim: H9 [Selim is reading the earthquake location and other students are recording them on the map.]

Anne: I9 [Anne is reading the earthquake location and other students are recording them on the map.]

Alice: E8 [Alice is reading the earthquake location and other students are recording them on the map.]

Sam: L7 [Sam is reading the earthquake location and other students are recording them on the map.]

Liam: C5 [Liam is reading the earthquake location and other students are recording them on the map.]

Anne: K5 [Anne is reading the earthquake location and other students are recording them on the map.]

Jack: Those have been recorded earthquakes, we measured those, but you know, you can see an obvious pattern, right? Where are these earthquakes occurring?

Liam: (..)

Jack: (..)

Anne: (..)

Jack: A lot of these I gave you are they are current in the oceanic, in the ocean, and you see a lot of evidence here [shows the map which is showing the earthquake patterns.] (37:47-40:41)

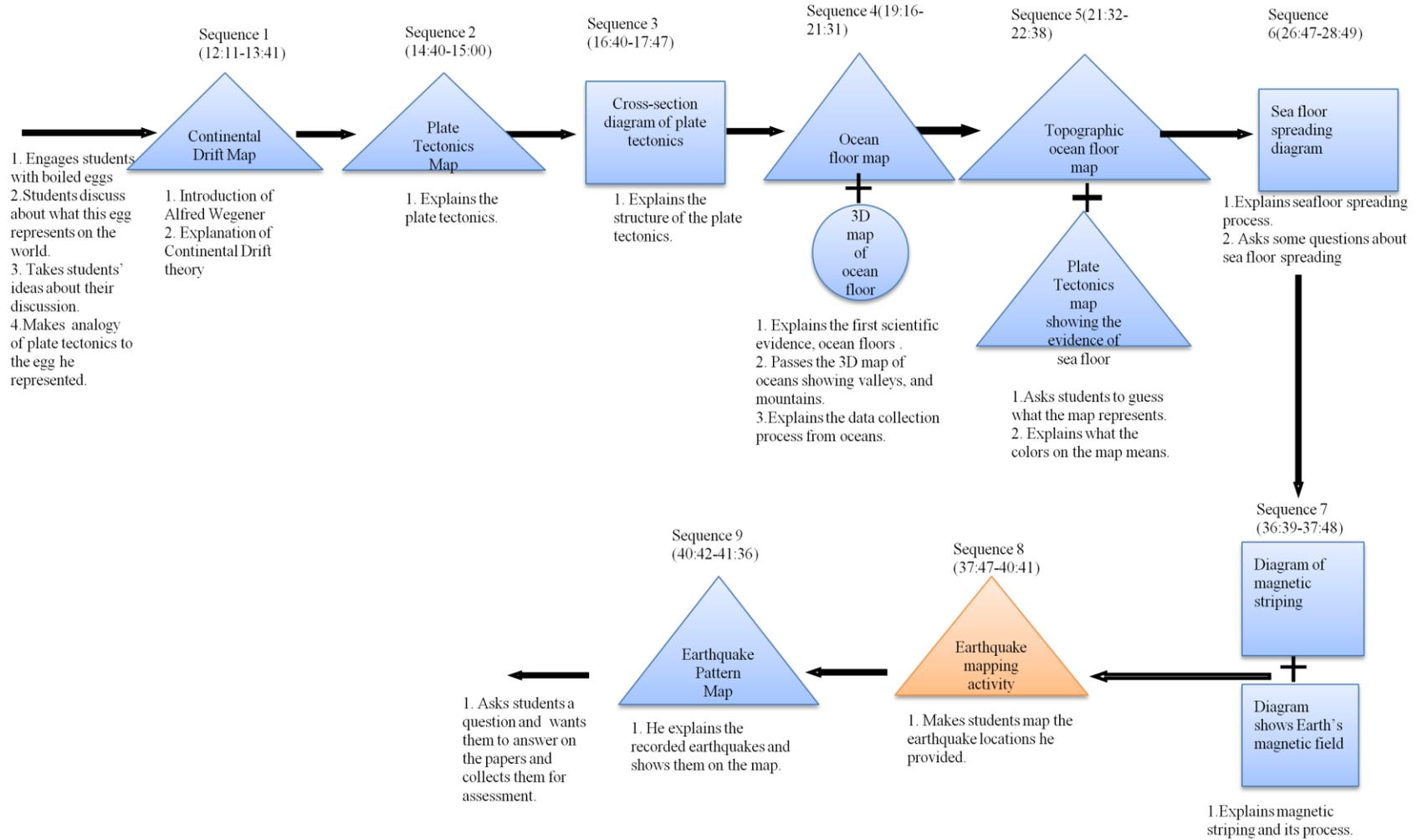
As it is seen from the excerpt, he provided the maps and the data of already collected earthquake locations. Students recorded these locations on the map, so that they displayed the data on the map inscription. Displaying earthquake locations on the map is creating the normative inscription or practice of data plotting on the map, which is considered as scientific practice. After students plot their data on the map, Jack is asking,

“Those have been recorded earthquakes, we measured those, but you know, you can see an obvious pattern, right? Where are these earthquakes occurring?” to interpret their inscriptions, which is also a scientific practice. Through this activity, Jack engaged students in inscription practices (creating and interpreting). After students interpreted them, he showed the whole earthquake patterns that have been recorded so far.

### **Summary of Jack’s lesson**

Jack’s lesson map is provided in Figure 4-4. He used pedagogical and normative inscriptions in nine sequences. In Sequence 1, 2, 3, 4, 5, 6, 7, and 9 inscriptions serve as a platform to convey final form scientific information. In these instances, he tried to engage students in interpreting or reading the inscriptions through asking various questions, and employed various gestural practices while conveying the information through the inscriptions. He used a normative inscription in sequence 8 to engage students in scientific practice. In this sequence, he engaged students in creating and interpreting the inscription.

### Jack's Plate Tectonics Lesson



**Figure 4-4 Jack's Lesson Map**

## **Sam's Story**

Sam is a secondary education major with chemistry option preservice teacher. Sam's lesson is on properties of solids, liquids and gases. He used inscriptions for different purposes in 4 sequences represented in his lesson map provided in Figure 4-5. In the first sequence, he used inscriptions to make students' ideas visible, and as a result of making students' ideas visible he can have an idea of their understanding, so he also used inscriptions for formative assessment purposes in this case. In the second sequence, he used inscriptions as data or example from nature to represent the process of a phenomenon by combining inscriptions. In the third sequence, Sam engaged students in scientific practice and also assessed their understanding through their drawings, so in this instance the purpose was to engage in scientific practice and formative assessment. In the last sequence, Sam used inscription to explain final form scientific information. All these instances are provided in the following sections along with some context from the lesson.

### **To make students' ideas visible and formative assessment**

Sam began the lesson by taking students' ideas about the properties of solids, liquids, and gases and wrote them on the board. He then wanted students to give examples for solids, liquids and gases, then engaged students in activities with the mixture of cornstarch and water, and shaving cream and asked students to observe their characteristics. After the observations, he wanted students to discuss their observations and he compared the observations with their prior ideas written on the board. Then, he

explained the properties of solids, liquids and gases in the PowerPoint slides, and made students do the activity, “Let’s Hold Hands”: acting like a solid, liquid and gas. After doing the “let’s hold hands” activity, he wanted students to draw the picture of what solids, liquids and gases look like. These pictures are pedagogical inscriptions that are used to represent the molecules in different states. The following excerpt is his explanation of the activity in Sequence 1:

Sam: The next thing I want to do is come up with pictures of what solids, liquids and gases look on the molecular level. So I would like each group take out piece of paper and we are going to draw three deeper looking items for (...) and I want you to draw molecules to look like for a solid liquid and gas. [While students are drawing on the papers, Sam is also drawing empty buckets on the board and labeling them as solid, liquid and gas] Discuss this in your groups. [Students are talking to each other.] You can use an example you don’t necessarily have to use. [Sam is visiting tables and talking to groups, looking at what they draw] So, who is the volunteer? [One student is approaching to the board] which one you pick?  
Anne: Solid.

Sam: Okay, solid state. Liquid and gas people [Two more students approached to the board and began drawing pictures of solid, liquid and gas. Students are drawing on the board. After they finished drawing Sam approaches to the board.] All right, so solids [touching and pointing to the molecules on the board in solid state] draw molecules packed together that was like pretty ordered, there is nice structure there. These [touching and pointing to the molecules on the board in liquid state] are spaced a little bit more, it is slightly more disordered. And here [looking at the gas state], there is tales I am assuming [looking at Mark who drew gas state] they are like moving up directions.

Mark: Arrows.

Sam: Excellent, okay. These [touching and pointing to the molecules on the board in gas state], there is lesser than in this space and they are moving in different direction, they are more spread out, more disordered. Very good. Okay, you guys are really smart. (28:03-31:48)

In this instance, he made students draw the pictures of solids, liquids and gases on the molecular level, so because students are drawing these pictures I interpret this instance as these inscriptions are used to make students’ ideas visible. In addition, because he asked students to draw these pictures after they engaged in many observations

with real substances and also after their discussions of the properties of solids, liquids and gases, making students draw these pictures also aims assessing their understanding. Therefore, I interpret it as also for formative assessment purposes. After students drew the pictures, he interpreted their drawings.

