

ABSTRACT

Title of Document: FROM INTERACTION TO INTERACTION:
EXPLORING SHARED RESOURCES
CONSTRUCTED THROUGH AND
MEDIATING CLASSROOM SCIENCE
LEARNING

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Recent reform documents and science education literature emphasize the importance of scientific argumentation as a discourse and practice of science that should be supported in school science learning. Much of this literature focuses on the structure of argument, whether for assessing the quality of argument or designing instructional scaffolds. This study challenges the narrowness of this research paradigm and argues for the necessity of examining students' argumentative practices as rooted in the complex, evolving system of the classroom. Employing a sociocultural-historical lens of activity theory (Engeström, 1987, 1999), discourse analysis is employed to explore how a high school biology class continuously builds affordances and constraints for

argumentation practices through interactions. The ways in which argumentation occurs, including the nature of teacher and student participation, are influenced by learning goals, classroom norms, teacher-student relationships and epistemological stances constructed through a class' interactive history. Based on such findings, science education should consider promoting classroom scientific argumentation as a long-term process, requiring supportive resources that develop through continuous classroom interactions. Moreover, in order to understand affordances that support disciplinary learning in classroom, we need to look beyond just disciplinary interactions. This work has implications for classroom research on argumentation and teacher education, specifically, the preparation of teachers for secondary science teaching.

FROM INTERACTION TO INTERACTION:
EXPLORING SHARED RESOURCES CONSTRUCTED THROUGH AND
MEDIATING CLASSROOM SCIENCE LEARNING

By

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Chapter 1: Impetus for this study: The observation of variation

While working on a professional development project for high school science teachers, I had the opportunity to observe many science classrooms and participate in meetings where teachers discussed segments of video snippets from participating teachers' classrooms.

I was intrigued that teachers considered that they implemented the same learning activities, which mainly meant that they were using the same curriculum material, and yet their classrooms looked so dramatically different. Furthermore, it often seemed easier for students in some teachers' classrooms to engage in inquiry-rich conversations than students in other teachers' classrooms, even when the students were comparable in grade level and previous schooling experiences and when the teachers used the same opening question and similar questioning probes. There was something different about the classrooms where inquiry-rich conversations were more prevalent. There seemed to be the right atmosphere for inquiry to grow: the students seemed excited to share their ideas and responded to each other's questions. In contrast, in other classrooms, students seemed to be holding back their thoughts and presented no enthusiasm towards making arguments. When watching snippets of rich classroom interactions in teacher meetings, most of the teachers showed that they were able to attend well to the substances of students' ideas, and those whose classrooms were less active often wished that their students were "as thoughtful" or as "interested," as though it were these qualities in their

students that facilitated or obstructed this type of interaction. I wanted to understand what was going on in these different classrooms. Yet, the data we collected for that project (usually less than six visits to a classroom per semester) did not allow satisfactory explanations to be generated for such a phenomenon, as interactions at any moment did not exist alone, but was contextualized by its participants' interactive history, to which an occasional guest had no access.

This observation of classroom-associated inquiry participations suggested a research angle that I saw worthy of exploration: *What differentiated one classroom from the other in terms of how they afforded inquiry learning?* Holding the assumption that the differences I saw could not be solely accounted for by students' intrinsic properties (e.g., how thoughtful or interested they were), I found myself particularly interested in the variation evident in and enabled through classroom learning interactions, especially in classrooms where quality inquiry conversations seemed the norm, which prompted this question: *What do the teachers and students do that promotes such learning interactions?* This is the question that stirred my curiosity and drove my dissertation work. Considering the limited time, energy and resources I had as a graduate student, I chose to focus on understanding a single high school biology classroom, documenting what it looked like when this single classroom afforded or constrained productive science learning, and exploring how such affordances and constraints developed over time. This dissertation documents my exploration of these phenomena.

Before talking about what affords or constrains productive learning, I will first illustrate my concept of "learning" and what I mean by "productive learning." This is done in the chapter that follows, as part of my conceptual framework. Through

summarizing and comparing several perspectives on learning established by theorists in the field, especially where they suggest we should look at in order to understand learning, I situate my work within the broader corpus of research on learning, clarifying, and hopefully bringing justification to employing a socio-cultural lens for understanding learning. Drawing on ideas agreed upon by philosophers of science and scholars in science education, I then characterize my sense of productive learning in the science classroom, both theoretically and through analysis of an exemplary snippet. In alignment with such guiding perspectives on learning, I describe the theoretical lens I built through localizing the cultural-historical framework of activity theory (Engeström, 1987, 1999; Vygotsky, 1978) and defining the key analytical concepts involved.

My methodology fell from a set of research questions refined in light of my conceptual framework. In Chapter 3, I describe my site selection, data collection and analysis, justifying how they inform the questions this study explored. Also, I provide a rationale for reducing the focus of my analysis from productive science learning in general to particular aspects of scientific argumentation.

Chapter 2: Conceptualizing learning in classroom

2.1 What learning is and where it locates – What does the literature say?

To establish my orientation to what learning is and where learning locates, I consider differing perspectives offered in existing literature.

For those who assumed universal mechanisms of how the mind works, learning happens within an individual's head. Influential ideas following this paradigm; theories such as schema theories (Anderson, 1977; Bartlett, 1932; Minsky, 1975; Rumelhart, 1980), cognitive developmental theory (Piaget, 1970) and conceptual change theories (Carey, 1985, 1999; Chi, 1992; Chi & Roscoe, 2002; Kuhn, 1989; Posner & Strike, 1982; Vosniadou, 2002), pursued cognitive principles without significant emphasis on the role played by external factors.

Researchers who hold different assumptions challenged these tenets. Scholars concerned with the idea that the mind does not work in separation from the outside world raised the need to theorize cognitive laws of learning within external conditions such as domain specific constraints (Jones, Reichard, & Mokhtari, 2003; Kolb, 1981) and individual learning styles (Kolb, 1984; Riding, 1991). Similar arguments have been specified into various research areas, including expertise (Ackerman, 1996; Alexander, 2003; Chi, 1978), personal epistemology (Hofer, 2000; Kuhn, 1991) and transfer theory (Brown, 1990; Gentner, 1983). Furthermore, some theorists take learning out of the mind completely. Instead of seeing learning as controlled by cognitive laws, they take

for principles what rules the structure or function of a society or a culture, explaining cognition or learning practices as reflecting such structure (Lévi-Strauss, 1958/1983; Lévy-Bruhl, 1923/1966) or serving such functions (Malinowski, 1939). The universality assumption was moved from inside out—culture was still viewed as an external, relatively static construct that could afford or shape mind.

For the most part, all of the perspectives discussed above shared an unambiguous division between internal (mind) and external (culture), even if they acknowledged influences of one on the other. Other scholars, however, eschewed getting at mechanisms for learning either from the internal or the external. These theorists did not make clear-cut demarcation between mind and culture, rather, they focused on how learning occurs through the exchanges between the two, mind and culture. For example, Dewey's (1938) theory of experience characterized one's present learning experience as formed through the interaction between past experience and the present situation. While this had a flavor of Piaget's constructive learning theory (new knowledge was constructed based on the old), Dewey relocated the construction process from individual cognition to the interaction between internal and external worlds. Vygotsky's (1978) cultural-historical activity theory offered a similar lens, suggesting that learning activities happened through interactions between social and cognitive planes. Such focus on the processes and properties of interaction gave birth to new research branches. Some of the influential ideas delivered by scholars on this track are summarized as follows:

- **Learning as situated.** Situated cognition theorists considered learning as happening through and shaped by “situations.” Their constructs of learning situations were distinct yet overlapping. In her study on people's cognitive differences when solving

math problems in school and everyday life, Lave (1988) referred to situations as the environmental setups and the interactions between people and their environments. When Brown, Collins and Duguid (1989) argued against learning outside of authentic situations in which knowledge could be meaningfully used, what they considered as “situations” were the norms and rules that informed how to do something within a certain community. Hutchins’ (1995) work on distributed cognition focused on interactions among people, which can also be taken as an aspect of situation; it considered cognitive processes as “distributed across members of a social group” through both interpersonal coordination and intrapersonal coordination.

- **Learning as mediated.** What situated scholars respectively considered as the situational foundations for learning, when synthesized, matched the mediational factors suggested by modern activity theory scholars. Vygotsky’s (1978) original activity theory described a single individual’s object-driven actions as mediated by material and symbolic tools. Engeström (1987) expanded this work and developed a framework that illustrated collective and collaborative activities oriented by shared objects, in which contextual factors such as rules, community norms and labor divisions were considered as mediating activities, as they worked together and shaped how a group interacted. Other researchers who investigated collaborative learning (Crook, 1998; Dillenbourg, Baker, Blaye, & O’Malley, 1996) have also referred to both traditional tools and the contextual factors as “*mediational resources*.”
- **Learning in interaction.** One message conveyed through experience theory (Dewey, 1938), situated cognition theories (Brown, Collins, & Duguid, 1989; Hutchins, 1995; Lave, 1988) and activity theory (Engeström, 1987; Vygotsky, 1978) is that learning,

especially the learning of a community of learners (such as a classroom) take place in their interactions with each other and with the environments. While traditional cognitive learning theories focused on the mental structure of knowledge and individual acquisition of such structure, researchers from this situative perspective (as referred to by Greeno, 2000) emphasized learning as ongoing interactions, or as Sfard (1998) suggested, “constant flux of doing” rather than “permanence of having (knowledge).” The focus is more on the processes rather than the consequence. To gain insight into learning from this perspective requires understanding the organization of an interactive system and how efficient it is in affording different types of participations.

I start my work with these aforementioned assumptions about learning. As stated at the beginning of this chapter, I saw classroom affordances of learning as developing over time, and aimed to gain understanding of the process of such developments. For my work, I consider learning taking place in the classroom as located in continuously evolving interactions, in which individual cognition and social communication can hardly be separated. Asking whether learning mechanism locates internally or externally is like looking at learning through two mirrors sandwiching the phenomena of learning: at first sight, we may see from one mirror only the image of one side and hold it to be what learning looked like; however, when looking carefully into the mirrors, we would find that they both unavoidably showed a little bit of the other side as well by reflecting the image in other mirror. The images in the two mirrors are therefore not against each other (though their position may suggest so) but complementary. The side-taking arguments about where learning locates then become meaningless. Since

classroom learning denotes dynamic processes rather than static objects and since this study focused on interaction patterns emerging from such processes, looking into either “mirror” only may lead to misinterpretation; in order to see the whole, images from both sides need to be integrated.

The theoretical construct of mediation (Cole, 1996; Engeström, 1987) provided an access to such an “integrated” view of learning. It denotes the coordination between ongoing social and cognitive processes on different levels. For an individual’s interaction with material environments, when a physical tool is employed to conduct a task, the properties of the tool shape the actions one takes; for an individual’s interaction with social environments, when culturally defined signs and symbols are presented, their roles resemble that of the physical tool as the meanings they carry are involved in one’s cognitive processes that produce social responses. For complicated interpersonal interactions in an activity system, broader contextual resources play a similar role, as they function in a way that allows or constrains how people interact in local activities. The sense of mediation on this level is close to the idea of affordance—certain type of learning practice can be considered as well afforded by an activity system if its associated interaction patterns¹ well suit the norms, rules, and interpersonal relationships constructed in a community.

¹ Practice and pattern are two terms frequently employed in this work. In the core, they both addressed recurring events, but the differences reside in the level of events they referred to, the time and space that holds the recurrence of such events, and the roles they serve in my analytical work.

Use of the term *practice* aligns with how it is widely used in science education literature, which denotes categories of individual or group phenomena that are recognizable to a certain community. This is a general, overarching theoretical construct. The recurrence it represents took place over the ample time and space of the community’s developmental history and ongoing activities. For example, teaching practices refer to what teachers do to support student learning, scientific inquiry practices get at what scientists (and in educational contexts, science learners) do in their pursuit of understanding and explaining natural phenomena, humor practices point to what people do in social interactions that produce incongruity and usually cause laughter, etc. This work focuses on the class’ scientific argumentation practices, which is

Establishing this perspective of learning, I next lay out my criteria for “productive learning” in high school science classrooms.

2.2 Productive learning in science classrooms

For this work, my sense of productiveness for school science learning is grounded in the argument that a general objective of science education is to introduce students to the scientific community, cultivating a population who can understand and critically analyze scientific claims (NRC, 1996, 2007). This broader goal provides the rationale for emphasizing scientific inquiry over specific facts or findings in science learning: while information accumulates and findings update at high speed, learners need to be prepared with the motivation and tools to participate in scientific thinking and continuously

considered central to scientific inquiry. In the field of science education, scientific argumentation practices are usually identified by the logic structure underlying scientists and science learners’ discourses. In this work, I define scientific argumentation practices mainly by the functional roles they play in the work of science community—basically, what scientists and science learners do to solve discrepancies they encounter in their pursuit to understand and explain certain natural phenomena.