### **Using as data or example to represent the process**

After talking about intramolecular forces that keep molecules together in the solid and liquid phases, they discussed that temperature causes breaking these intramolecular bonds between molecules. Then, he showed the “heat it up” slide, and in this slide he put photos of ice, water and steam next to each other. These photos are pedagogical inscriptions. The conversation during this slide happened in sequence 2 is provided in the following excerpt:

Sam: Adding energy to the system in the form of heat will cause ice to turn in water, and eventually steam. Now, does anybody have an idea of why this might happen?

Andy: Because once you heat, you have more kinetic energy, and that molecules vibrate.

Sam: Excellent, the connection between the heat and the kinetic energy of a molecules vibrates faster. (33:34-33:58)

In this instance, Sam put photos showing ice, water and steam in a sequence representing the process of phase change. Even though he did not refer to the photos in this instance, he said, “Adding energy to the system in the form of heat will cause ice to turn in water, and eventually steam”. The photos are complementing what he said. He used these photos to show the process because he did not make them observe the actual

process of phase change, I interpret he used them as data or example to represent the process of the phenomenon.

### **To engage students in scientific practice and for formative assessment**

Before this instance, he explained why it is more difficult to go from liquid to gas than go from solid to liquid and also the reason why the temperature of ice does not rise when the heat is added in 0 °C. After these explanations, he engaged students to create a graph showing the phase changes. This graph is a normative inscription, which scientists would use to communicate to each other. The conversation in this instance in sequence 3 is provided in the following excerpt.

Sam: Another activity that we are going to do is take out another piece of paper. I want you create a graph with temperature on the x-axis, sorry, temperature on the y-axis, time on the x-axis, we are going to show what happens as water is heated between -10°C to 140°C knowing just we learned from the last part. First talk about this in your groups. When you finish your graph, can you put your hands up I know you are done? [Students are drawing their graphs, and Sam is visiting tables] Very good [he is commenting on one of the students' graph]. One other thing, can you label solid, liquids and gases? [As he is looking at the graphs, he is asking questions to the students based on their graphs] Okay, take another minute to finish up. (36:29-39:45)

In this instance, Sam gives the data values to the students and students create the graph, so creating a graph is an inscriptional practice, and I interpret this inscriptional practice as engaging in the scientific practice. When Sam was giving directions, he also said, “knowing just we learned from the last part.” Therefore, he is trying to assess students' understanding of why it is more difficult to go from liquid to gas state than to go from solid to liquid state and also the reason why the temperature is constant during

the phase changes. Thus, I think Sam is also using this inscription for formative assessment purposes.

### **To convey final form scientific information**

After he made students draw the graphs, he showed another slide and explained the names of the forms when there is change from solid to liquid, solid to gas, liquid to solid, liquid to gas, gas to liquid and gas to solid, and wanted examples for these forms from students. Then, he showed the graph, representing phase of water from  $-10^{\circ}\text{C}$  to  $140^{\circ}\text{C}$  on the slide and explained the graph. The graph is a normative inscription. His explanation of the graph in Sequence 4 is provided in the following excerpt:

Sam: Bringing it all together, this is what the graphic should've looked something like on your papers. Here [pointing and touching on the graph's first part showing the temperature increase in solid phase] we have solid, which should have been heated. Here [touching and pointing to the graph's constant temperature part from solid to liquid] we are going to phase change, so temperature is constant. Melting or freezing depending on which direction you are going. Now, as you are going, here [pointing to the liquid phase] we have a liquid being heated. What did you notice about this line [pointing to the liquid phase] and the line right down at the bottom [pointing to the solid phase]?

Student: [Inaudible].

Sam: Don't think about [inaudible], how about length.

Student: [Inaudible.]

Sam: Excellent. Okay, this [Pointing to liquid phase] is obviously much longer than this [pointing to solid phase]. That has to do with how much energy the system have, so it takes a lot of energy to break the intramolecular bonds in liquid than as you are going to solid to liquid. Liquid this here [pointing to the liquid phase], and right here [pointing to the transition part from liquid to gas] this is the transition liquid to gas, so as remaining constant temperature vaporization happens. Once you get the heat, once you get the gas, keep notice [pointing to the gas phase] the temperature will increase (41:30-42:42)

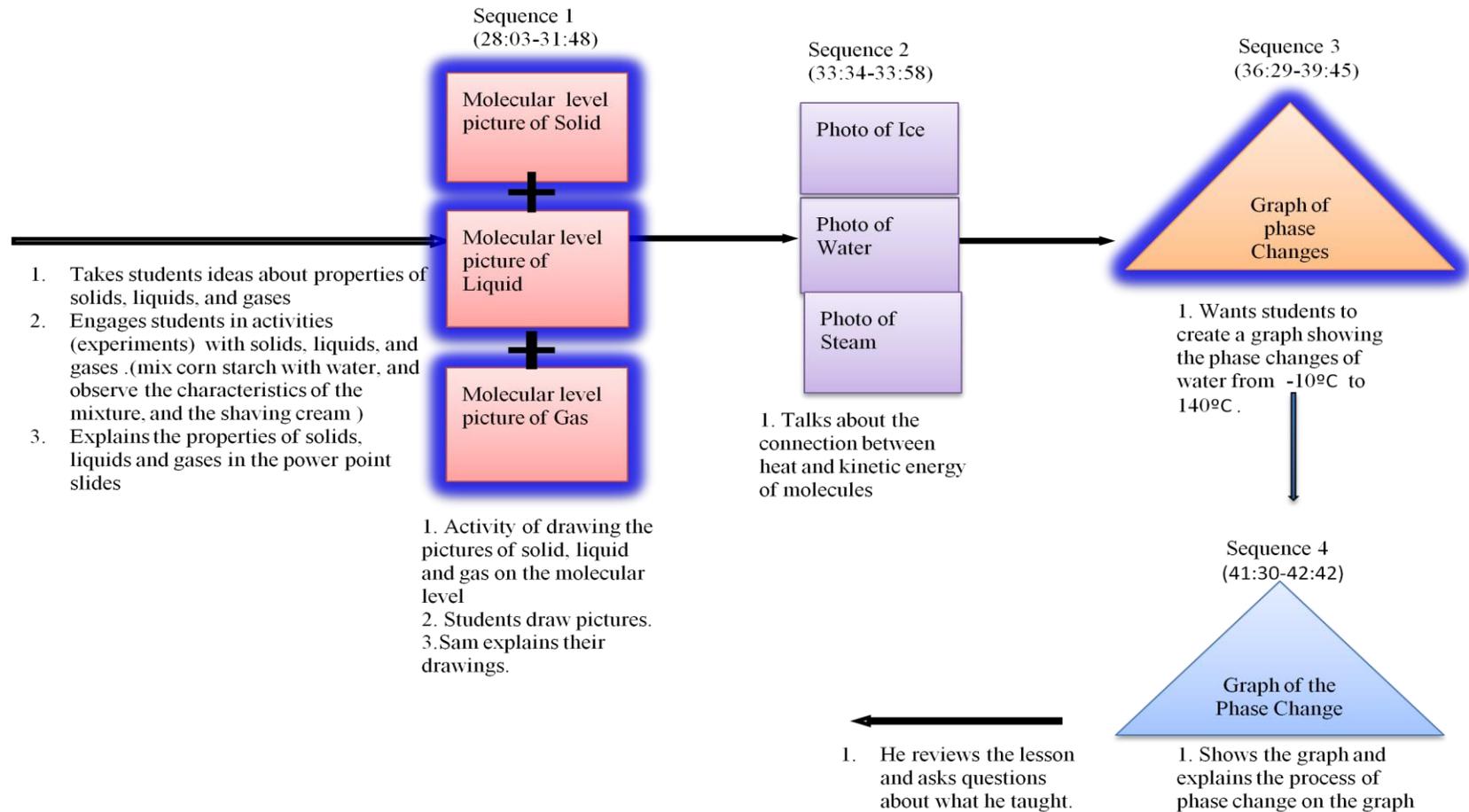
In this instance, he explained the phase changes of water on the graph. He used the graph as a platform to explain the final form scientific concepts related to phase

changes. Sam tried to involve students in interpreting and reading the graph through asking questions along with his explanations. In addition, when he is explaining the graph, he used extensive gestural practices to show and emphasize the parts of the graph.

### **Summary of Sam's Lesson**

Sam's lesson is on properties of solids, liquids and gases. Sam used inscriptions 1) to make students' ideas visible and as a result of that for formative assessment, 2) as data or example from nature to represent the scientific process by combining inscriptions, 3) to engage students in scientific practice and also for formative assessment, 4) to explain final form scientific information by using gestural practices and involving students through questioning.