Pattern, in contrast, is an analytical construct I employed to summarize specific features I repeatedly observed in the class’ interactions. The events it associates with are individual interaction features, on a different level than that of *practice*—as in, types of interactions. Therefore, detecting patterns required closer analysis on a finer grain size. Also, the recurrences of such events were distributed within the class’ interactions over the semester (or time periods within the semester), which is a more limited time and space when compared to that of *practice*. One can talk about interaction patterns from many aspects. In this work, I mainly address the class’ discourse and participation patterns as they emerge through multiple episodes. Examples include things like the students provide evidence and reasoning based arguments following the teacher’s probes for disagreement; the students challenge canonically established scientific concepts without the teacher’s probe; the teacher acts as an arguer; the students take up the role of scaffolding each other’s arguments, etc. If classified, the first two would fall in the category of discourse patterns, as they refer to prevalent types of discourse contents and structure; and the later two would be taken as participation patterns, as they emphasized the role of participants in certain interactions. Obviously, discourse and participation patterns are not two independent entities. Rather, they are twisted and interwoven with regards to any specific interaction. For example, the students’ challenging canonically established correct answer (discourse pattern) indicated that they are not in the role of blind follower who would accept anything told by the teacher, but to certain extent play the role of critical thinker and idea sharer (participation pattern).

Noticeably, most of the interaction *patterns* I draw upon in this work are *patterns* of argumentation *practices*. While argumentation practices serve as the central object of my investigation, the discourse and participation patterns extracted across classroom interaction episodes are what I use to characterize the class’ argumentation practices.

develop new understandings. Scientific inquiry practices, as the ways in which the scientific community goes about investigating the world, should be considered when engaging students in school science learning.

For a set of working principles on what distinguishes scientific inquiry from other types of inquiry, I align with consensus views that have emerged from both mainstream philosophers of science and science education researchers:

- Scientific inquiry aims to construct causal explanations about the physical world (Hempel, 1965; NRC, 1996; Salmon, 1998);
- Scientific inquiry pursues internal coherency of ideas and consistency among ideas (Hammer, Russ, Mikeska, & Scherr, 2008; Kuhn, 1970; NRC, 1996; Popper, 1935);
- As a community, practitioners in scientific inquiry engaged in scientific argumentation, which is characterized by supporting arguments with evidence and reasoning, especially mechanistic reasoning (Driver, Newton, & Osborne, 2000; Kuhn, 1993; Latour & Woolgar, 1986; Machamer, Darden, & Craver, 2000);
- Epistemologically, scientific inquiries produce problematic, man-made theories; scientific knowledge is dynamically evolving rather than staying as unchanging truth (Carey & Smith, 1993; Kuhn, 1970).

This list was not created to fully characterize scientific inquiry, but rather, in this proposed study, I use these traits as guidelines to locate *productive* science learning in classroom discourse. In classroom observations, when causal explanations were generated, when ideas were constructed with internal consistency or critically analyzed in terms of internal consistency, when evidence and/or reasoning based scientific arguments

were made, and when problematic view of scientific knowledge was conveyed or reflected, I would recognize the interactions at the moments as productive science learning.

To exemplify how the criteria for productive scientific inquiry will guide my analysis, I draw on an example from the pilot data I collected from a classroom of Sarah's (not the same one that forms the basis of this study). While I will introduce Sarah and the contexts later, below I use the data only to illustrate evidences for productive inquiry practices:

Sarah organized in her class this "philosophical chair" discussion (Seech, 1984) in early September, on the fifth day of class, before she introduced the biological criteria of life. Sarah asked her students, "Is the sun alive?" Towards the end of last class, students were given several minutes to jot down a yes or no answer with justification or a "maybe" with questions for each side. At the beginning of this class, students were asked to line up according to their own positions in a continuum from "sun is alive" to "sun is not alive" and divided into three groups. After a five-minute group discussion collecting ideas, the "yes" group and the "no" group would take turns to debate, trying to win over the "maybe" group.

This transcript unfolds from the beginning of the debate:

1. Eddy: Jose [in the "maybe" group], the sun is alive, it's alive because it's going to die soon enough, you can't die if you're not alive. Rocks don't die. And then so, and then also 'cause of um, energy. If you don't give off energy, you're not alive. Like rocks, don't give off energy.

2. Sarah: OK, anybody else here want to chime in, add anything on to what they said?

Go ahead Tony

3. Tony: Not only does the sun give us energy, but it also gives the plant energy, you know in order for the plants to grow.

4. Sarah: OK, anybody else with that? You got anything to say?

5. Tyler: The sun is always happy. [Class laughter]

6. Eddy: As you would see in the pictures where the sun is wearing sunglasses.
[Class laughter]

7. Sarah: Jesse and Jennifer.

8. Jennifer: OK, the sun is not alive because you see, it's just a ball of gas and like if fire is not alive and it gives off heat, what makes the difference between the sun and fire? And then on top of it when they say the sun's going to die, they don't actually mean it has a heart that is going to stop, they just mean that the gas is going to burn out. So the sun is not alive and um, and it gives off heat for us to live, it doesn't mean that it is alive. So that's all I got say.

9. Sarah: Jesse, do you want to add anything?

10. Jesse: Um...all right, when you throw gasoline on the ground and light it on fire, it doesn't mean that it's alive so...[Class laughter]

11. Jennifer: I love that kid.

12. Sarah: Anybody else from the "no" side want to add anything in?

13. Christian: Yeah

14. Sarah: Yep, go ahead Christian

15. Christian: Um...living things breathe and living things need water, and I wouldn't think the sun breathes or drinks water so

16. Everett: It doesn't need to.

17. Sarah: OK, Everett you want to say something back?

18. Everett: Yea, um...you don't need a heart to be alive.

19. Sarah: OK, for example?

20. Everett: As trees don't have a heart and when you think about it, if you're not alive...like if the sun wasn't alive, like how would we survive? We can't breathe without the plants, and the plants can't live without the sun. So therefore all of it is like a big chain.

21. Jennifer: But it doesn't mean that the Sun is alive. Waters are not alive but you need it to live.

22. Student: Rocks.

23. Student: The difference between the sun and the trees...

24. Eddy: You don't need water to live.

25. Jennifer: Yea you do!

26. Student: [inaudible] the trees actually breathe.

27. Student: But like how do we know- [Students argue on top of each other]

In terms of general discourse structure, this conversation mostly consisted of students going back and forth. The teacher's main role was to direct students to take turns so that both sides got chances to speak. For the whole five minutes Sarah only conducted one close scaffolding move, which was in line 19, pushing Everett to back up his point with evidence by asking "for example?"

This five-minute snippet contained many examples of students carrying out evidence- and reasoning-based scientific argumentation. For example, Eddy in line 1 used the obviously non-living rock as the evidence that things not giving off energy are not alive; Everett in line 20 used the tree as the evidence that you don't need a heart to be alive; Jennifer in line 8 drew a line of analytical reasoning between fire and the sun on the basis that both "give off heat," arguing against the "Yes" group's point (the sun is alive because it gives off energy) by tossing a question back—"what makes the difference between fire and the sun (on the issue of alive or not)?" When making his argument in line 20, Everett first went through a forward chaining (a type of mechanistic reasoning, see Machamer, Darden, & Craver, 2000): "we can't breathe without the plants, and plants can't live without sun," and then concluded with an analogy—"so therefore all of it is like a big chain," which indicated the central point that, since sun is at the starting point of this "life chain," it also has to be alive.

I also found examples of students making well-structured causal explanations.² For instance, Christian's idea in line 15 could be read in a deductive-nomological format: the initial condition is that sun does not breathe or drink, and the law is that all living things breathe and need water, so the conclusion is that sun is not alive. Eddie's first argument in line 1 can be read in a similar manner.

Finally, there is also evidence that students attended to the internal coherency of other students' reasoning and counter-argued a line of reasoning by picking on embedded

² Without fulfilling the Humean requirement of a cause preceding effects relationship, the examples of Deductive-Nomological explanations I used here might not be counted towards causal explanation in Salmon's (1998) sense, but according to Hempel's (1965) definition, DN explanation is an account of causal explanation. It is still an arguable issue that should be categorized as a causal explanation, but a deductive-nomological explanation that has been widely accepted as a standard format for scientific explanation.

inconsistency: in line 8, Jennifer argued against Eddie's and Tony's previous reasoning that the sun is alive because it gives off energy by pointing out that its giving off energy for us to live does not have a necessary link to its own being alive.

Later in this class period, when introducing the biological criteria for life to students, Sarah emphasized that these criteria are just "what biologists chose to use," "not the only ones," neither necessary "the right ones." Later in the semester, I observed students challenging what the teacher or curriculum stated. (For example, when they discussed a food web diagram from the curriculum that showed a food chain from mole to llama to wolf, students asked how scientists knew that wolf would not eat the mole even if it was really, really hungry. Sarah valued this idea and encouraged the students to add information about possible relationships they knew from other resources after analyzing the given relationships on the diagram when writing food web BCR (Basic Constructed Response, an open-ended prompt on the state test). Scenarios like these, I argue, support claims that students took on more epistemologically nuanced views of science, as they conveyed problematic views of scientific theories, and/or promoted critical thinking even in the face of authoritative information.

While the "sun is alive" snippet demonstrated what one form of productive learning may look like in a science classroom, it did not exist on its own. Rather, it was embedded within the much broader social contexts and much longer interaction history. Conversations in this classroom did not start with high-quality scientific inquiry right from the first day of school, nor was it consistently stable at all times in the semester. How can we, then, explain the occurrence of productive learning? How might previous interactions afford and constrain student learning in the snippet we just saw? What effects

would conversations like that have on student learning interactions in the future? I now elaborate on the conceptual framework I adopted to gain insight from the data to these questions.

Pursuing these questions, I drew on Engeström's (1987, 1999) Activity Theory as my conceptual framework, as it pointed to where I could look in order to understand the complex, evolving system of a classroom. In the following section, I explain the way I understood classroom learning using the language of activity theory.

2.3 Localizing activity theory for understanding classroom interactions

Vygotsky's (1978) original activity theory illustrated how an individual pursued an object through the use of the material and the symbolic (language, gestures, etc.) tools. This theory was usually represented by a "basic mediational triangle" (Fig. 1, Kuutti, 1996). Engeström (1987) later formulated it into a framework for how collective subjects carried out object-oriented activities, which were represented as the "expanded mediational triangle" (Fig. 2, Engeström, 1987). This model expanded the analysis unit to an activity system with multiple participants. Accordingly, the conception of mediation was extended to include the shaping power from contextual components. The subjects' actions and interactions within an activity were therefore mediated by both traditional artifacts and contextual components, such as rules, norms and values held by a community, as well as the division of labor.

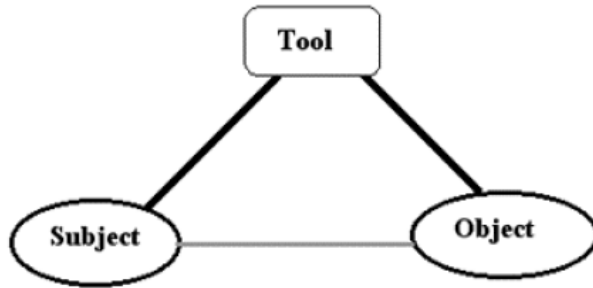


Figure 1. Basic Mediation Triangle

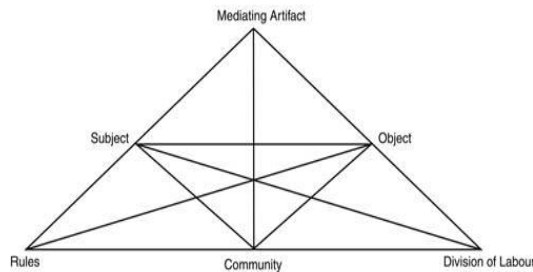


Figure 2. Expanded Mediation Triangle

In his later work, Engeström (1999) emphasized *mediation* as the idea that “breaks down the Cartesian walls that isolate the individual mind from the culture and society” (p. 29) since it allowed us to control our behavior “from the outside.” He pointed out that activity theory emphasized the dynamic, developing nature of the activity system right from its root in the cultural-historical perspective, seeking to “explain and influence the qualitative changes in human practices over time” (p. 378). The evolution of an activity system, as he suggested, happens through internalization and externalization in an expansive cycle. An inference from here: What mediates a system should not be taken as fixed accounts but should be considered as continuously constructed through such expansive cycles. Since mediation is the key of control “from outside,” the evolution of such mediational functions is the “key” to the evolution of the activity system. Therefore, under the guidance of the activity theory, research should not only focus on how artifacts

and contextual components mediate interactions, but should also look at how these mediating factors get renewed through interactions.

In order to conceptualize my research, I localized Engeström's (1999) activity theory to fit some specific features of high school science classrooms, considering one classroom as a continuously changing activity system and considering the learning activities carried out by this class as providing the momentum for such changes.

In a classroom, a teacher and a specific group of students together form the subjects. They interact with each other as well as the material environments, carrying out activities driven by learning objects that they collectively pursue. By regarding the objects as collective, I am not trying to claim a common intention shared by all participants, as the internal psychic status is usually unobservable, especially when the object is not explicitly negotiated. As a researcher, I interpret the collectiveness of objects from a cultural and societal perspective, basing it largely on the semantic orientations of the activity discourse and its outcome.

Classroom activity is immediately mediated by material tools, such as the textbook and worksheet used and communicative tools, such as the language used (artifacts). Contextually, it is also mediated by particular norms and routines of the classroom (rules), values and norms held by broader contexts, such as the school and the educational system (community), and teacher-student relationship and their roles ("labor division" in classroom setting). I referred to all these elements as *mediational resources*, or resources for short.

The term "resource" has already gained various meanings within the field: Hammer and Elby (2003) employed it to describe the conceptual and epistemological

“knowledge in pieces” (diSessa, 1988) brought to learning by individual students. Crawford, Kelly, and Brown (2000) used it to denote both individual knowledge of science practices and the artifacts affording science practices. Engle and Conant (2002) broadly defined “resources” as supporting settings ranging from available space of class time to classroom constructed artifacts and norms to modes of discussion. In this study, the meaning of *resource* is closer to Engle and Conant’s (2002) use, but even broader (e.g., including epistemic resources), and focusing on a functional common ground, that is, when functioning together, resources afford certain interactions and constrain others.

In the analysis I later present, I identify resources of different categories, such as the argumentative tools of critically attending to the substance of ideas and supporting one’s arguments with evidence and reasoning, the unique sharing norm that “it is OK to share what people would laugh at,” the epistemological value attached to criteria-driven scientific knowledge, as well as the comfortable-to-share relationship between teacher and students. In addition, while looking at the construction and functioning of these resources in a classroom, I also take into account possible influences from the larger community, especially the systemic pressure embodied through high-stake testing and accountability.

Building on the work of activity theory, the analysis unit for this research will be a classroom *activity system*, which I use to refer to the network involving all the above structural and functional elements that features a specific class and how learning activities are carried out under such circumstances. A classroom activity system has a relatively fixed body of participants (subjects), but a dynamic structure, which, as Engeström (1999) suggested, evolved over time through participants’ internalization and

externalization. From a starting system without specific mediational resources to a more developed system with all kinds of resources brought in and constructed through learning activities, an activity system is continuously transformed.

2.3.1 Classroom science learning activities

Classroom science learning activities take place when certain scientific topic(s) serve as shared objects and classroom interactions are organized around it. The topic(s) can be brought up by either the teacher or the students. Some classroom time does not qualify for this activity category. The class I observed spent time talking about test dates, handing in lab fees, assigning homework, discussing school schedules, etc. They sometimes had “family bonding” time, in which they discussed their personal lives rather than scientific ideas. Also, before each unit exam, the teacher would go around and share her hand lotion with the students, which she called the “good-luck lotion.” These are all examples of classroom activities that are not oriented towards science learning.

In the research communities that employ activity theory, defining activities with boundaries remains problematic (Engeström, 2000). In order to fit the scale of this investigation, activities in this study are mostly bounded by conversational topics, usually on a time scale of several minutes to tens of minutes. Between science learning activities sometimes there are clear boundaries (i.e., the teacher directs students from discussion to note-taking), while other times, boundaries are more difficult to identify (i.e., a conversation gradually runs off topic.)

At any time in a science learning activity, participants can hold differentiated or even conflicting goals (which are not accessible to my observation unless played out in the interactions). Objects that drive an activity, however, emerge through interactions and

represent what discourses have mainly attended to during a certain time period. Such objects can be explicitly or implicitly negotiated (as shown in the analysis of scenario 3 above) or adopted from conventions (when no identifiable negotiation happens but the activity discourses clearly follow certain objects). The power relationship between teacher and students can easily play into the object negotiation or adoption, impacting whether the class should shift into a different activity or continue the previous activity.

As defined above, science learning activity in this sense does not ensure the productiveness of learning. It is just a general term referring to what teacher and students attend to in a science class.

2.3.2 Constructing shared mediational resources for classroom science learning

This study focuses on intersubjectively shared mediational resources for science learning in a particular classroom activity system. Again, since in a certain activity, we rarely have access to ideas from every student (i.e., we will not be able to interpret a student remaining silent in a whole class discussion), here by “intersubjectively shared” I am not trying to claim a cognitive agreement on certain mediational resources among all subjects, but rather refer to collective orientations that can be interpreted from observable discourses. In this sense, any learning-associated mediational elements accessible to the whole class (or at least a large portion of the class) and appearing to be comprehensible for the discourse participants would be considered as “shared” at a certain level. For example, discourse moves frequently employed in classroom discussion (communicative tool), the routine of making “vocabulary cards” (material tool and norm), the argumentative norms specified by the teacher or suggested by students (rules), would all count as shared mediational resources. Conversely, some resources, such as side-talks, or

what students write on their own notebooks, would not be counted into this pool, since their mediational effects are only for specific student(s) rather than for the whole activity system.

The construction of such shared mediational resources begins when a teacher and a new group of students come together into a classroom and start their learning activities (Engeström, 1999; Varenne & McDermott, 1993). Many of these mediational resources (as my previous analysis showed) may exist or even be shared prior to the formation of this class, as teachers and high school students have all been “in school” for many years, they have formed understandings of how school works or how science class works even ahead of their communication. But before classroom interactions start, there is no chance for this specific group of people to jointly construct or bring in their mediational resources; and since observation is not available before this point, as a researcher I have no data to infer such preexisting mediational resources. Therefore, in this study, any personally held mediational resources would only be taken into consideration if it is publicly shared and accepted (or sometimes acquiesced if so widely accepted).

Shared mediational resources for learning can be constructed both explicitly and implicitly. Explicit construction occurs through actions/interaction with clear goals of setting up certain mediational resources for current and/or future learning activities. Generally speaking, such situations are not as common for implicit constructions, in which learning interactions are not directly focusing on setting up mediational resources, but as learning interactions frequently representing certain discourse moves, roles of participants, values, norms, and so on. Some of these elements would gradually obtain

higher intersubjectivity through communication and therefore gain the potential of mediating the current and future learning activities. The explicit and implicit constructions of culture are very much intertwined and in many cases assisting and reinforcing each other.

2.3.3 Function of mediational resources

Mediational effects can also be either explicit or implicit. There are occasions in which participants directly draw upon resources constructed earlier as the rationale for their current actions/interactions. But in most situations, resources such as classroom norms for sharing, teacher-student relationships, routines for argumentation mediate through subtle orientations of attention, which are not apparently mentioned in the discourse but are to be interpreted from teacher and students' actions and interactions. It is hard to make a firm causal explanation regarding mediation, since a researcher's own interpretations are unavoidably involved, and one can always argue that such actions/interactions are associated with the classroom dynamic at the moment rather than any mediational resources constructed over time.

Focused on how shared mediational resources afford or constrain productive learning interactions, I will specifically look at whether, over time, learners demonstrate higher quality participation in scientific inquiry, and whether they would follow the patterns of learning interactions established before. The changes in the types, contents, and structures of classroom learning interactions, I assume, should suggest the mediational effects. This assumption, of course, has its own limits. For example, students who do not participate much in learning interactions can still be very productive learners but we will not have evidence for that.

Mediated learning interactions can also be the constructive processes of mediational resources. Through externalizing one's own ideas and internalizing other people's ideas, individuals also communicate the similarities and differences in their understandings of certain mediational resources and can therefore result in modifying such resources or establishing a stronger sense of intersubjectivity.

I began my work with this framework. I also anticipated that more precise understanding of shared mediational resources and the development of the classroom activity system would emerge as I looked closely at the classroom data. In the last chapter of this dissertation, I reconsider my conceptual framework and propose a new theoretical construct that I argue better captures the phenomena I studied.

Chapter 3: Methodology

3.1 Research question reframing

My conceptual framework emphasizes both the constructive nature of shared mediational resources and their mediational role in learning activities. According to this framework, my research question can also be rephrased into the following two sub-questions:

How are shared mediational resources constructed through learning interactions in a high school biology class?

How do the constructed shared mediational resources mediate learning interactions in a high school biology class?

These two questions guided my methodological choices for data collection and data analysis.

3.2 Data collection

3.2.1 Site selection for classroom observation

The teacher Sarah, whose class I observed, was young and new in practice. She has an undergraduate degree in marine biology and recently graduated from a graduate-level secondary teacher certification program where learning to attend to student thinking was a major focus. At the time of this study, she was in her third year teaching biology at a large urban-suburban high school with a diverse student population. Sarah participated in the professional development project run by our research team. During that project (one

year before data collection for this dissertation), she was identified as a teacher who sought to scaffold argumentation and students' mechanistic thinking. While all teachers in our biology cohort (n=10) used the same curriculum guide and bore the same institutional pressure of preparing students for the state's High School Assessment, video from Sarah's classroom demonstrated that she actively strove to elicit student ideas and support productive scientific inquiry practices. Sarah's classroom was a suitable site for my data collection since it both represented the reality teachers work within and yet still evidenced the potential to provide the productive learning phenomena I wanted to study. Sarah's classes often were rich in student talk and exchange, another advantage for collecting classroom discourse data.

The class I observed was an honors biology class of 24 students: 11 females and 13 males. Students represent a mixture of grades, including 13 tenth graders, 10 eleventh graders and one ninth grader. It was also ethnically diverse, consisting of 11 Caucasians (45.8%), 5 Hispanics (20.8%), 4 Asians (16.7%) and 4 Blacks (16.7%). This distribution was close to the demographics of the school district (on average 38.1% Caucasians, 22.7% Hispanics, 15.6% Asians and 23.2% Blacks, according to the county website at the time of the study). While the class' gender ratio, diversity in grades, and diversity in ethnic background could have influenced the ways in which students interacted, this was not the focus for my investigation. The main purpose for including this demographic information is to inform the readers about the general setting of this classroom, which embedded the interactions I describe and the whole story I tell.

I also observed a regular class taught by Sarah. The two classes were very similar in terms of the type of learning activities in which students engaged. I ultimately

decided to use the data collected from the honors class, since that class was more talkative, which provided a convenience for the type of analytical work that grounded this study.

3.2.2 Classroom observation

To address my research questions, my data needed to afford critical analysis into ongoing learning interactions and to suggest the dynamics of classroom interaction patterns. To this end, I observed a high school biology class taught by Sarah each day for the entire fall semester, 2008-2009. In Sarah's school, biology was a semester-long course, meeting 90-minutes on alternate days. Every class was videotaped except for unit exam days; these testing days contained little classroom discourse. In total, I collected 54 hours of videotapes (36 lessons). Since this encompassed the scope of the course, and thus was all I had access to in this school, I hoped that such length of time would allow me to identify interaction patterns. Classroom observation – and associated video - served as my main data source. At times when it served my analytical needs, classroom data was triangulated with data from teacher interviews, and a focus group student interview in order to cross-check my interpretation.

Through these long-term observations I aimed to identify the class' interaction patterns in various types of activities; I could then consider how Sarah and her students constructed mediational resources that afforded or constrained their science learning interactions.

3.2.3 Teacher and student interviews

I conducted five semi-structure interviews with Sarah, which primarily entailed 1) what she perceived to be going on at specific moments that drew my attention; 2) what she expected students to learn through specific activities and 3) what she attended to in specific learning interactions and why. Interviews were scheduled on days when I observed and identified distinguishing interactions in her class (things that I perceived as unique to this class). Since many of the significant interactive features I found were revealed relatively early in the semester, three out of the five interviews were conducted within the first month, while the other two were scheduled in the middle and by the end of the semester, respectively. Driving questions for each interview were constructed around the contents and contexts of the selected interactions; video snippets were used to stimulate memory of specific interactions when needed. Sarah's responses to such questions helped me to see how the teacher viewed and rationalized the construction of mediational resources, and suggested on the side how shared mediational resources mediated the way she interacted with students.

The student interview was conducted at the end of the semester. A group of six (four males and two females, randomly selected) participated. They were showed snippets of classroom argumentation practices from the semester, and were asked to reflect on: 1) their understandings of the teacher's and their peer students' discursive moves; 2) their own learning experiences in those activities; and 3) how this class was similar to or different from students' previous learning experience in science. Such data might provide access to students' localized epistemologies (Hammer, 1995), as well as

their views of and contributions to the patterns of learning interactions. (See Appendix A for interview protocol.)

3.2.4 Epistemology survey

I adopted a survey questionnaire modified from what Elby (in progress) used to explore teachers' epistemological beliefs for detecting general epistemological changes among the group of students I observed. The survey contained 12 questions on a five-point Likert scale, among which eight questions encompassed students' opinions on science and learning, while the other four concerned students' expectations (or experience, for the post-survey) about learning in this class. It also contained three questions that asked for written comments. (See Appendix B for the detailed survey questionnaire.) The survey was given to the class by the teacher both at the beginning and the end of the semester. Twenty-two students (one student took only the post-survey and another took neither) fully accomplished pre- and post-surveys were collected. Paired-t tests were run on the pre- and post-answers of each item to detect any significant changes.