## Sam's Properties of Solids, Liquids and Gases Lesson



**Figure 4-5 Sam's Lesson Map**

## Mark's Story

Mark is a physics major preservice teacher. His lesson is on the physical characteristics of gases. His lesson map is provided in Figure 4-8. In his lesson, he used inscriptions 1) to make students' ideas visible and to engage students for the lesson, and 2) to connect the relationships between multiple concepts by using multiple inscriptions.

### To make students' ideas visible and to engage students for the lesson

When Mark started his lesson he referred to Sam's lesson on properties of solids, liquids and gases and elicited students' ideas regarding the properties of solids, liquids and gases. Then, he wanted students to draw a picture of what solids, liquids and gases look like. These pictures are pedagogical inscriptions that represent atomic structures of matter in different states. Mark's explanation of this activity in Sequence 1 is provided in the following excerpt:

Mark: Can I get someone from that group to draw a picture of what solid look like, someone from that group draw the liquid, someone from that group draw the gases. [Three students are drawing the pictures of solid, liquid and gas on the board. After students finish drawing Mark is explaining them.] So, we have [pointing to the student's drawing of the solid] some wonderful flooding solid. And we have [pointing to the drawing of gas particles] enormously gas particles. We should put (...), [he is drawing a line under the drawing of solid] so it doesn't fall, that seems dangerous. All right, so we did the right idea, like you said they [pointing to the drawing of the solid on the board] are all compacted, and then they [pointing to the drawing of the liquid] are spread out a little more, and then here [pointing to the drawing of gas particles] they are spread out a lot, and moving all over the place. So this [pointing to drawing of the gas particles] is good, because this is what we are going to talk about in thirty seconds. So that's awesome. (02:10-04:20)



**Figure 4-6 Students' drawing of atomic structures of matter in different states.**

In this instance, Mark wanted students to draw a picture of what solids, liquids and gases look like. Students' drawings are represented in Figure 4-6. These pictures are pedagogical inscriptions, which teachers would use to explain conceptually the atomic structures of matter. He wanted students to draw in order to understand their ideas about the atomic structures of matter in different state. After students drew them, he interpreted and explained their drawings by using gestural practices. In addition, at the end of his explanation, he said, "this is good because this is what we are going to talk about in thirty seconds." This means he is connecting these drawings to the rest of the lesson. Therefore, he used these inscriptions to engage students for the rest of the lesson.

### **To connect the relationships between multiple concepts with multiple inscriptions**

Prior to the Sequence 2, Mark explained the properties of solids, liquids and gases and introduced the kinetic molecular theory after eliciting students' ideas about what is special about gasses. After that, he introduced the real and ideal gas by comparison on the

board. In addition, he made students build barometers and have them discuss how barometers tell the weather. Then, he explained the concept of pressure and how barometers measure the atmospheric pressure. After all these explanations, he showed a web-based, diagram and graph combination layered inscription. This layered inscription is combination of a normative and a pedagogical inscription. The conversation around this inscription in Sequence 2 is provided in the following excerpt.

Mark: Now, I am going to put my little demo thing up here. [He is opening the link on the Internet.] Now, this like gas, this is the pressure up here [showing the bottom to change the pressure] so, we can change the pressure by the way with other things within the little box here [pointing to the box], so what do you think compared to the volume here to make the pressure go up?

Liam: Decrease the volume

Mark: Decrease the volume [repeating student's answer, and decreasing the volume from the bottom]

Mark: And, what about with the number of little dots in here [pointing to the atoms in the box]?

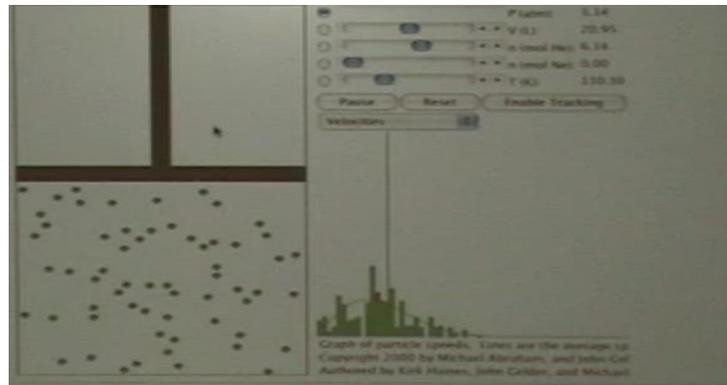
Anne: if you increase those.

Mark: Increase those, increase the pressure? [Repeating student's answer and increasing the number of dots with the bottom] Okay.

Mark: And then what about the temperature?

Alice: If you increase the temperature.

Mark: Increase the temperature. [Repeating student's answer and increasing the temperature.] Awesome, pretty successful. So, the point in this pressure thing is it is easiest if I increase the number of things here [increasing the number of atoms in the box with the bottom], you can see all these little guys [pointing to the molecules in the box] bouncing around are hitting the walls. So whenever they hit the wall, they are absorbing pressure on the wall because of their little tininess it is bouncing of the wall [pointing on the wall and making bouncing motion]. And, like you said, pressure is force per unit area. So, we found that lag on the wall they are causing force against the wall on little area, so the more times they collide on the wall, the higher the pressure is in the container. So, like you said if you decrease the volume [he is decreasing the volume] then there is less area for them to hit, so pressure goes up or if you increase the number [increasing the number of atoms] and also temperature [increasing the temperature] is also really going. (26:46-28:29)



**Figure 4-7 Mark's web based layered inscription**

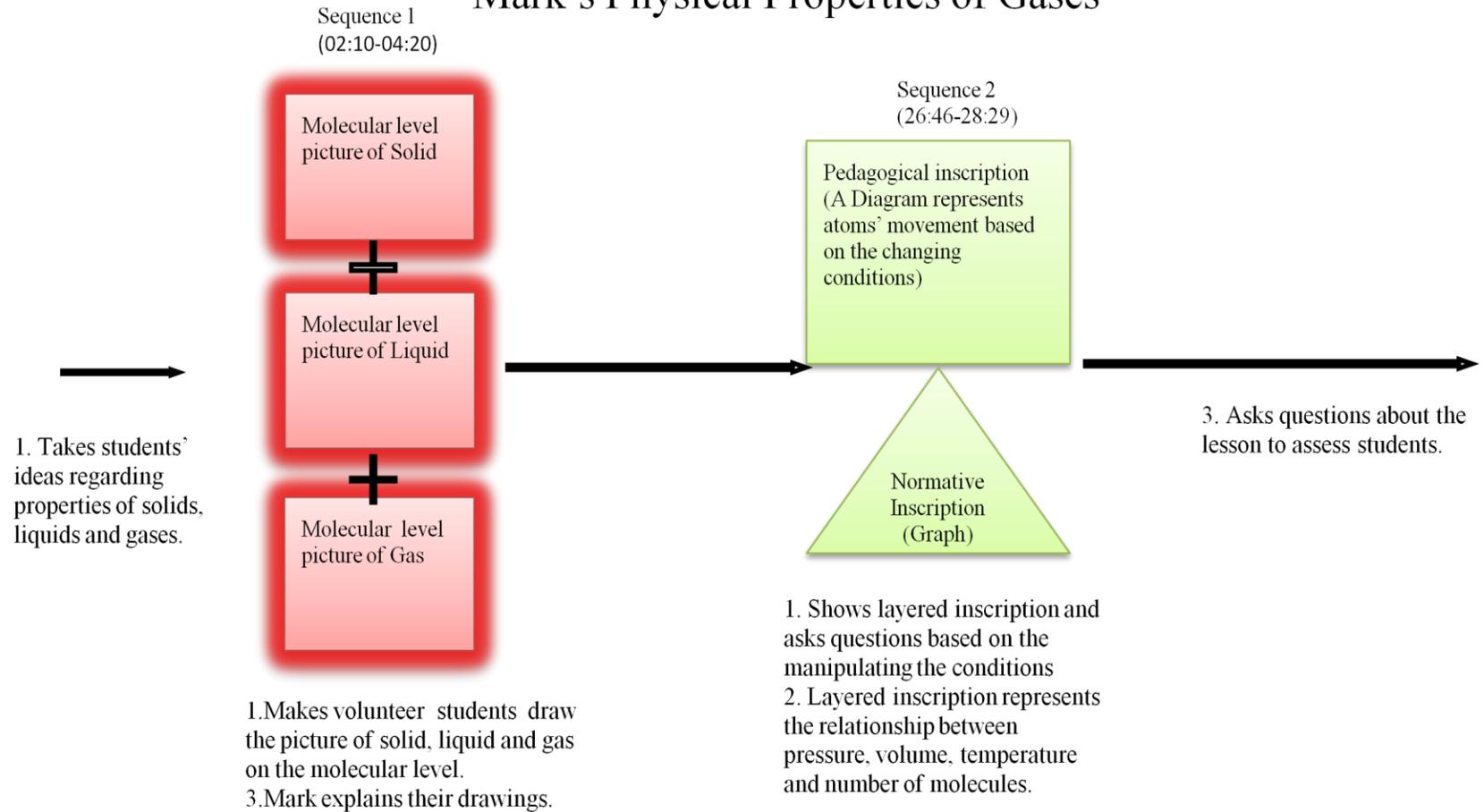
In this instance, he changes the volume, number of particles, and temperature compared to the pressure and tries to represent the relationship between these concepts using the inscription in Figure 4-7. Before he explained the relationships, he asked students to tell what the relationships are between different concepts, so he involved students through asking questions to explain the relationships. He represented the relationships between these multiple concepts by manipulating the components of the layered inscription. Therefore, he uses this inscription to visualize the relationship between multiple concepts by creating a real time input-output system.