In a primary analysis of the survey data, I found few questions detecting significant changes,³ which made it hard to generate any reliable interpretation about the

³ Among the answers to the 12 questions, only two turned out to have slightly significant changes ($p < .05$). Question No. 7 asked how strongly students agreed or disagreed with the statement "Using common sense is helpful while learning biology/life sciences": mean score on this question decreased from 3.95 to 3.45 but the median doesn't change (with 1 standing for strongly agree and 5 standing for strongly disagree; $p = .045$). Question No. 11 asked how students strongly agreed or disagreed with the statement "The main reason for homework is so the teacher can grade how well we understood what we learned in class": mean score on this question decreased from 3.73 to 3.23 and the median from 4 to 3.5 (with 1 standing for strongly agree and 5 standing for strongly disagree; $p = .047$). Such changes might suggest that Sarah's class helped the students value the use of common sense somewhat more, and that the homework the students did in this class was a little bit less for teacher's grading purpose than they thought it would be. However, the slightly significant changes on these two items were diluted by the lack of significant changes on all the other items.

course's influence on the class' general epistemologies. The reason for such lacking of significant changes can be quite complex. Therefore, I determined to exclude the survey results from my analysis, drawing no conclusion on the class' general epistemological beliefs.

3.3 Data analysis

3.3.1 Productive learning in discourse

A critical issue for this analysis is the need to address how I bound productive learning in science classroom discourses. As I suggested at the beginning of my conceptual framework, I identified productive learning with the class' engagement in scientific inquiry practices. This take on productivity aligns with a sociolinguistic perspective (Carlsen, 1991) that considers learning outcomes not as a measure of students' performance on achievement tests, but as revealed by how immediate objectives (or objects, in activity theory language) get accomplished through local discourses.

Defining scientific inquiry as “the pursuit of coherent, mechanistic accounts of natural phenomena (p. 13),” Hammer (2008) characterized some essential epistemological actions/interactions that would evidence scientific thinking, including mechanistic reasoning, pursuing coherence within and between ideas, building up scientific argumentation, supporting arguments with evidence and so on. Such characterizations can be practically used for identifying inquiry practices in a classroom. (For discourse examples that I saw as counting towards such epistemological actions/interactions, see page 11-14.) As Warren (2001) argued, classroom scientific inquiry practice is not limited to rigorous scientific language and reasoning; sense-

making of everyday experience through everyday language can be a powerful tool for students to conduct scientific inquiry.

In combination, the above literature suggested that, in order to recognize productive learning in a classroom, close observation and critical analysis should be conducted to detect inquiry-evidenced interactions, especially those carried out in everyday language, which would easily be missed if one simply attended to the use of formal scientific language.

Through the lens of activity theory (Engeström, 1987, 1999), I see an activity system as evolving through the development of mediational resources, which takes place in moment-to-moment interactions. Therefore, the effects of local discourses are not limited to the outcomes of local activity, but also extended to the class' learning interactions in the future through the construction of mediational resources over interactive history. In the sense of such long-term effects, productive learning also aligns with the emergence and persistence of more inquiry-affording discourse and participation patterns (Erickson, 2004).

Educational researchers who looked closely at classroom discourses argued that some classroom discourse structures may indicate and afford productive learning while some others may suppress it. For example, Lemke (1990) suggested that the prevalent discourse pattern of "triadic dialogue" (also known as the IRE sequence (Mehan, 1979), in which a teacher throws out a question, a student replies with an answer and the teacher gives a positive or negative evaluation), while appearing to involve a good amount of student participation, does not usually provide chances for high-quality critical thinking, since the focus can easily be fixed on the superficial correctness rather than the substance

of student ideas. In contrast, “reflective toss,” in which the teacher catches the meaning of a student idea and throws it back as a probing question, was identified as a more productive discourse pattern in terms of eliciting students’ further thinking along the line (van Zee & Minstrell, 1997). Similarly, while many have recorded that classroom inquiries often get dismissed or cut short by teacher’s authoritative closing remarks (Cazden, 1988; Lemke, 1990; Mehan, 1979), Cazden (1988) also suggested that ongoing back-and-forth among teacher and students around certain idea(s) indicates better chances of quality inquiry practices.

Additionally, as some sociolinguistic scholars point out, when certain linguistic expressions get frequently used by participants in a group over time, they may serve as discourse markers that signal potential communicative purposes (Fraser, 1996) and facilitate interpretations of communicative situations (Risselada & Spooren, 1998). In my case, it is, therefore, worthwhile to watch out for expressions repeatedly employed by the teacher and the students (e.g., the teacher’s use of “there is no right or wrong answer”), as understanding the pragmatic meanings associated with such expressions may assist in understanding how local discourses afford productive learning.

Finally, since an ultimate goal of scientific inquiry learning is to afford students to actively investigate natural phenomena and scientific concepts on their own (NRC, 1996; Diver, Newton, & Osborne, 2000; Nesbit, Hargrove, Harrelson, & Maxey, 2004), I consider the independence of students’ inquiry practices as an important criterion for evaluating their learning productivity. This concern points me to examine how the students participate in their inquiry practices, especially how their inquiries get initiated and maintained. Inquiries initiated by the students and maintained with less scaffolding

effort from the teacher are considered as evidence of more active participation in productive learning.

In summary, I attended to productive learning first as evidenced by their scientific inquiry practices—the kinds of epistemological actions/interactions involved, their frequencies and lengths, and the depth they went to in regard to specific contents and contexts. On that basis, I also attended to another closely related layer of learning productivity, that is, the class evolving into an activity system better for meaningful engagements in scientific inquiry practices, as evidenced by observable discourse and participation patterns. While productive learning in this sense can be seen as what affords productive learning in the former sense, my investigation of affordance and constraints goes deeper than pattern identifications but attempts to understand the possible processes of how such patterns got formed. Aligning with the types of productive learning I attended to and the investigational goal I had in mind, my analysis closely focused on their moment-to-moment classroom discourses, mainly speech, but also includes contextualization cues (Gumperz, 1982; Duranti & Goodwin, 1992) such as eye gaze, gesture, writing, and pictures or other visual representations on the board, as they turn out to play significant roles in the local meaning construction processes.

3.3.2 Primary analysis

In primary analysis, I went through the whole semester's videotapes, summarizing in notes the contents of classroom interactions every one to five minutes. The intervals were determined by natural shifts in classroom interactions. Taking the 10 minutes at the beginning of the philosophical chair activity as an example, my notes read as follows:

Content log 4B philosophical chair 9/9/08 tape1

...

26:22-28:00: Sarah poses the philosophical chair question: "Do you think the sun is alive?" asking the students to spend 5 minutes writing down their ideas without talking to each other. Requirements include reasons for "yes" or "no," or questions if answering maybe. *"There is no right or wrong answer."*

28:00-31:09: Students write in their notebooks.

31:09-32:20 <tape change>: Sarah asks the students to go to the back of the classroom, standing in the "yes" or "no" lines depending on their own positions.

Content log 4B philosophical chair 9/9/08 tape2

1:42-2:30 Students split into "yes," "no," and "maybe" groups, taking turns to share their ideas. In the "yes" group, for several times the group comments on each other's ideas.

Every group chooses their "speakers." Students adjust in a position to face each other. Sarah announces that they can move from one group to another during the debate, and emphasizes that the debate is an "educated discussion" rather than a contest on who talks the loudest.

2:30-4:20 first round of debate (*Sarah gestured speakers to face the "maybe" group*)

Speakers of both "yes" and "no" groups made their main arguments and other people chimed in:

"Yes" side: Charles and Fidel make arguments; Candy is "good for now."

"No" side: Acer makes argument, citing the "ball of gas" idea Jeff shared within their group.

Tristan moves from the “maybe” to the “yes” side while Acer speaks, *causing class laughter.*

Kara added in her idea, “need to have cells and need to be able to reproduce,” which quickly gets challenged by Charles’ *exceptional counterevidence*: “*a liger can’t produce!*”

Charles repeatedly makes the claim “it’s living!” with a “shooting” gesture; Sarah reminds him that it is “not about talking the loudest.”

As one can see, the intervals are defined by the flow of events rather than a fixed period of time. The interval sequence represents the natural shifts in discourse: debate topic announced—individual work—debate setup—group discussion—first round of the debate.

Another noticeable feature of my notes was that some of the intervals at this stage were very detailed, citing students’ words and even pointing to specific gestures (2:30-4:20), while some other intervals were described in single sentences (28:00-31:09; 31:10-32:20). The thickness of the descriptions was determined by the richness of the discourse data in terms of the inquiry practices involved and the interaction patterns carried when viewed from a longitudinal perspective. Many of the details were not included in the first round, but identified when similar observations were made in later episodes. For examples, in the notes above, Sarah’s setup remark of “there is no right and wrong answer” and her gesturing speakers to face the “maybe” group were both added when I saw Sarah used this expression or directed students to speak to their fellow students in later situations. Also, Charles’ argument through exceptional counterevidence was marked and described in detail (together with the arguments before and after this point)

when I saw how prevalent such arguments were in their argumentative interactions over the semester. (The examples were marked in italics for this discussion, not in the original notes.)

3.3.3 Pattern identification and episode selection

As notes accumulate, inquiry practices of different types and lengths were identified. The philosophical chair debate noted above, for instance, was marked as a major episode of scientific argumentation, lasting for approximately 30 minutes.

Discourse and participation patterns as well as pattern shifts on different levels also started to emerge. The main types of patterns I attended to include:

- a. Classroom discourse structure such as triadic dialogue (Lemke, 1990), student question and teacher response (Watt, Alsop, Gould, & Walsh, 1997), reflective toss (van Zee & Minstrell, 1997), and back-and-forth (Cazden, 1988). Interactions demonstrating better inquiry-affording discourse structures (e.g., reflective toss, back-and-forth or teacher response that turn student question into investigational topic) are put in thick description. For example, in the above note, the back-and-forth between students in the debate is what gets recorded with the most details.
- b. How inquiry practices were initiated and maintained. The notes above exemplify cases set up by a question from the teacher. In their later interactions, I observed argumentations initiated by questions or comments from the students. Regarding how inquiry was maintained, I focused on the types and amounts of scaffolding moves involved, concerned with things like what question(s) the teacher asked before a counterargument was brought up,

how many probing question(s) were used before students elaborated on the reasoning and evidence behind their claims, and whether the students scaffold each other's arguments in the same way the teacher did, etc.

- c. Repeatedly seen expressions that could serve as discourse markers. The expression of "there is no right or wrong answer," for example, was frequently employed as part of the teacher's instruction before open-ended discussions.
- d. The formality of discourse language. When book-style definitions of concepts were stated or many vocabulary words were involved in the discourse, it was taken as the evidence of using scientific language; when students referred to examples from their personal experience, it was often put into everyday language (Warren, 2001). Certainly, there were many cases when the two were used in combination.

Such analytical treatment was functionally similar to the typical grounded approach of coding (Strauss, 1987; Strauss & Corbin, 1990), in which codes are generalized from the texts by the researcher in a more inductive manner, rather than by checking against a starting list created before coding. However, the patterns I referred to here were not trimmed into the kind of concise codes commonly used in qualitative research (Miles & Huberman, 1994), but remained nested in contexts because my main purpose was to select pattern-bearing episodes for further analysis rather than parsing the discourse data or drawing inference.

Episodes containing rich evidence of inquiry practices (e.g., scientific argumentation), bearing patterns or demonstrating shifts in patterns (e.g., when discourse structure changed from triadic dialogue to back-and-forth), were selected out for

transcription.⁴

3.3.4 Shrink to argumentation

Initially, I proposed to investigate all the aspects of the class' productive learning. However, looking across the selected episodes while considering the inquiry-related science education literature, I saw the merits of reducing this scope and focusing my later analysis on how this class developed affordances and constraints of their scientific argumentation practices. First, scientific argumentation was the natural tenet for the class I observed. A large portion of the selected episodes involved argumentation practices or the potential for such practices; and the teacher told me in the interview that getting students to “disagree with each other's ideas” and “going back-and-forth” were two of her major teaching goals. Second, scientific argumentation has been widely recognized as central to scientists' practices. Many of the other aspects of productive learning, such as reasoning mechanistically, seeking for causal explanation, and attending to the (in) consistency in and between ideas, can be well integrated in the practices of argumentation. Third, scientific argumentation has been well attended by researchers in the field. Many arguments and much practical effort has been made for promoting it in

⁴ Two types of transcript conventions were adopted in this dissertation. For analytical work on the affordance and constraints of scientific argumentation practices, I followed the transcript conventions most commonly used in science education literature, which show little beyond the speakers, the turns, and the content of what was said. For the analysis on humor practices, I started to follow the more detailed type of transcript convention (Engels & Conant, 2002), including things like where speeches overlapped, where laughter started, tones (roughly) and gestures. There were two reasons for doing that. For one thing, going along with the analytical work, I started to find such details important for discourse interpretations, but there was no time to redo all the transcripts and relating analysis. For another, the interpretation of humor practices required more details: the location of laughter contained much information regarding what the class laughed at; there were often more overlapped talks taking place at times of class laughter; also, much more shared cultural insights were packed into humor practices, which made the interpretation work especially hard for me. Since I did not grow up in this country, I could not always appreciate the sense of humor familiar to American teachers and students.

classrooms; this allowed this study connect to a broader conversation in existing science education literature.

3.3.5 Close discourse analysis

Taking the above factors into account, I focused the following analysis on understanding how the class' scientific argumentation practices developed and changed over the semester, as well as how such developments and changes aligned with the mediational resources they continuously constructed.

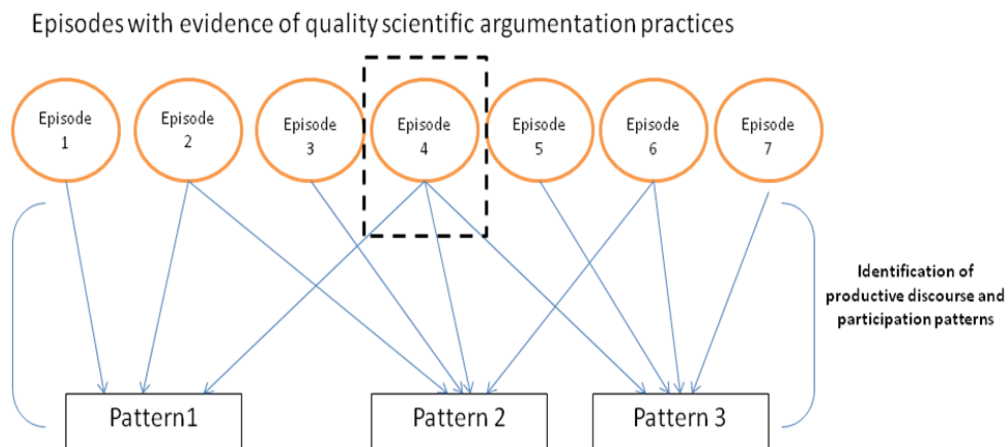
The following developments in scientific argumentation practices corresponded with the two intertwined aspects of productive learning that I have laid out:

- 1) Regarding the quality of individual scientific argumentation episodes, I examined whether students' claims were justified by reasoning and evidence, whether and how often they argued by picking at incoherencies within and among ideas, how specific discrepancies on the table got solved (or left unsolved), and how the students reacted to comments or ideas from the teacher.
- 2) Regarding the developments in the class' discourse and participation patterns, I closely attended to when, on what and in what situations students started to initiate scientific argumentations, how long and how well such argumentations were maintained, and the roles the teacher and students played in different argumentations along the timeline, especially changes in the amount and types of teacher scaffolding moves over time.

Based on such analysis, I then selected from all the quality scientific

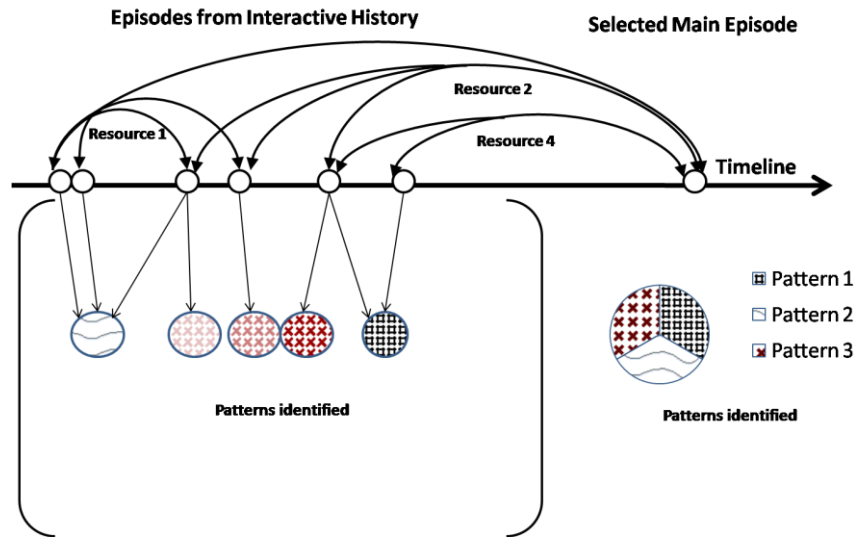
argumentation episodes of a representative main case, which bore most of the argumentation-affording discourse and participation patterns I had identified throughout the semester (see figure 1). Since classroom argumentation in this case was significantly cut short by the end, it was also a good starting point for exploring how constraints on argumentation practices got constructed in this class.

**Figure 3. Selection of representative main episode
(starting point for reflection on interactive history)**



This main representative case occurring about a month into the semester served as a potential connecting point. I tied it back to other primarily selected episodes that took place prior to this one (not limited to the ones that involved scientific argumentations), based on parallel discourse and participation patterns they bore. They then formed a series of interactions through which one could see how certain patterns emerged, repeatedly presented or gradually developed (see figure 2).

Figure 4. Tying patterns back to interactive history



For the main episode and the episodes that formed its interactive history, some of the interaction patterns could be clearly linked with resources rooted in the immediate interactive contexts. For instance, in the philosophical chair debate activity, the existence of two opposite camps could partially count for the back-and-forth discourse structure between students; such camps directly resulted from the students' side-picking following the teacher's setup instructions.

For some other patterns, however, it would be hard to generate easy explanations only through analysis of the immediate contexts. For example, in the representative main episode, a student presented a challenge based on a piece of exceptional counter evidence. That particular activity was not framed for students to think of exceptions; but tracing back, we saw that the class has experienced multiple activities that encouraged the students to identify exceptions. These interactions attached value to exception discovery and conveyed the epistemological idea that there was "there is always an exception" rule to biological concepts, which might have contributed to the students' later arguments through exceptional counterevidence.

Such possible historical roots of specific interaction patterns were central to my

analytical work. The identification of mediational resources and their construction processes greatly depended on my understanding of what was going on as a researcher and a long-term observer. A large portion of the story recorded below was devoted to drawing out the underlying meanings of fine-grain classroom discourses and illustrating the possible social processes through which learning interactions got shaped into the way they are (Erickson, 2004; Gee, 2000; Kelly, 2005).

It is important to clarify here that this work is not trying to make causal explanations for the discourse and participation patterns I observed. Indeed, by tying episodes back to previous interactions and digging through interactive history for roots of patterns, I attempted to picture salient alignments of patterns and the roles of possible resources behind the patterns; but I am not claiming any resource(s) as sufficient cause of any discussed pattern, since there were so many other aspects to the complex system of this classroom that I choose not to touch (e.g., student identity, students' previous experience with school science learning, etc.), which would also contribute to the ways they interacted and their engagement in inquiry practices.

The specific discourse analysis theories, such as ones on the functions of using certain personal pronouns, origins and functions of humorous interactions, changing tones, stress and rhythm would not be systematically employed but would be introduced and drawn on when needed for extracting the underlying meaning of specific discourses. For example, in analyzing how Sarah set up a "serious" learning goal for test preparation while maintaining (even reinforcing) her alignment with students for "fun," I focused on her vague use of personal pronouns, draw on the theory that such vagueness has the

important discourse function of creating cohesion or distance (Halliday, 1994; Kamio, 2001).

3.4 Chapter structure

The next chapter situates my work in argumentation literature. By drawing on different literature in this area and comparing this work to them, I clarify my theoretical positions relating to argumentation and the rationales for some of my methodological choices. From there I move into my data analysis chapters.

In the first analytical chapter, I explore particular interaction patterns associated with this class' productive scientific argumentation practices. Tracing back interactional histories, I examine how their previous interactions fed into each of these patterns. This lead to an in-depth description on how related learning goals, norms, values, teacher-student relationships and epistemic messages got constructed. A major finding was that many of the participation patterns that lead to productive argumentation on scientific topics rooted in general, not learning-targeted, interactions.

While the class demonstrated affordances for productive scientific argumentations, such practices were not always prevalent; and, often, the argumentations that did emerge were limited in depth and length. I devote a chapter to explore how possible constraints on argumentation practices grew out of the class' interactive history and how they played out in particular activity settings.

In the last analytical chapter, I explore the role humor plays in classroom interaction. While I had not anticipated that this would emerge, it appeared to be too significant to ignore for the particular classroom I studied. In this chapter, I draw on several typical scenarios that involved humor from that class, analyzing what made each

case humorous and exploring the different roles humor played in subsequent classroom interactions.

I end with a discussion about classroom culture, which I propose as an overarching construct that emphasizes the dynamic, locally constructed and integrated nature of classroom phenomena. From this cultural perspective, I argue that, in order to better understand group learning, we need to build more holistic and interactive accounts on how complex activity systems (such as classroom) develop over time.

Chapter 4: Situating the work

There is consensus in science education that argumentation is central to scientists' professional work and, therefore, should be promoted in school settings (Driver, Newton, & Osborn, 2000; Duschl & Osborne, 2002; Kelly, Druker, & Chen, 1998; NRC, 1996, 2000; Sandoval, 2005). The literature has explored a range of phenomena and research questions, employing various theoretical assumptions, on such things as how to conceptualize argumentation, what characterizes productive scientific argumentation practices, and in consequence, what related learning goals should be pursued.

In this chapter, I aim to situate my dissertation within this literature, by comparing and relating it to other studies in this area, illustrating how it contrasts, aligns with, or extends different pieces of work. I also suggest how my work may speak to the broader education literature that concerns the design of learning environments.

4.1 From structure to function

For the purpose of defining argumentation and establishing measures of quality of students' scientific arguments, Toulmin's (1958) philosophical model of formal argument is frequently employed by educational researchers (Bell & Linn, 2000; Dawson & Venville, 2009; Jiménez-Aleixandre, Bugallo-Rodríguez, & Duschl, 2000; McNeill, Lizotte, & Krajcik, 2006; Osborne, Erduran, & Simon, 2004).

The original purpose of Toulmin's (1958) work was to problematize the traditional, inference-centered view of argument, which claimed that at the core of

argumentation lay idealized formal logic, and that quality of all the arguments could be assessed based on its logic structure. His challenge was constructed through emphasizing justification as the primary function of practical arguments, and pointing to aspects of arguments that can apply across disciplines and fields that depend on disciplinary argument. In *Return to Reason* (Toulmin, 2001), he further clarified that his main goal writing *Use of Argument* (1958) was for philosophers to broaden their scope in analyzing substantive argumentations and attend to the role of situation. However, when adopted as the framework for conceptualizing argumentation in education, the field-dependent part was rarely addressed and the model was often reduced to just the field-invariant part, which consisted of six typical structural components of argument and the functional relations between them.

Briefly, the Toulminian components include *data*, which refers to the evidence used to support *claim*—the point-making statement, and the logical statements bridging the two, the *warrant*. Most studies employing a Toulminian framework draw upon these three components. In addition, Toulmin included three other components—*qualifier* (express degree of certainty), *rebuttal* (state on the restrictions of a claim) and *backing* (certify the credibility of warrant)—that are often cut out in science education, both in terms of understanding argumentation or scaffolding it. For example, Bell and Linn (2000) and McNeill et al (2006) left qualifier and rebuttal out of their frameworks. McNeill et al (2006) modeled argumentation through three components—claim, evidence (data) and reasoning (which they suggested as a combination of warrant and backing); Bell and Linn (2000) organized their coding schemes in a similar way, but with warrant and backing staying in separated categories.

There were several reasons for such simplification. First, their investigations focused on students' written arguments rather than ongoing argumentation; with no counter argument presented, there is not much need to include components such as rebuttal. Second, as design-based studies, they reduced the complexity to focus students on primary components, and changed the terms to ones more familiar to teacher and students. Their evaluation criteria were then also set in alignment. Third, as McNeill et al (2006) suggested, backings and warrants often blend together, which leads to difficulty teasing them apart in analysis or function. Such difficulties in distinguishing warrants and backings, or data and warrants, have been reported by many other studies as well (Dawson & Vanville, 2009; Erduran, Osborne, & Simon, 2004).

Such common adoption and modification of Toulmin's framework reflects a shared theoretical assumption that logic structure is central to scientific argumentation and argumentation quality, which runs counter to Toulmin's stated intention of his work (Toulmin, 1958). As a consequence, this framework oriented researchers towards identifying, evaluating and promoting student arguments in terms of the structural components.

One common thread of research into students' scientific argumentation is to illustrate how students participated in classroom argumentations according to a Toulminian coding scheme (Chinn, O'Donnell, & Jinks, 2000; Jiménez-Aleixandre, Bugallo-Rodríguez, & Duschl, 2000). While this research largely avoided direct evaluations, its analytical focus implied that the quality of argumentation could be inferred from the involvement of structural components. Jiménez-Aleixandre, et al (2000) examined how a 9th grade biology class engaged in "doing school" and "doing science"

over six class sessions on Mendelian Genetics. Their analysis of the class' "doing science" moments focused on characterizing students' argumentation practices in terms of structural components (based on the Toulmian account) and epistemic operations involved. By coding and counting the frequency of each structural component within the whole discourse, they suggested that naturally emerging student arguments (meaning without implementation of argumentation-supportive interventions) are often dominated by claims, showing a lack of justification by data and warrants; they posit that this could result from their lack of opportunities to solve problems and discuss science in classroom. Chinn, et al (2000) looked at the degree of complexity of both group argumentation and individual's written arguments, judged primarily by the number of claims and justifications involved and the complexity of their relationships. Their results suggest that the complexity of a group's peer argumentation is predictive of the complexity of individual participants' written arguments.