### **Summary of Mark's Lesson**

Mark's lesson is on the physical characteristics of gases. He used inscriptions for multiple purposes. In his lesson he used inscriptions 1) to make students' ideas visible and to engage students for the lesson, 2) to connect the relationships between multiple concepts by using multiple inscriptions. In the first sequence, he made students draw the inscriptions then he explained these inscriptions. In the second sequence he also made

students explain what would happen by involving them through questions, then he explained the relationships.

## Mark's Physical Properties of Gases



**Figure 4-8 Mark's Lesson Map**

### **Selim's Story**

Selim is a physics major preservice teacher. His lesson is on circular motion, and as compared to other participants, he mostly used the white board instead of PowerPoint slides to teach his lesson. His lesson map is provided in Figure 4-12. As it is seen in the map, he used many pedagogical and normative inscriptions. He used inscriptions to make thinking visible and create a shared space in Sequence 1, 2, 3. He used multiple pedagogical and normative inscriptions to represent the physical concept in mathematical forms (equations) by connecting, and transforming them in Sequence 4 and 5. Finally, he made students create inscriptions to explain the observed phenomena by reasoning with the inscriptions, thus to make thinking visible.

### **To make thinking visible and create a shared space**

Selim used inscriptions to make thinking visible in the first three sequences in the lesson map. Of these sequences, in Sequence 1 Selim used inscription to make his thinking visible and in sequence 2 and 3 he used inscriptions to make students' ideas visible. Therefore, I provide the excerpts of sequence 1 and 2 in order to represent these two instances in the following sections.

Selim began his lesson by asking questions and taking students' ideas about these questions. He used inscriptions while taking students' ideas upon student's request. To represent this situation the conversation in sequence 1 is provided in the following excerpt:

Selim: I want you guys to think about the times you have been either riding or driving the car go around the turn. All right, so there are two questions I want you guys to think about. First thing is how do you feel like physically when you go around turning the car? And the second question is, is there force acting on you? If so, what is the direction of that force? Discuss among yourselves for a little bit. [Students begin to discuss among themselves. After discussion, he takes students' ideas and writes down on the board.]

Selim: So, you guys have answers, all right, let's start out. How do you feel? Someone.

Anne: You feel like you have to lean the other way.

Selim: You feel like you have to lean the other way [repeating student's answer and writing that on the board.] All right. What are some other things you feel?

Liam: Pressure of the ceiling to your bottom.

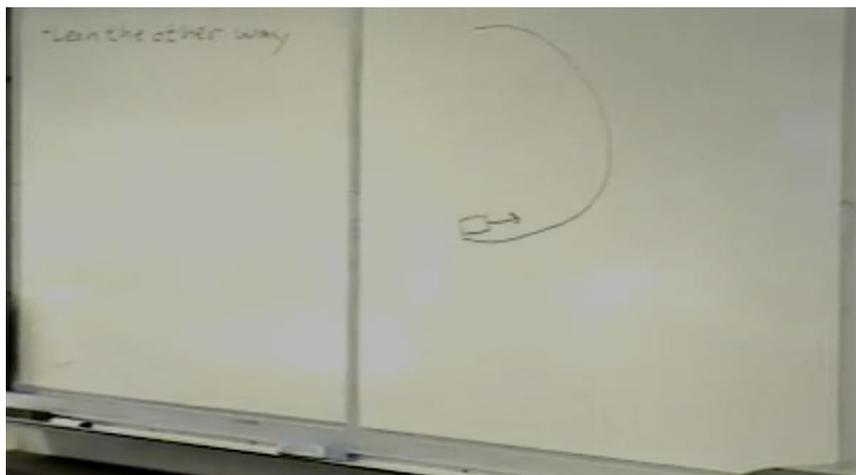
Selim: All right, specific to going around the turn.

Jack: All right, draw on the board which way we are going.

Selim: Okay, this is [he is drawing a u-turn on the board] it is a nasty u-turn around, we are going like down the mountain of 322, you know that one part [representing with his hands a u-turn]

Jack: yeah.

Selim: That is where we are right now. You always realize that you are going a lot faster than you think you are, that part right there. We are going around like this, this is [he is drawing a box in the u-turn diagram, and makes an arrow showing the direction of the car in front of the box], all cars are boxes in physics, and so that's our car right there. You feel like you have to lean the other way, what other general physical feelings you have? (00:16-03:38)



**Figure 4-9 Selim's inscription use in Sequence 1**

As it is seen in the excerpt, when Liam answered the question his answer was not related to what Selim was asking, so he said, “specific to going around the turn” meaning I am looking for a somewhat different answer. Thereupon, Jack wanted him to draw on the board exactly what he meant, so that they can understand each other. Selim drew a diagram (in Figure 4-9) showing a car in the turn on the board upon Jack’s request. Therefore, in this instance, the diagram enables Selim to make his thinking visible to the classroom and serves as a shared space for the classroom community to talk about their sensations regarding going around turning the car. Thus, this diagram helps classroom members to communicate more easily. This is a pedagogical inscription that Selim used to facilitate the communication among classroom members.

### **To make student thinking visible and to create a shared space**

After Selim took students’ ideas about their feelings in the sequence 1, he continued to second part of the question and asked them about the forces acting on them and took their ideas. The conversations happened around second question in Sequence 2 is represented in the following excerpt.

Selim: Okay, we have those things that’s how we feel, all right, now, let’s actually go this board, I am gonna draw the car a little bit bigger [he is erasing the previous box and drawing a bigger box representing the car]. All right so, what forces do we have? Or none. Let’s go around and have everyone kind a give where they think the force would be. Let’s start here.

Mark: Start with me.

Selim: This is [he is pointing and touching to the diagram he drew on the board] like an overhead view, this, we have left, up and down, right [he is drawing arrows around the box showing the direction) or may be some other way.

Mark: Force on you?

Selim: Yes, net force on you.

Mark: Net force on you? I can go to the inside.

Selim: To the inside [he is marking the inside direction on he diagram to show Mark's idea]  
 Jack: I am going to the outside.  
 Selim: Outside, [he is marking the outside direction on the diagram to show Jack's idea] all right, which is good.  
 Andy: I'll think about it, I don't know.  
 Selim: All right, we will come back to you.  
 Anne: If you go to the, well, straight.  
 Selim: So, like this force [pointing to the up direction on the diagram].  
 Anne: Yeah  
 Selim Okay. [Marking the up direction on the diagram]  
 Sam: I'll go with the right.  
 Selim: This one here [he is pointing to the right direction on the diagram]  
 Sam: Right. [Selim is marking the right direction on the diagram to show Sam's idea.]  
 Tammy: The left  
 Selim: Left [marking the left direction on the diagram to show Tammy's idea.]  
 Liam: Left  
 Selim: [marking the left direction on the diagram to show Liam's idea.]  
 Alice: Left  
 Selim: Left [marking the left direction on the diagram to show Alice's idea.]  
 All right we get majority to the left, ohh we wait [he is realizing that he did not get Andy's answer]  
 Andy: I'll go to the right.  
 Selim: All right, yeah. [Marking the right direction on the diagram to show Andy's idea.] Okay. So, we have 5 kind a to the inside, 3 to the outside and our loner going up. (05:01-06:44)



**Figure 4-10 Selim's inscription use in Sequence 2**

In this instance, students know what the box and the diagram mean from the first sequence, so Selim helped students to understand the meaning of the inscription by situating them in the inscription practices throughout the lesson. In this instance, Selim created this pedagogical inscription and then he took students' ideas and represented their ideas on the inscription. Thus, he used this pedagogical inscription to provide a shared space and to make students' ideas visible to the classroom community. This instance is very similar to sequence 1 except in the first sequence the inscription was used to make the teacher's ideas visible and in the second one it was used to make students' ideas visible.

### **To connect physical forms to mathematical by connecting and transforming multiple inscriptions**

In sequence 4 and 5, he used many inscriptions to connect mathematical to physical forms by transforming and combining inscriptions. Sequence 4 is provided in the following excerpt as an example of this situation.

Selim: So, Someone tell me what force is"

Mark: Mass times acceleration"

Selim: Right, continuum with Newton's law, force is mass times acceleration. [He is writing the formula on the board.] What is acceleration?

Anne: Speeding up, or slowing down"

Selim: Speeding up, slowing down, okay, what about more mathematical definition.