Many other researchers are more explicit about their structure-centered positions, developing structure-based rubrics for assessing argumentation quality. Osborne, Erduran, and Simon's (2004) work, for example, divided argumentation quality into five levels, with level one being a single claim versus a counterclaim, level five being more developed argument with more than one rebuttal, and increasing involvements of data, warrants, and single rebuttal characterizing the levels in between. Using this set of standards, they assessed arguments made in classroom discussions at the beginning and the end of an instructional intervention. Results of this assessment suggested improvements in students' argumentation abilities and skills. Likewise, the four-level quality scale Dawson and Venville (2009) developed marked level one with single claim,

level two the inclusion of data and/or warrant, level three the addition of backing or qualifier, and level four the addition of both backing and qualifier. This scale was used to assess arguments high school students made in semi-structured group interviews, and resulted in a claim that level-two arguments (claim, with data and/or warrant) were most prevalent.

By focusing on structure alone, such research and assessment leave out the contents and contexts of student argumentation. Structure was imposed, with no connection to particular discourse functions they could serve in specific situations. After employing a Toulminan model to code argumentation in discourse, Kelly, Drucker and Chen (1998) questioned their own analytical methodology: since language can be flexibly used in conversation, and the need for justification is often shaped by the interactive history and shared knowledge, there is no reliable linguistic marker one can use in coding. Such analytic moves makes it difficult to identify argument components without closer consideration of related contexts and conversational dynamics, and even harder to draw fair inference on students' argumentation abilities or skills based on the structure of their arguments in an interactive discourse.

To align with the focus on argumentation structure, specific curriculum and instructional strategies were developed to scaffold the construction of arguments, such as explicit teaching of general reasoning patterns (Zohar & Nemet, 2002), using open-ended argumentation prompts and writing frames (Osborne, et al., 2004), and replacing written scaffolds with teacher introduction of an explanation framework (McNeill, et al, 2006). Through pre- and post-assessments designed to measure the structural completeness or the usage frequency of certain components, these interventions showed satisfactory

changes in students' argumentation discourses.

Other scholars combined structure-based approaches of argumentation with the goal of learning particular content knowledge. According to their criteria, quality arguments should include a complete set of structural components and also show the mastery of canonically correct disciplinary knowledge. For instance, McNeill, et al (2006) assessed students' written scientific explanation (which they used interchangeably with the term "argument") by scoring the involvement of each structural component. According to their rubric, making more accurate (canonically correct) claims, employing more pieces of evidences, and providing more generalizable reasoning together counted towards better arguments. Similarly, in Zohar and Nemet (2002) assessment of student arguments in classroom discussion and written worksheets, quality arguments were associated with both the inclusion of multiple justifications and the use of correct knowledge on the specific biological topics they studied.

While such research claimed that their criteria addressed substance (i.e. content), their concerns about content focused entirely on its correctness. Argumentation became another tool for learning canonically correct content, losing the discrepancy-solving and knowledge-building roles it plays in scientists' work. If such assessments were adopted in a classroom, it could risk conveying the message that argumentation was simply a format of presenting correct, unproblematic scientific knowledge (Russ, Coffey, Hammer, & Hutchison, 2008).

Emphasizing the functional role of argumentation over its structure and canonical correctness, some argumentation literature extends beyond structure-based frameworks, and argues instead that argumentation productiveness should be examined in terms of

what it allows students to do. Through close analysis of an emergent and sustained argumentation on whether killer whales are whales or dolphins, Engle and Conant (2002) showed discourse evidence that, with that argumentation, the students dived into this particular classification problem, refining their ideas to make it more persuasive, reevaluating their original beliefs based as evidences accumulated, critically commenting on the credibility of information resources, and raising further questions. The value of the argumentation resided in that it enabled to make progress – to “get students to somewhere (p. 403).” The “somewhere” pointed not to a correct answer or just the inclusion of more structural components, but to the opportunities for students to share ideas, the expended ways for them to consider the same disciplinary issue, and the motivation for reasoning through, challenging or building on each other’s ideas. One would easily miss such values of this argumentation case if simply focusing on its structural components. For example, consider the following excerpt:

136. Samantha: [to Ms. P] no we went with our whale group, [to other students] but see, you guys, I don't see- there were two trainers right? and ONE of them was doing all the talking, and SHE was the one that wasn't sure, the other one was ABSolutely positive. So why won't you believe the other trainer?

137. Toscan: [to Samantha] but the- in their sci- en- ti- FIC!

138. Brian: [to Samantha] we don't believe both of them.

139. Toscan: [to Samantha] that their skin is LIKE a dolphin, and their dorsal fin is like a dolphin, and it goes like that [moving his arm like a swimming dolphin]. and all the other whales go like that [again moving his arm like a

swimming dolphin]. they don't go [moving his arm to swim like a fish]. So maybe they're A:::LL dolphins [sweeps hand forward], or maybe they're A:::LL [sweeps hand back towards original position] whales! (Engle & Conant, 2002)

In terms of structure, a deficiency one may quickly detect in Toscan's argument is the lack of warrant. He described how whales and dolphin share similar features such as the skin and dorsal fin and the way that they appear to swim, then jumped directly to the claim that "so maybe they are all dolphins or maybe they are all whales," without stating why these three similarities, of which only one (the dorsal fin) would count as anatomic evidence, could sufficiently support the conclusion that the two should be classified into the same group. Only when interpreting this argument as embedded in the discussions prior to and after this point, does it become evident that Toscan was actually not arguing for categorizing all whales together with dolphins, but the opposite. By then the only evidence in support of the "killer whale is dolphin" claim was the feature of dorsal fin they have in common; and both Brian and Toscan himself have suggested that many other whales besides killer whales also have dorsal fin. Put together, as Toscan argued in the snippet above, such reasoning would lead to the nonsense conclusion that "all whales are dolphins."⁵

To sense the significance of this argument, one needs to read it in the context that the class has been arguing for a while on whether they should trust the trainers in the sea world (who told them killer whale may be dolphin) as an information resource, and that Samantha just emphasized again how one of trainers was "absolutely positive (about that

⁵ Some may argue that he is being inconsistent. Here I'm not entering this debate.

killer whale is dolphin)". The exchange set aside the debate about whether the trainers had authority or whether they were believable, and refocused the argumentation onto making their own judgment through comparing the two in terms of observable features.

There is one more thing worth mentioning about this particular study. Toscan's argument above did not follow any specific explanation framework, nor did it draw on many biological terms (except for "dorsal fin"), but was mostly voiced in everyday language. Such everyday mode of argumentation, as Warren and Rosebery (2001) argued, is a tool for student's sense-making activities. They demonstrated through analysis of several cases how everyday language afforded students to make sense of the biological concept they were introduced to.

In this study, I align with the likes of Engle and Conant (2002) and Warren and Roseberry (2001) in consideration of students' scientific argumentation. I start from the assumption (in part based on the limitation of not doing so) that the functional role argumentation plays outweighs the particular format in which it is presented. I interpret quality of argumentations not as subjected to fixed structure-based criteria, but in terms of what was allowed to happen locally, which, as we see in Conant and Engle's work, could not be separated from the contexts and contents of specific activities, or classroom mediational resources developed over time. When challenges are raised against canonically established concepts, when arguments pop up in classroom activities not planned for argumentation, when students initiate argumentation to solve discrepancies they detect themselves, when the learners start to scaffold each other's ideas by asking for better articulation or proofs, the change in argumentation quality, I believe, is not less, probably even more significant than, say, whether they provide multiple pieces of

evidences to each claim following some particular worksheet requirements (McNeil, et al, 2006).

4.2 From individual ability to social activity

Many researchers started from the position that engaging in scientific argumentation requires an individual to have certain cognitive abilities or skills (Kuhn, 1991, 1993; Lizotte, Harris, McNeill, Marx, & Krajcik, 2003; McNeill, et al, 2006). To learn argumentation, then, requires the acquisition of such abilities or skills. This perspective drove researchers to examine how students, on the individual level, were competent in making quality arguments (or scientific explanations⁶), and explore ways to promote such competency.

Kuhn's (1991) early work was the preeminent example. She examined how individuals reconciled their interpretations of specific scenarios with the presence of non-covariate evidences. Based on the interview results that children and lay adults often failed to address the differences between evidences and theories and tended to ignore evidence inconsistent with their own theories, she claimed that such participants lacked cognitive abilities in coordinating evidence and theories. This general conclusion showed little concern for the role of the interactive contexts; yet contexts might contribute to how different participant groups responded (e.g., participants of different ages and educational backgrounds might perceive different power relationships with the interviewers; they might have different degrees of familiarity with similar tasks; and they might interpret the same interview questions differently; etc.). Such research results, therefore, have limited

⁶ The two terms were often used in an exchangeable manner, as suggested by McNeill, et al (2006).

power in predicting or understanding what students are able to do when they engage in classroom exchanges.

Lizotte, et al (2006) and McNeill, et al (2006) both explored students' individual abilities in making scientific explanation by assessing the structure-based quality of their written arguments. The involvement of higher level structural components (such as warrant or multiple pieces of evidences, according to their rubric) was therefore taken as evidencing better cognitive abilities of argumentation. At the same time, they also both associated the students' abilities with the effectiveness of the curriculum material or instructional support they implemented. Lizotte, et al implemented a four-week chemistry curriculum that resulted in moderate pre- to post- ability changes based on their assessment of the quality of students' written work. With this feedback, they revised the curriculum to include a lesson on explanation, which primarily served to make their rubric transparent to students. In the second enactment, the ability gain was greater than the first one. McNeill, et al (2006) implemented two types of instructional supports over an eight week intervention period. For one treatment group, structural scaffolds were continuously provided to guide students in their written work (e.g., claim, two pieces of evidence, reasoning, etc); for the other, such scaffolds were provided at the beginning, but faded over time. According to their analysis of pre- and post- tests, the two treatment groups showed comparable improvement, but the faded treatment group scored better in reasoning in posttest, which did not provide scaffolds.

While such design-based studies document notable pre- and post- intervention changes in students written arguments, the subsequent interpretation of these results leave open questions. First, as I argued in the last section, a singularly focused structure-based

quality assessment leaves much out of scope. Second, like Kuhn's (1991) work, their analysis treated individual cognitive ability as context-independent. This assumption allowed them to draw on the quality of specific written argument as evidence of cognitive ability. Third, while attributing pre-post gains in argument quality to the implementation of curriculum or instructional strategies, their analyses provided little insights on what happened in those classrooms and how such changes developed over time. The lack of classroom data made it difficult to distinguish whether the structural changes resulted from the imposition of specific argument formats, or whether something in the curriculum helped students develop deeper understandings of how to construct powerful arguments.

Within literature that examines argumentation in classroom interaction settings, much work focuses on correlating changes of students' argument structures and intervention implementation (Osborne, et al, 2004; Erduran, Simon, & Osborne, 2004). Osborne, et al (2004), for example, coded and then assessed students' argument structures for two group discussions (two groups were taped and coded for each discussion) per classroom, one taking place at the beginning and the other towards the end of intervention. Similar to the work discussed above (Lizzote, et al, 2003; McNeill, et al, 2006), they detected changes by comparing the pre- and post-assessment results, but could not speak with direct evidence to what afforded the pre- and post- changes.

In contrast, other researchers closely looked at how argumentations occurred through classroom interactions (Berland & Reiser, 2009; Engle & Conant, 2002). This research assumed that students were cognitively able to engage in the social activities of argumentation, and emphasized the need for understanding how such practices get locally

supported, resulting in efforts to understand complex argumentation phenomena taking place in particular learning environments. Engle and Conant's (2002) work, for example, focused on explaining what afforded the emergence of a lasting argumentation case in a Fostering Communities of Learners (FCL)⁷ classroom. They proposed four principles for fostering productive disciplinary practices: students should be encouraged to problematize what they study; they should be given the authorities to produce and own knowledge; they should be held accountable to others and classroom and disciplinary norms; also, they should be provided resources that would afford their disciplinary engagement. The researchers carefully illustrated the case of argumentation, pulling out discourse evidence to establish the class' disciplinary engagements during the argumentation. Then in order to explain what occurred in that case, they reflected back to previous interactions to show how the classroom learning environment was constructed following the four principles they suggested. Their explanation of that construction focuses primarily on what the teacher did that embodied the principles and contributed to the establishment of affording learning environments.

Again, my work aligns with Engle and Conant's (2002) work in that it tries to understand emergent cases by looking at an interactional history, tracing back what happened in the past, and assuming certain continuity in classroom interactions. Methodologically, we both locate evidence of productive learning within local interactions, and employ fine grain discourse analysis instead of pre- and post-tests to

⁷ Fostering Communities of Learners is a program Brown and Campione (1990, 1994) started in Oakland, CA. It focused on reconceptualizing and redesigning classroom, aiming to promote students' engagement in collaborative learning and disciplinary practices. Inheriting the Vygotskian (1978) perspective that learning is a social process, one main feature of this program is the effort on understanding the construction and the functions of classroom learning environments, and how rich learning happens through interactions. It started with classroom-based research in reading and writing but later expanded to all the other subject areas.

shed light on it. Furthermore, we both explore how affordances of productiveness was constructed locally, in and through interactions.

My work also extends that of Engle and Conant's (2002). First, as I suggested above, their explanation for how argumentation affordances developed in that classroom primarily pointed to the teacher. Their guiding principles did not address how students contribute to the construction of learning environment, as they *were encouraged* to take on what they learnt, *given* the authority, *held* accountable to disciplinary norms and *provided* resources. Also, while they showed students' disciplinary engagement in argumentation through close discourse analysis of classroom interactions, their explanation on what afford such argumentation case did not examine the class' interactive history in the same manner or on the same detail level, but focused on providing general accounts of what the teacher did. Combining with the guiding principles put in passive voice, this made it sound like that the students were only involved in such affordance construction process through following the teacher's instructions. In my study, coming from the perspective that emphasizes continuous interactions as where evolution of an activity system takes place (Engeström, 1999), I explore how teacher and students together contributed to the construction of classroom argumentation affordance through classroom interactions. As my analyses repeatedly demonstrates, in the classroom I studied, there were not only moments when teachers instructed the students on what they should do and how they should participate, but also moments when students and the teacher negotiated about their learning goals, when students held teachers accountable for certain classroom norms, and when students initiated the use of certain argumentative strategies. In such situations, students played

significant roles in the construction of affordance. Herrenkhol, Palincsar, DeWater & Kwasaki's (1999) also investigated how a class' notion of theory evolved through continuous classroom interaction, and focused on the role students played in the construction.

Second, while Engle and Conant's (2002) work focused entirely on interactions that reflected the class' disciplinary engagement, my scope of data analysis extends beyond that. When tracing back the interactive history to understand the development of classroom learning environment, I looked beyond interactions involving argumentation, even beyond just disciplinary interactions. While bounded for research's sake, such boundaries cannot separate argumentation or broader disciplinary learning from the flow of classroom interactions. The continuity of classroom interactions allowed resources constructed in non-disciplinary interactions to contribute to future disciplinary learning as well. As my analysis shows, the teacher-students relationships in the classroom I studied were first built through activities such as introductions and "family-bonding," activities outside of disciplinary learning activities. When continued in the class' disciplinary learning activities, such classroom relationships contributed to lowering the threshold for sharing ideas, making it easier for teacher and students to focus on the substances of each other's ideas.

Berland and Reiser's (2009) work also point to the need to broaden the research scope to better understand the ways in which non-disciplinary factors contribute to the disciplinary practices of argumentation. Their work examined how students argued in both written work and classroom discussions when supported by IQWST, a Toulmian model-based curriculum and instructional framework. They found that students fulfilled

two of the three learning goals of argumentation—sense-making, that is, constructing evidence-based arguments; and articulation, that is, expressing their understandings in coherent causal explanations—but were not oriented towards engaging in persuasion. The obstacle, as they suggested, was the traditional social norm that prevented students from going against or judging others’ ideas, and the lack of reason for students to persuade. Therefore they called for learning environment designs that address such challenges, constructing supportive classroom norms and purposes for persuasion. While they specifically focused on curricula, the need of forming social norms and purposes is applicable to the construction of learning environments in a broader sense as well.

4.3 General research context

While most research looks at argumentation within curriculum and instructional contexts designed to explicitly support students’ engagement in argumentation (Berland & Reiser, 2009; Engle & Conant, 2002; Erduran, et al, 2004; McNeill, et al, 2006), my work, like that of Jiménez-Aleixandre, et al (2000), considers argumentation as it emerges from formal curriculum that does not have argumentation as an explicit goal. I did not ask the teacher to implement any curriculum or instructional strategy. Rather, the teacher valued scientific argumentation and made moves to promote it in her classroom. Unlike other university-based design-based curriculum development and research efforts (Berland & Riser, 2009; McNeil et al, 2006), my work occurred within a more traditional classroom setting, complete with existing institutional pressures that did not reinforce the teacher’s goals for argumentation.

My work was exploratory in nature, which allowed me start with a more general goal of understanding how productive scientific argumentation unfolded in that classroom, staying open to a range of classroom interactions and paying more attention to possible constraints from broader contexts. Promoting argumentation was just one of their learning goals. When played out in a classroom, it often had to make way for or stay in balance with all the other goals, especially those more emphasized and supported by the broader institutional system, such as the emphasis on content and objective coverage, terminology, and test-taking strategies. My study gave me opportunity to see into that dynamic and speak to how argumentation practices evolved in such complex system.

4.4 Relate to broader literature

In addition to situating my work in science education literature, particularly that which concerns argumentation, aspects of this study can also connect to a broader literature on classroom learning environments. Researchers have emphasized the critical need to study the dynamics of learning environments (Brown, 1992; Herrenkhol, Palincsar, DeWater, & Kwasaki, 1999; Scardamalia & Bereiter, 1994). Brown (1992) pointed out the methodological difficulty design-based studies often encounter: it is simply impossible to study any single aspect of classroom learning or the effect of any single factor on classroom learning, as learning occurs through complex, constantly changing human situations, for which changing one thing would naturally cause other things to change. While Brown suggested dynamics as intrinsic to learning environments, Scardamalia and Bereiter (1994) set it as a goal for learners to contribute to such dynamics. The core idea of their design-based research is to turn classroom into a second order environments, in

which “learning is not asymptotic because what one person does in adapting changes the environments so that others must readapt (p. 267).” Although the two seem to hold different positions regarding whether the dynamics of learning environments is something unavoidable or something that needs to be promoted, they both point at the necessity of understanding elements of learning environments as interconnected and locally developed. It is this perspective that drives me to explore how classroom mediational resources afford (or constrain) argumentation and get constructed over time in multiple, interdependent aspects. Fine grain discourse analysis was required to identify such processes since resource construction was often implicit and occurring through interactions.

In my final chapter, I connect to literature on culture and propose classroom culture as a theoretical construct that better captures the phenomena I studied. I adopt a view of classroom culture that emphasizes the ways in which a learning environment (or culture) is continuously shaped by participants, locally constructed through interactions, and consisting of locally integrated resources. This cultural perspective suggests methodological implications for research that focuses on the relationship between learning environments and classroom interactions: in order to explain what contributes to the features of classroom interactions in an episode of interest, we can first trace back the class’ interactive history, looking at how their interaction patterns develop over time; then through close discourse analysis, we can investigate how such patterns emerge as various classroom mediational resources get constructed through local interactions; finally, we may consider how these previously constructed resources integrate and function in the local contexts of the episode of interests.

Chapter 5: Constructing affordance of argumentation practices

5.1 Argumentation: Structure, skills and classroom norms

Over the last half-century, there have been increasing concerns about science as social activities (Driver, Leach, Millar, & Scott, 1996). From that perspective, philosophers of science have suggested scientific argumentation as playing a central role in the production of scientific knowledge, constituting a core element of scientists' practices (Fuller, 1997; Latour & Woolgar, 1986). Following in suit, reforms in science education have made efforts to promote classroom argumentation practices (Driver, Newton, & Osborn, 2000; Duschl & Osborne, 2002; Kelly, Druker, & Chen, 1998; NRC, 1996, 2000; Sandoval, 2005).

Many researchers in science education have used the framework from Toulmin's *Use of Arguments* (1958) to conceptualize argumentation (Bell & Linn, 2000; Driver et al., 2000; Sandoval, 2005). While this work's original purpose was to challenge the traditional, inference-centered view of argument with practical arguments' emphasis on justification, it was reduced to a model consisting of the typical structural elements of argument and the functional relations between these elements. In short, *data* refers to the evidence used to support *claim*—the point-making statement, and the logical statements bridging *data* and *claim* are named *warrant* (other elements [e.g., *qualifier*, *rebuttal* and *backing*]—are less frequently employed in research).

This general account of formal argument has been modified into important tools for examining and evaluating argumentation practices in classroom (Dawson & Venville,

2009; Erduran, Simon, & Osborne, 2004; Kelly et al., 1998; Jiménez-Aleixandre, Bugallo-Rodríguez, & Duschl, 2000). Some research directly applied the Toulmian model as a coding scheme, analyzing argumentation discourse for how frequently specific structural components got involved (Kelly et al., 1998; Jiménez-Aleixandre et al., 2000); others developed scaling measurements, assessing the quality of student arguments based on their structural completeness (Dawson & Venville, 2009; Erduran et al., 2004).

With a similar emphasis on the componential structure of argument, early work from Kuhn (1991, 1993), though not employing a Toulmian framework but aligning with Walton (1989), also linked argument structure with individuals' cognitive skills in coordinating theoretical claims and evidence.

Findings from research focusing on argumentation structure, unsurprisingly, pointed to both the incomplete structure of students' arguments and the weaknesses in students' argumentation skills. For example, many found that the students often argued by stating their claims without justification through warrants and data (Dawson & Venville, 2009; Jiménez-Aleixandre et al., 2000). Through interview studies, Kuhn (1991, 1993) suggested that adolescents and lay adults lack the skills to distinguish data and theoretical explanation of data, and that they are not able to make two-sided arguments. Such deficiency reports motivated the development of specific curriculum and instructional strategies for initiating, supporting and scaffolding students' argumentation practices, such as explicit teaching of general reasoning patterns (Zohar & Nemet, 2002), using open-ended argumentation prompts (Erduran et al., 2004), creating opportunities for peer or small group discussions (Erduran et al., 2004; Kuhn & Udell,

2003), and replacing written scaffolds with teacher introduction of an explanation framework (McNeill, Lizotte, Krajcik, & Marx, 2006). Through pre- and post-assessments designed to measure the structural completeness or the usage frequency of certain components, these interventions showed satisfactory changes in students' argumentation discourses.

While this research proves prevalent, its guiding framework and overarching goal greatly limits the scope of understanding for classroom scientific argumentations. As a structural account of formal arguments, the Toulmian scheme provides neither tools nor language for analyzing argumentation as a goal-driven, socially constructed discourse phenomenon, embedded in either classroom discourse or the broader discourse of science (Driver et al., 2000; Kelly et al., 1998). Judging the quality of a scientific argument according to structural features, in separation from its functional role and sociocultural-historical contexts it is rooted in, can be misleading. First, as Kelly et al. (1998) suggested, language can be flexibly used in conversation, and the need for justification is often shaped by the interactive history and shared knowledge, it is therefore hard to identify argument components without considering the related contexts and conversational dynamics, and even harder to make fair inference on individuals' abilities or skills in argumentation based on the structure of their arguments in an interactive discourse.

Second, the value of argumentation for science rests in its power of resolving scientific discrepancy (Driver et al., 2000). If argumentation skills get foregrounded and established as the learning goal, but learners are not pursuing something that would raise the need to argue, we have little to ensure that argumentation gets developed into a useful

discourse tool that students can draw on, but may risk making it into another school requirement they need to fulfill.

With this concern, some scholars suggested that scientific argumentation should be established into a classroom norm (Driver et al., 2000; Engle & Conant, 2002). They called for argumentation to become a type of discourse that permeate all kinds of classroom activities, emerging naturally as part of students' regular sense-making interactions. In alignment, recent research started to investigate the complexity of classroom argumentation phenomena, taking into account multiple, interdependent factors of the learning environments. Studies on how learning contexts motivate engagement in argumentation suggested the important roles of factors such as social norms of classroom interactions (Berland & Reiser, 2009) and epistemological resources (Louca, Elby, & Hammer, 2004). In a case study of an emergent and lasting classroom argumentation, Engle and Conant (2002) demonstrated how a class' disciplinary engagement was constructed through continuous effort in fostering a learner community from many aspects, covering attitude and values towards controversial ideas, positions and roles of students, accountability for disciplinary norms, and supportive classroom resources. A message conveyed by this line of research is: to understand classroom affordance of meaningful argumentation practices, we need to closely look at the non-linear, multifaceted developmental process of classroom learning environments.

This is not to say that

Following this train of thoughts, I explore through the present ethnographic study how classroom norms conducive to scientific argumentation took shape and gave rise to students' sense-making interactions. From a sociocultural-historical perspective

(Engeström, 1987; Vygotsky, 1978), I view learning as continuously occurring in interactions between the social and individual planes, mediated by both artifacts and sociocultural contexts developed through the interactive history of the specific group and broader communities. Based on the above, my research questions are:

- What affords or constrains the use of scientific argumentation in students' interactions in science classrooms?
- How do classroom affordances and constraints of argumentation get constructed over time through classroom interactions?

5.2 Through the lens of activity theory

Adopting the lens of the activity theory (Engeström, 1987), I consider scientific argumentation as a general form of interactions that can serve the objects of different classroom activities. For such interactions to emerge, the class needs to develop shared understandings of when argumentation is allowed, what type of language to use and how to participate. The norm of argumentation also needs to be compatible with other classroom norms, both content wise and context wise. To illustrate the establishment of such argumentation “norm,” we have to look into the complexity of an evolving classroom system. The influence of classroom mediational resources is not limited to the structure of arguments, but reaches the content, purpose, values and interaction patterns of classroom argumentation.

In the analysis that follows, I first selected a main argumentation episode occurring in the middle of the semester, which represented most of the discourse and participation patterns associated with the class' productive argumentation practices. From

there I traced back the class' interactive history before this point, attending to prior episodes (including many other instances of teacher-structured or student-initiated argumentations) that demonstrated any pattern contrasting or in parallel to the patterns represented by in the main episode. This pattern mapping then allowed me to see where patterns started or changed through interactions. Associated episodes were subject to close discourse analysis (Gee, 2000; Erickson, 2004; Kelly, 2005), aiming to reveal the critical resources that could afford such pattern generation and pattern shifts, including particular learning goals, classroom norms, values, participant relationships and roles. The analysis illustrated both the mediational functions of identified classroom resources and the ways they got continuously constructed through local interactions.