Anne: Change in velocity over change in time

Selim: Right, acceleration is the change in velocity over the change in time [writing the formula on the board.] Those of you that have taken enough amounts of physics will remember this, but we are going to do a little vector stuff. Let's take a look at our diagram here. Pick two points, let's say, this is our first point A, this point here is point of B, so what is the direction of the velocity in point A?

Liam: It is directly up.

Selim: Why is that?

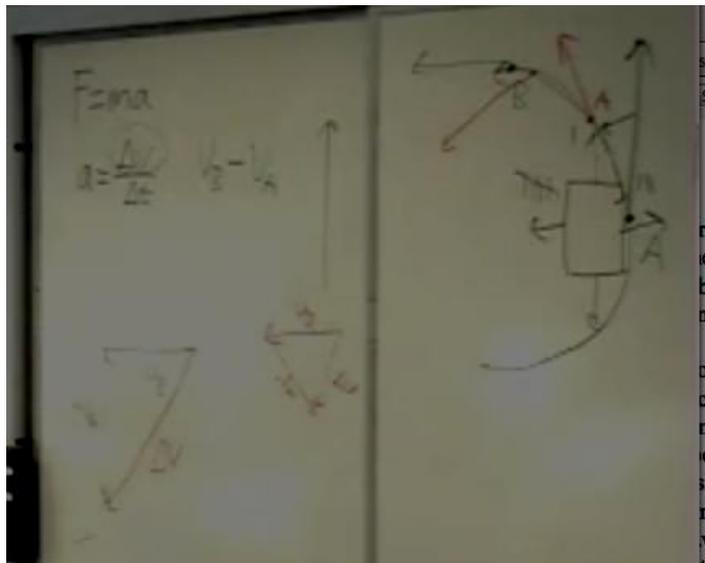
Liam: Because that was,

Tammy: Because your body wants to go there.

Selim: Right it is the way your body wants to go. The other thing you can remember too is whenever you are going a circle; the instantaneous velocity is gonna be tangent to the circle. Our velocity in point A is gonna be straight up to the circle [drawing the arrow showing the direction], what about in B?

A student: Left

Selim: Straight to the left [drawing an arrow showing the direction of B] We are gonna do old school vector addition right. So, our change in velocity in this piece here [drawing a circle around the change in velocity in the mathematical equation of acceleration] we can write that as Velocity of B minus the Velocity of A. [He is writing that using signs]. We start of with Velocity of B....*continues* [He is drawing vector additions to see the change in velocity and connects this change in velocity to the direction of acceleration and the direction of force.] Now, we have this idea that direction of the acceleration and the force is going to be towards the center of the circle when you are travelling the circle, but we would like to kind a extend that and get an idea of how big this acceleration is gonna be. (09:32-16:19)



**Figure 4-11 Selim's inscription use in Sequence 4**

After getting students' feelings about the force and direction of force, in Sequences 1, 2, and 3, in sequence 4 he used normative and pedagogical inscriptions to explain the direction of the force and acceleration in circular motion by combining and transforming these multiple inscriptions into new form inscriptions. In this process, he tried to involve students through asking questions. Selim did this very detailed inscription

transformation through verbalizing his each step and modeling the transformation process for the students, thus he situated students in the transformation of inscriptions.

### **To make student thinking visible**

In Sequence 6, Selim showed a video and wanted students to explain what is happening in the video and suggested doing a free body diagram to explain the phenomenon in the video. The inscription the student used is a pedagogical inscription. The following excerpt shows how he engaged students in the activity and how one student (Anne) used inscriptions to explain the phenomenon.

Selim: So, I have a little YouTube video to watch. [He is showing the video and students are watching the video. Video is about a circular motion in a cylindrical ride and after some time, the floor of the ride is not supporting people.] Watch what happens in this ride. As you can see they are no longer supported by that floor, okay. Using what we know about centripetal acceleration, let's think about; try to come up with explanation to how this happened okay? I know there are at least two physics people here to explain how this happened. I suggest may be doing free body diagrams to kind a explain this, obviously something is upping this otherwise gravity should be pulling you down. So, in your groups try to come up with possible explanation for why that's happened. [Students are discussing among themselves.] Okay, let's come up with some hypothesis, So we have some ideas here, does anybody have any free body diagram they wanna put up here? Come on!

Anne: I'll do it.

Selim: Because, I am not going to try to redraw your free body diagrams.

Anne: [Anne is approaching to board and drawing] It's kind a like this [she is drawing a circle] that's the circle. This is the person. [Drawing a point in the circle] And that direction of their velocity is that way. [Drawing an arrow from the person] the direction of the acceleration and force that way [drawing an arrow towards the below] and direction of the gravity is into the board. [Drawing another arrow]

Selim: So, what is supposing gravity?

Anne: Well, nothing is like pulling them up.

Selim: Well, do they fall?

Anne: Because it is just like in the car. It is like in the car when it is turning [she is gesturing turning motion on the board] they want to keep going straight. It is kind a attaching to the wall, I don't know, the wall is like making them turn.

Selim: Okay, there is this idea, it is turning but they want to keep going straight. We don't have time to discuss this we will do it next time. (36:41-43:00)

In this instance, Selim said, “using what we know about centripetal acceleration, try to come up with explanation to how this happened” and suggested drawing a free body diagram. Here, he is trying to get students use inscriptions to make explanations of the observed phenomenon. Anne came up with a free body diagram to explain the motion. She is reasoning with the diagram to explain the motion. After Anne finished her explanation, Selim wanted to explain the reason behind the motion, but the class time finished so he connected that to the next lesson. In this instance, Selim made students use the inscription to make explanation of the phenomenon. By this way, he made student's ideas visible and encouraged students to use inscriptions as reasoning tool to explain the phenomenon.

### **Summary of Selim's Lesson**

Throughout Selim's lesson, he used inscriptions in six sequences, which constitute most of time duration of his lesson. During the lesson, he used inscriptions to make thinking visible and to create a shared space in the classroom in the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> Sequences. In the 4<sup>th</sup> and 5<sup>th</sup> sequences, he combined and transformed multiple inscriptions to connect mathematical to physical forms. Finally, in the last sequence he made students use inscriptions to reason with in order to explain the observed physical phenomena. Thus, he made students' ideas visible and had an idea of their understanding.

## Selim's Circular Motion Lesson

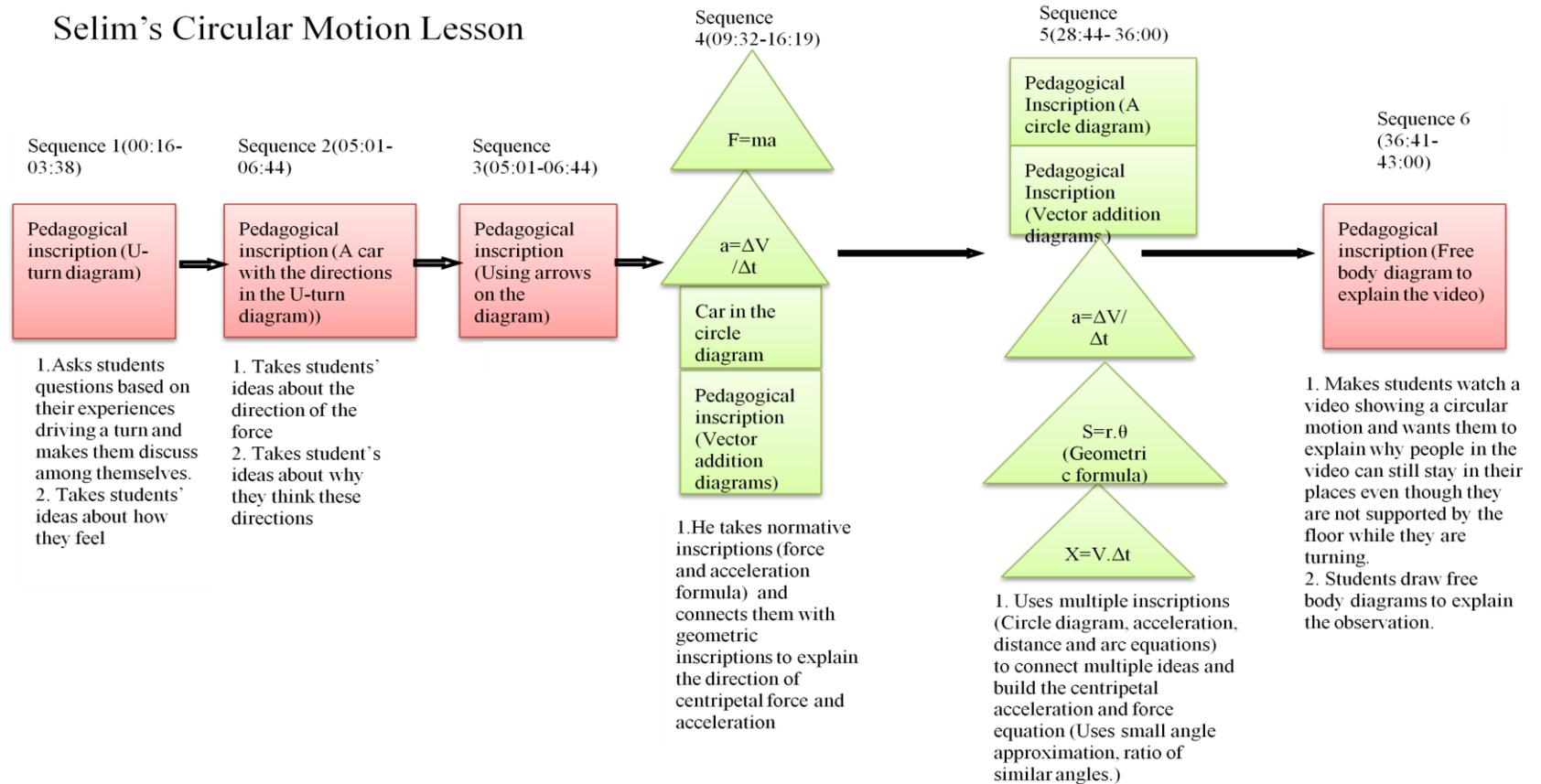


Figure 4-12 Selim's Lesson Map

## **Tammy's Story**

Tammy is a biology major preservice teacher. Her lesson is on the origins of biological diversity. Her lesson map is provided in Figure 4-13. As it is seen in her lesson map, she used many pedagogical inscriptions and one normative inscription. She used all pedagogical inscriptions, which are photos of different species, to provide data or examples from nature of the concept she is teaching in Sequence 1, 2, 3 and 4. She used one normative inscription to organize the species, which is a scientific practice, so she used this inscription to engage students in scientific practice in Sequence 1. I will give the conversation in sequence 1 to illustrate these two purposes. In the lesson map, the first sequence consists of 11 pedagogical inscriptions and one normative inscription; I will explain in the following sections why I organized multiple inscriptions in the same sequence.

### **To provide data and to engage students in scientific practice**

In sequence 1, Tammy showed 11 photos and wanted students decide on what they see and she organized them in a chart with the students. Since she showed all photos consecutively and she created the chart about them along with showing the photos, I organized all these inscriptions in the same sequence, Sequence 1. The conversation in this sequence is provided in the following excerpt:

Tammy: Today, we are going to talk about origins of biological diversity. I am going to show you guys 11 pictures and we can choose from them okay.

[She is showing a picture of dog]

Tammy: Say aloud.

Alice: Dog

Anne: Puppy

Liam: Animal

Tammy: Dog, are you seeing dog?

Anne: Puppy

Tammy: Okay [She is writing on the board.]

Mark: Do we need to agree on them or disagree?

Tammy: Yeah, we need to agree on them

Selim: Animal

Mark: I love puppy.

Tammy: Puppy [She is writing on the board “puppy” as a category and under the that she is she is writing the type of the puppy] Okay.

[She is showing a vegetable]

Anne: Veggie

Tammy: Okay. [She is writing “veggie” as a category and under veggie she is writing the type of the veggie in this case broccoli]

[She is showing a puppy picture]

All students: Puppy

[Tammy is writing the type of the puppy under the puppy category]

[She is showing a skunk picture]

[All students are laughing]

Some students: Skunk

Tammy: Okay [She is writing skunk as a category under this category she is writing the type of skunk]

[She is showing another veggie]

All students: Veggie

[She is writing the name of the veggie under the veggie category on the board]

[Tammy is showing another veggie picture]

All students: Veggie

[She is writing the name of the veggie under the veggie category on the board]

[She is showing a puppy picture]

All students: Puppy

[Tammy is writing the type of the puppy under the puppy category]

[She is showing another veggie]

All students: Veggie

[She is writing the name of the veggie under the veggie category on the board]

[She is showing another skunk picture]

All students: Skunk

[She is writing the type of skunk under the skunk category]

[She is showing another puppy picture]

All students: Puppy

[Tammy is writing the type of the puppy under the puppy category]

[She is showing another veggie]

All students: Veggie

[She is writing the name of the veggie under the veggie category on the board]

Tammy: Okay, what were your criteria for grouping them? What was your criterion, how did you divide these things into categories?

Andy: Vegetables grow and growth right, puppies walk.

Tammy: Do you think they [pointing to the board] are different species?

[There is no answer from the students.]

Tammy: Okay why don't you guys do this come up with definition of the species?  
(00:06-03:56)

In this instance, she showed 11 photos of different species and wanted students to decide what they see. And based on their agreement, she organized them in a chart. As it is seen in the first lines of the conversation students could not decide what to say for the first photo. In the other photos, they all agreed. These photos provide a shared social space for this classroom community to talk about the species and when they look at these shared spaces they decide on the type of the species. Tammy provided these photos to students as data or example of the species from nature. Since the subject of her lesson is related to the species, she needed to provide examples of these species from nature. The conversation is over the photos to decide them what kind of species it is, so Tammy showed photos as data, and from that they built a chart of species, which classifies different types of species. Therefore, I interpret these photos as data and the chart is a data table, which organizes the species in a biological order, so building the chart is a normative inscription building, which imitates how scientists organize the species around their features and how they decide and agree on the classification. Therefore, Tammy used inscriptions in this sequence to engage students in scientific practice through creating the normative inscription with the students. Since bringing all these species in the classroom is difficult, these photos serve as data to talk about the scientific concepts.

### **Summary of Tammy's Lesson**

Tammy's lesson is on Origins of biological diversity. She used several photos, which are pedagogical inscriptions and a table chart, which is a normative inscription. She used all photos to provide data or examples from nature of the concept she is teaching in Sequence 1, 2, 3 and 4. She created the table chart that organizes the species around some kind of organization structure. Since she engaged students in the creation of the chart she used this inscription to engage students in scientific practice in Sequence 1.

## Tammy's Origins of Biological Diversity Lesson

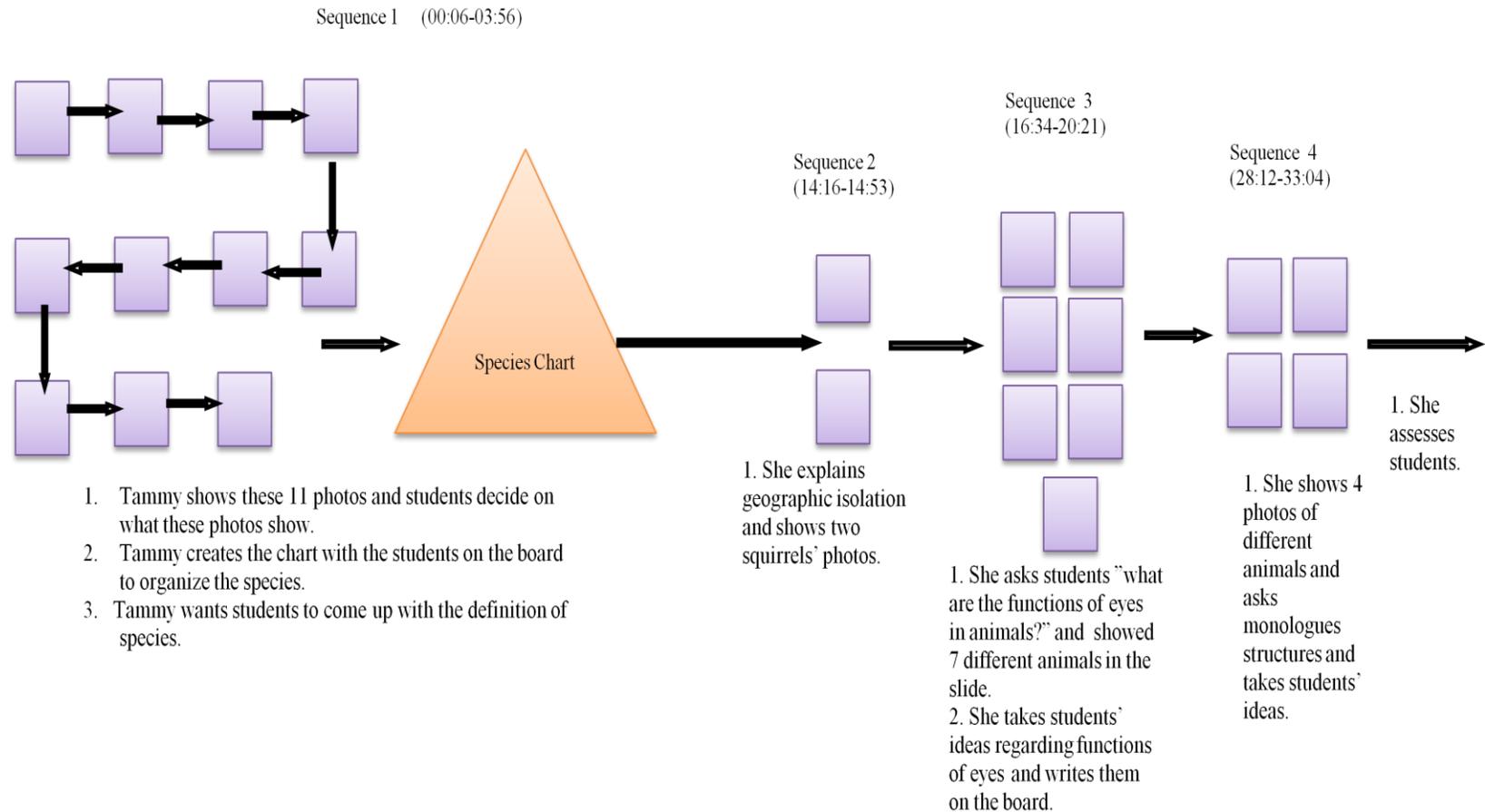


Figure 4-13 Tammy's Lesson Map

## **4.2 Chapter Summary**

This chapter provided detailed descriptions of why and how preservice teachers used inscriptions in their lessons. The lesson maps and summary of the lessons are provided for each participant. Thus, the following chapter provides cross-participant analysis for the inscription use.

## Chapter 5

### CROSS-PARTICIPANT ANALYSIS AND DISCUSSION

#### 5.1 Introduction

As described in the previous section, all participants exemplified different stories regarding the use of inscriptions in their peer teaching lessons. Although their stories are different, they provide a pattern of purposes for using inscriptions across the stories. Understanding these patterns will help researchers to understand how and why preservice teachers use inscriptions in science teaching. In this chapter, I will report the cross-participant analysis organized around the research questions.

#### **What kinds of inscriptions do preservice science teachers use in their peer teaching activities?**

The first research question was largely descriptive and I reported that in the findings section. There are two important things came out of the first research question. One of them is the pattern of types of inscriptions preservice teachers used in their teachings confirms Lemke's (1998) results about the pattern of inscriptions in scientific journals in terms of the different disciplines. Lemke found that two journals, *Physical Review Letters* and *Science*, have differences in terms of the type of the inscriptions they contain. He found that mathematical expressions were less frequent in *Science*, but visual representations such as photographs, molecular diagrams are more common. Therefore,

the pattern of kinds of inscriptions in the journals for the disciplines in Lemke's study is consistent with the inscription use of the teachers' trying to teach the scientific disciplines in the lessons. The other important thing is the differentiation of inscriptions as pedagogical and normative. Preservice teachers used pedagogical inscriptions to help students bridge everyday concepts to scientific concepts. Preservice teachers also used normative inscriptions, which are the ones that scientists would use in their theory development or to communicate scientific theories, facts, and laws in scientific communities. The details of this differentiation were described in the individual stories and also in the next section where I provide cross participant analysis.

### **How and why do preservice teachers use inscriptions in their peer teaching?**

Through my analysis I found that preservice teachers use inscriptions for multiple purposes. They used inscriptions to convey final form scientific information, to make ideas visible, to help students engage in scientific practices, to connect multiple concepts across multiple inscriptions, to provide data or examples from nature. In addition to these purposes, depending on the context of the use of inscriptions, preservice teachers may have purposes such as formative assessment, to engage students with the content at the beginning of the lesson, and to review the lesson through use of inscriptions. The details of these findings are discussed in the following sections.

### **Convey final form scientific knowledge**

One of the reasons participants used inscriptions was to convey final form scientific knowledge. Among participants, Anne, Alice, Jack, and Sam used inscriptions to convey final form scientific knowledge. These participants showed inscriptions in their PowerPoint slides in a ready format, which means inscriptions were already created and brought to the classroom. Preservice teachers used these ready inscriptions as a platform to explain discipline-specific content to the students. In these instances, inscriptions serve as mediating device that helps preservice teachers introduce canonical scientific concepts to the students. In their review, Roth and McGinn (1998) described these type of inscriptions as boundary objects, so I considered inscriptions as inherently boundary objects. When using inscriptions to convey final form scientific knowledge, preservice teachers translate these canonical concepts to the science classroom community who are new to these science concepts through these boundary objects.

When using inscriptions to present final form science, preservice teachers used extensive gestural practices such as pointing, drawing, and highlighting on the inscriptions. Especially Alice's lesson and Jack's lesson were very rich in terms of the use of inscriptions to convey final form scientific knowledge. All four preservice teachers made many purposeful moves towards inscriptions in order to emphasize important parts of the inscriptions with gestural practices. Of these four preservice teachers Alice, Jack and Sam tried to involve students in the interpretation of the inscriptions through asking questions, however Anne preferred to explain the concepts on the inscriptions by herself in an authoritative way. Even though preservice teachers tried to involve students through

questioning, most of the time they made the final interpretations of the inscriptions by themselves.

Latour (1987) states in *Science in Action*, his intent is not to focus his analysis on the final products, but instead he will observe scientists in their laboratories and analyze production as a process. However, in the classrooms, it is not always possible for students to produce their own scientific inscriptions as scientists would, so in these cases teachers bring the products of final form science into their classrooms through these inscriptions that scientists created and try to convey or translate them to the students. Teachers need to bring some of the content to the students to use as a tool for understanding of the lesson. Thus, conveying final form scientific information through inscriptions is necessary to communicate science content to the students.

### **Make thinking visible**

One of the reasons preservice teachers used inscriptions was to make thinking visible. Among all participants Alice, Mark, Sam and Selim employed inscriptions for this reason. Using inscriptions to make student thinking visible is common for all of these participants, however, how they made thinking visible varies among them. In Alice's case, she used inscription through asking students to manipulate a heart diagram where she provided the diagram and aimed to see students' understanding of the concept through their manipulation of the diagram. When she was introducing the activity, she said, "I have a quick activity for you guys just to make sure that you understand the diagram and how blood flows through." Therefore, she used inscription at the same time

for formative assessment purposes along with making thinking visible. In Mark's and Sam's cases, they both asked the students to draw what a solid, liquid and gas look like on the molecular level. While Sam wanted students draw the pictures after he taught the concepts, Mark wanted students to draw the pictures at the beginning of the lesson. After students drew the pictures, both Mark and Sam interpreted students' drawings. In fact, when Mark was interpreting the drawing of gas particles, he said, "they are spread out a lot, and moving all over the place. So this [pointing to drawing of the gas particles] is good, because this is what we are going to talk about in thirty seconds." While Sam was aiming to get at students' understanding through their drawings for formative assessment purposes; Mark was aiming to engage students for the rest of the lesson.

The way Selim used the inscriptions to make thinking visible is different from the other participants. In his case, in the first three sequences, he drew the inscriptions to make his thinking and students' thinking visible and in his last instance he made students come up with the inscription to explain the observation. As I mentioned in his story, his first use of inscriptions was due to a student's request. After he drew the inscription in the first sequence, this inscription became a shared space among classroom community and he used the inscription in the second and third sequences to make students' ideas visible. Therefore, in his first three instances he created the inscriptions in the classroom and the inscriptions served as a shared space between classroom members to communicate the meanings. Thus, he used inscriptions as communication tool. In his last case, when he encouraged students to do free body diagrams in order to explain the video, he said, "Using what we know about centripetal acceleration, let's think about; try to come up with explanation to how this happened okay? I suggest maybe doing free body diagrams

to kind of explain this”. As it is apparent from his directions, he wants students to reason with the inscriptions in order to explain the phenomenon. Therefore, in this case he is trying to make students’ ideas visible and make them use inscriptions to make explanations.

Roth & McGinn (1998) showed how inscriptions were turned into the subject of the discussion and how they are used to facilitate communication. Especially in Selim’s case, the inscriptions constructed in the classroom facilitated the communication among the classroom community. Säljö (2005) describes, “inscriptions are tools for thinking, communicating and acting” (as cited in Carlsen, 2009, p. 58). This is consistent with the purpose of most of the preservice teachers use’ of inscription as making thinking visible.

All four preservice teachers who used inscriptions to make thinking visible could have chosen to do so based on the topics of their lessons. Circulation and respiration, circular motion, physical characteristics of gases, and properties of solids, liquids, and gases may require preservice teachers use inscriptions to make thinking visible. Since these topics include micro scale and complex scientific concepts, inscriptions could help preservice teachers see how students externalize these complex concepts through drawings, or manipulating the inscriptions. Since complex and micro scale concepts are difficult to grasp for students, preservice teachers make students use inscriptions to show their conceptual understanding of these concepts.

### **Engage students in scientific practice**

One of the other reasons preservice teachers used inscriptions was to engage students in scientific practice. Alice, Jack, Tammy, and Sam were among the participants who employed inscriptions for this purpose. When engaging students in scientific practices, these participants either had students collect data and wanted them create an inscription out of this data, or they provided the data and wanted students to create inscriptions out of the provided data. While Alice implemented the former type, Jack, Sam and Tammy implemented the later. Alice engaged students in creating a graph, reading the graph and then connected graph interpretation as an engagement tool for the rest of the lesson by saying “Basically, we can see our results, now what we want to do is explain exactly why we see this increase for a minute, so I want you guys to be thinking about this as I gave you more information about circulation and respiration because at the end of the class I want you be working in groups and try to explain what is going on, why we see this increase.” In addition, at the end of the lesson, after her instruction she wanted students to interpret the graph and this time, she used graph interpretation as a review or assessment of the lesson along with engaging students in inscription interpretation. Therefore, throughout her lesson, she situated students in inscriptional practices (creating, reading, interpreting) to co-construct the meaning of the inscription as a classroom community, thus simultaneously she also reached multiple purposes within the use of this inscription. Jack, Tammy and Sam provided the data for students to create the inscriptions. While Jack wanted students to map the measured earthquake locations on the world map and wanted students to interpret the pattern on the map, Tammy wanted

students to decide on what kind of species they saw on the photos, and classified those species around some organization structure with the students. Sam wanted students create a graph showing the phase changes of water in given temperature values. While Sam was introducing the activity, he said, “we are going to show what happens as water is heated between  $-10^{\circ}\text{C}$  to  $140^{\circ}\text{C}$  knowing just we learned from the last part”, so with this activity Sam also wanted to assess students’ understanding. Therefore, Sam’s case was different from those of Tammy and Jack, because he has multiple purposes, engaging students in inscriptional practice and formative assessment.

Reform documents emphasize that students should engage in scientific practices through creating, reading and interpreting inscriptions. (American Association for the Advancement of Science, 1993; National Research Council, 1996) These inscription practices are considered fundamental elements of science education standards and valued as important scientific practices. In the current study, preservice teachers engaged students in these scientific practices by providing instructional activities and situating students in these activities.

Preservice teachers and scientists use inscriptions differently. Preservice teachers ask students create, read, and interpret inscriptions; however, scientists create, read and interpret inscriptions by themselves. Preservice teachers’ uses of inscriptions to engage students in inscriptional practices are not very sophisticated to reflect how scientists use inscriptions, and thus, for students, this may cause a limited understanding of scientific practice and how scientists work with inscriptions.

### **Use multiple inscriptions to connect multiple concepts**

Preservice teachers use multiple inscriptions to connect multiple concepts and relationships. Alice, Mark, and Selim employed these multiple inscriptions in their lessons. How they used these multiple inscriptions varies among these participants. Alice superimposed diagrams and photos to connect and represent different scales. Mark used an online diagram and graph combination layered inscription to represent the relationships of different concepts and integrated students in the interpretation of the layered inscription. Selim used multiple inscriptions to connect physical concepts with mathematical forms. He combined many geometric inscriptions with physical inscription and transformed these inscriptions into new inscriptions.

Star (1995) stated, “Several inscriptions can easily combined and superimposed, leading to their heterogeneous and layered character” (as cited in Roth and McGinn, 1998, p. 38). Roth and McGinn (1998) also described how teachers establish inscriptions on a new scale and place them into different documents for their instruction, combine or superimpose various images into new, layered inscriptions, and recreate inscriptions comparatively low cost. In the current study, preservice science teachers also played an important role in terms of recreating different origin inscriptions into new-layered inscriptions depending on the purpose of their lesson. While one of the preservice teachers used an already layered inscription, the other two preservice teachers recreated the inscriptions for their instruction. In her study, Gabel (1999) described how high school teachers move between the macroscopic, submicroscopic, and symbolic

representational levels without highlighting their interconnectedness. However, in this study, preservice teachers used multiple inscriptions to connect these different scales.

### **Provide data or example from nature about a concept**

Preservice teachers use inscriptions to provide data or example from nature about the concept being taught. Anne, Sam and Tammy used photos for this purpose in their lessons. Anne used a photo for this purpose in one instance when she wanted to show an actual example of fault. Sam used photos to represent the process of phase change by combining the photos. Tammy used photos as data or example to show different species. In these instances, the photos are not representing very complex relationships or principles, but they are supporting teachers' explanations or they are assisting teachers to show the objects that they could not bring in the classroom. The way teachers used inscriptions varies. Anne and Sam used photos in a way that complement their explanations. On the other hand, Tammy used them both to complement her explanation and to provide a shared space that trigger students' interpretation. When Tammy asked students what the photos represent, she used photos as shared space in the classroom to decide and agree on them as a classroom community. Therefore, in that case she used the interpretative nature of photos. Bastide (1990) mentioned because photographs and drawings provide examples from nature they complement and clarify written text, but they also have an interpretative nature that require scientists to explain their meanings. So, Anne and Sam primarily used photos in a way consistent with the first part of

Bastide's explanation whereas Tammy used photos in way consistent with Bastide's both parts of the explanation.

## **Chapter 6**

### **CONCLUSION**

This study was aimed to investigate preservice teachers' use of inscriptions in their peer teaching lessons. Considering these peer-teaching lessons as their first attempt to teach science, they used inscriptions in their teaching experiences and demonstrated a wide range of purposes using inscriptions. All different stories provided a wide spectrum of inscription use in science teaching.

Analysis demonstrated that preservice teachers used different types of inscriptions across the lessons. One of the results is while physical science major preservice teachers use mathematical inscriptions, biology and earth and space major preservice teachers use more photos and diagrams in their lessons. Thus, preservice teachers' use of inscriptions across different disciplines varies in terms of the complexity of the inscriptions they used. One of the other results for the first question is the distinction of normative and pedagogical inscriptions. I argue that preservice teachers use inscriptions in both normative and pedagogical ways. They use pedagogical inscriptions to bridge the students' everyday concepts to more scientific concepts. They also use normative inscriptions that a scientist would use to communicate scientific knowledge among scientific community. Even though preservice teachers are teaching science, they are using inscriptions in these pedagogical and normative ways that are different than the way scientists use inscriptions. Preservice teachers ask students to produce inscriptions in order to understand students' understanding of the concepts and make them represent

data, whereas scientists produce inscriptions to communicate scientific knowledge to science community. Scientists don't ask other people to produce inscriptions for them. In that sense, preservice teachers have different purposes using inscriptions from scientists. Preservice teachers' complex and integrated ways of uses of inscriptions may impact students' perceptions of how scientists use inscriptions and inscriptional practices. Through these complex ways of uses, students may not have a clear understanding of the difference in pedagogical and normative ways. Thus, this may cause partial understanding of how scientists work with inscriptions, and how inscriptions play a role in constructing scientific knowledge.

The analysis of the second question demonstrated that preservice teachers used inscriptions 1) to convey final form scientific knowledge, 2) to engage students in scientific practice, 3) to make thinking visible, 4) to connect multiple ideas with multiple inscriptions, and 5) to provide data or example from nature. In addition to these purposes, preservice teachers also used inscriptions for formative assessment, to engage students for the lesson, and to review the lesson with the inscriptions.

Different purposes of the sequences in the lessons could be conducive to these different uses of inscriptions. For example, if the preservice teacher is making explanations, they may use inscriptions to convey final form science, or if the teacher is in the explore section of the lesson, then the purpose of the teacher using inscription would be engaging students in scientific practice through inscriptions. Another example could be if the preservice teacher is asking students to create an inscription after s/he make explanations, this could be to make students thinking visible and at the same time for formative assessment purposes. Therefore, based on the results of this study, I claim

that different purposes of the sequences in the lesson could be responsible for different uses of inscriptions. Thus, inscriptions do not have inherent purposes, but instead are contextualized by teachers in the way that they use them. It looks like even the same inscriptions can get used for different purposes in different lessons. Therefore, science teachers should be aware of not only inscriptions do have a contextualized nature, but also they get used for multiple purposes in different lessons. When teachers use inscriptions in their teachings, they should consider the context they use inscriptions in order to have students understand the intended meanings of the inscriptions in their lessons.

Science topics of the lessons could also be a determiner of the different uses of inscriptions in the lessons. For example, when the topics of the lessons are origins of biological diversity, earthquakes, and properties of solids, liquids and gases, preservice teachers used photos in order to provide data or example from nature.

In addition, the different science topics in the lessons could lead to preservice teachers' use of certain types of inscriptions or patterns of inscriptions. For example, in circulation and respiration lesson, the circulation topic allows preservice teachers use blood circulation diagrams, the diagram of Krebs cycle and hearth diagrams. In order to explain the circulation and respiration, these diagrams are central to students visualizing the circulation and motion aspect of the blood and circularity system. Also, for example, in order to explain the circular motion, the free body diagrams representing the motion of a ride in a circle needs to be inscribed in order to explain the direction aspect of the circular motion.

The data of this study is limited to seven different topics of lessons, so in order to explore the relationship of inscriptions and topics of the lessons, different topics of lessons and also even the same topics of lessons could be analyzed for a future study. However, within the context of this data, it is clear that with the system types of topics, biological, earth or physical systems, diagrams could be used to represent the concepts in the systems. With the topics related to nature and living things, photographs could be used.

For a future study, in the continuum of this study, preservice teachers' discussions after the teaching experiences could be analyzed in terms of their attendance to inscriptions or inscriptional practices about their teaching experiences. This could provide insight about the beginning teachers' concerns or approaches to the inscription use in their first teaching experiences.

This study is limited to one experience of science teaching for each participant. For a future study, it would be beneficial if preservice teachers' teaching episodes in their field schools are also observed and analyzed for their development and change in terms of use of inscriptions. In that manner, this study will constitute a baseline for later studies.

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