5.3 Parasitism and predation

It was about a month into the semester, at the end of the ecology unit when the class started with a review of biotic relationships, on which they had taken notes a week earlier. Sarah first asked students to name different biotic relationships and explain their meanings. In the review of parasitism, it was agreed on by the class, and confirmed by Sarah that parasites usually do harm to but would not kill their host. However, by the time they moved to commensalism, Acer posed a question that dragged the topic back:

1. Acer: If there is like a parasite or something in the prey or whatever dies, like, because of it, would you call it predator or what or still parasite?"
2. Charles: Like you could die from mosquitoes, like the disease they carried.
3. Sarah: So the disease they carried like kills them, not the mosquito.
4. Charles: Well, the mosquito bit the person.

5. Students: Yeah.
6. Christine: Yeah, but it wasn't-
7. Sarah: But the bite didn't kill the person.
8. Christine: It is the disease-
9. Acer: Um, what, wha-, isn't a virus like a parasite?
10. Charles: But they inject the virus that caused the disease.
11. Sarah: So, here is, if I were gonna argue back with Acer. He just said isn't a virus like a parasite. If I'm gonna argue back-, does anybody else wanna argue back?
12. Students: No.
13. Sarah: I'm gonna argue that-
14. Charles: Because virus isn't an organism.
15. Sarah: Some people would not consi-, virus is kind of falling in this iffy place where we are not sure we should call them alive or not alive. So I would argue that is not a relationship between two living organisms. I would say that there are always exceptions to the rule, like, Tim said, "That's rare." There are exceptions though. So usually parasites don't kill their host. If they did kill them, I don't know, maybe you would want to call it a predator 'cause it hunts it and kills it.
16. Tim: But usually it just doesn't happen.
17. Tim: Like it would be predator and prey if that in that form. [*Inaudible*]
18. Sarah: What did you say?
19. Tim: It would be predator and prey if it happens a lot, but it can happen sometimes but usually the other animal doesn't die, so it is just parasitism.
20. Charles: Oh, my gosh, he sounds so smart. [*Class laughter*]

This conversation flew through many shorthanded and co-constructed arguments, demonstrating the students' engagement in scientific argumentation as well as reflecting their conceptual understanding of the scientific subject. Acer problematized the demarcation between parasitism and predation with a hypothetical overlap—a parasite in a prey that dies from it. His picking on such ambiguity implied critical scientific thinking. First, it required conceptual understandings on how both types of relationships are canonically defined. Then he also needed to draw comparison between the two, not just in abstract, but with concrete natural phenomena mapped to the theoretical, man-made categories, especially where they overlap.

The exchanges between Sarah and Charles showed a shared understanding of the pathological mechanism behind mosquito-borne, transmissible disease, but with different interpretations on what the killer is: Sarah identified the disease rather than the mosquito as the direct cause of death, whereas Charles defended by emphasizing the mosquito's initiator position in the causal chain—it “bit the person” and “injects the virus.” Here the same piece of mechanistic reasoning was employed to support two different causal explanations, with the actual discrepancy on whether causality should be defined as what straightly lead to the occurrence of something or what started a series of events that end with the occurrence of something. In further reflection, one could see how these two senses of causality often coexisted in scientific explanations. It was rational to characterize it either way.

The argumentation shifted when Acer brought up virus as an example. Charles and the teacher both argued through denying virus' status of living organism and excluding the precondition for it to be considered a parasite. By calling it the “iffy place,”

Sarah indicated the debatable nature of her rebuttal. She also took a step back, acknowledging the possibility of a loose boundary—“If they did kill them,” “maybe you would want to call it a predator ’cause it hunts it and kills it.” Tim argued against Sarah’s step back, emphasizing the differential probabilistic meanings behind accidental and normal phenomena.

This episode shows merits in terms of argument structure, involvement of scientific thinking, and students’ understanding of related content, but its significance extends far beyond that. First, the argumentation was initiated by a student’s challenge of the canonical boundary between parasitism and predation, which had been established by the teacher in previous class sessions and confirmed just prior to this episode in a teacher-student interaction. Such moves are rare, in our observations and in the common patterns of classroom argumentation interactions recorded by the literature, as usually argumentations start with an open question and without a “correct answer” being given (Engle & Conant, 2002). Second, this conversation occurred during a review activity, where checking conceptual understandings and knowledge of terminology is far more typical than engaging in scientific argumentation. Third, the students brought up arguments on their own rather than following specific probes from the teacher. Further, the class had not gone through any sort of training in argumentation skills suggested important by the literature (Erduran, Simon, & Osborn, 2004; Kuhn & Udell, 2003; McNeill et al., 2006). While the teacher’s scaffolding moves were very limited (The main move she made was bringing Acer’s argument to the class’ attention and asking “Does anybody else wanna argue back?”), the students attended to the substance of ideas from each other and from the teacher. Lastly, the nature of the teacher’s participation was

distinct from more commonly adopted roles: she was an arguer in the field, actively constructing her own argument. Though some might find authoritative flavor in her arguments, I noticed that the students treated her ideas on par with their peers' arguments rather than as ones to accept. They argued with her without hesitation, clearly demonstrating their understandings and critical thinking.

Understanding the features above is important for explaining how argumentation took place at that moment. These features also indicate that certain argumentation “norms” has been established, so that argumentation can naturally emerge and contribute to the class' sense-making process. The immediate contexts of this episode, however, do not explain what gave rise to these features. When examining this episode as embedded in the interactive history of classroom, I identified previous episodes that share or contrast this episode in certain features. Through comparison between multiple episodes, I analyzed how mediational resources conducive to scientific argumentation got constructed and contributed to the features seen here.

5.4 Affordance construction through teacher-structured whole class argumentations

The interaction patterns demonstrated above were not always the case for this class. As I went over their previous episodes of scientific discussions, I found it gradually developed through classroom interactions, along with the construction of classroom mediational resources in multiple aspects. My analysis first drew upon a series of three scientific discussions taking place at the beginning of the semester, describing the significant changes in the ways teacher and students participated in argumentative interactions. Through close discourse analysis, I identified episodes in which teacher and

students explicitly negotiated or implicitly shaped learning goals, values and rules that could contribute to the observable participation changes. In retrospect, I pondered on the possible influences of these resources on later classroom interactions, especially how they could afford some of the interaction patterns I saw in the predation and parasitism argumentation.

5.4.1 The tea brewery discussion

In the third biology class early in the school year, Sarah posed a question for the whole class: Why do we brew tea in hot water? Students soon came to an agreement that hot water works faster since molecules move faster in it. Sarah then followed with another question: “At the end of all, are we going to get the same product using hot water and cold water?”

At first, the class together made the “yeah” sound in a low-pitch, elongated tone, as if that answer was so self-evident. After Sarah pushed the question back twice, few students still remained in responding, and they provided a simple causal explanation for their previous judgment —“it (the tea) would eventually go into water.” As Sarah, again, pushed it back by explicitly asking for “anybody thinks no?” the following exchanges took place:

1. Sarah: Does anybody think no, we are not gonna get the same thing?
2. Nick: [*Raising hand*]
3. Sarah: Yeah? How come?
4. Nick: Because I think that’s the right answer.
5. Sarah: And? Why?
6. Nick: Because you keep on like, asking that.

7. Sarah: I'm just trying to get you guys disagree about stuff! One person said something and you were all like, yeah— [*Mimicking their lazy tone*] [*Class laughter*]
[*Tristan raises his hand*]

Initially, Nick simply raised his hand and voted for “not gonna get the same thing.” When Sarah probed for his reason by asking “how come?” he gave no causal explanation of the suggested phenomena but stated that he thought, “that’s the right answer.” It was after Sarah’s second push that he shared his interpretation that the teacher’s persistent push when everybody said “yes” suggested that the correct answer must be the opposite. Saying this, Nick did not receive any counterargument, laughter, or weird looks from his classmates; instead, the class remained silent with their eyes fixing on Sarah. Sarah did not show much surprise either. Claiming the purpose was to “get you guys disagree about stuff,” she then made fun of the way students casually threw away their agreements, indicating that she would interpret such answers as not resulting from critical thinking.

At this moment of the discussion, the discourse contained no evidence that the students were reasoning about the central phenomena; even the teacher’s scaffolding move was misinterpreted. Her efforts probing for disagreements were taken as cues for correct answer, not just by Nick, who explicitly made that comment, but also by his fellow students—as they stopped responding when sensing the push back, and their reactions to Nick’s interpretation implied that they were also waiting for an answer. In this instance, Sarah did not bring in her argument, but since the students would even accept what they thought she indicated, it is reasonable to guess that they probably would not focus on the substance of her ideas and argue.

This conversation did not end there. The following exchange took place right after Sarah clarified her purpose:

1. Tristan: Well, I disagree with it. Hot water evaporates so there is less water in there. [*Class laughter*] [*Students making the “Ohhhh” sound.*]
2. Nick: [*Rolling eyes, sarcastically*] Oh, what an AWESOME answer!
3. Sarah: Wait a minute, so hot water evaporates, so, you mean like the steam that comes off it?
4. Tristan: [*Nodding*] there is less water in there.
5. Sarah: There is less water which means?
6. Tristan: Higher concentration!
7. Sarah: Oh, higher concentration, more flavored, did you say more flavored?
8. Tim: That’s what I said.

Here Tristan provided a piece of mechanistic reasoning that would support the claim of a different final product: there would be less water in tea made with hot water due to evaporation. This argument was not taken seriously and respectfully, as the class immediately exploded in laughter and made funny “ohhh” sound. Nick threw out the comment “what an awesome answer” with rolling eyes, sarcastic tone, and an emphasis on “awesome,” suggesting that his real attitude could be translated into the opposite. Sarah, however, ignored this sarcasm and grabbed Tristan’s idea. She first offered Tristan a chance to repeat his argument to the class and then probed for a complete chain of reasoning: “There is less water which means?”

This discussion ended up with several students claiming higher tea concentration (or more flavored tea) in hot water, with the same mechanistic reasoning embedded. In

another class of Sarah's, discussion on the same topic ended up with the opposite conclusion, supported by detailed ideas such as "there would be the same amount of crystal (chemicals released from tea) in it" and "it (tea in cold water) would just taste weird because of the temperature." As Sarah also said in the interview, there was not "an exact right answer such discussion tried to reach." Reasoning-based arguments on either side would be counted towards fulfilling the purpose.

In contrast to the predation and parasitism argumentation, although this discussion was planned by the teacher to be an open-ended one, optimizing the opportunity for argumentation, the way the students participated indicated their expectation of a correct answer from the teacher. Instead of arguing with each other through mechanistic reasoning of concrete phenomena, the students tried to answer the teacher's questions and pursued her confirmation. When an unexpected idea came into the conversation, laughter and sarcasm were stirred up, but its scientific substance did not get attended to. I see in this interaction much scaffolding effort from Sarah: first she encouraged argumentation by pushing back reasoning-lacking agreement; then she probed Nick's answer for a causal explanation, and communicated with him (and the class) the purpose of her discursive move; finally, by requesting Tristan to articulate his chain of reasoning, she claimed value for this spark of scientific thinking, and set an example for the class on how to focus on the scientific substance of ideas.

When contextualized in the larger picture of school education and the settings of this classroom, what got communicated here was much more than what was explicitly said. Nick did not just accidentally misinterpret Sarah's discursive move, and the class did not accidentally accept his interpretation without surprise. Very likely, the idea that a

science teacher is looking for somebody to say the right answer if she/he kept pushing a question back has been repeatedly conveyed to Nick (and the class) during prior years of schooling. For him (and probably others), getting to the correct answer through a teacher's guidance was the overarching goal for classroom science learning. Therefore, by explicitly associating her discursive move with promoting argumentation and pursuing the scientific substance of an idea the class laughed at, Sarah not only suggested a new interpretative framework for her discourse, but also negotiated with Nick (and the class) a shift in the general goal and values of scientific learning.

5.4.2 Owl and snake

Their second scientific discussion took place right on the next day. Before introducing the major types of biotic relationships, Sarah organized a whole class discussion on an intriguing scenario: *Usually owls eat snakes and snakes eat owl eggs. But scientists found that the screech owls on the east coast of America let tiny blind snakes live in their nest. These snakes are too small to eat the eggs, and the owls don't eat these snakes either.*

Sarah started by introducing this activity and elaborating her expectation, in which she first highlighted the “unsolved” nature of the scenario—the scientists “have some ideas about what they think is going on” but “they don't know for sure.” Flowing from there, she framed this discussion as one with “no right or wrong answer,” so that everyone should participate and “any idea is valuable.” Then she suggested agreeing or disagreeing with an argument or posing new arguments as anticipated forms of participation. Finally, she distinguished the activity from the “teacher trick” of “pretend to solve a problem but really I already know the answer.”

Through such setup, Sarah purposefully removed the possible constraints associated with having a canonical correct answer, orienting the activity towards one of sharing possible explanation of a natural phenomena and engaging in reasoning through each other's ideas. This was in consistence with the learning goal they negotiated last time: instead of getting to the right answer, learning in this class valued reasoning-based scientific arguments.

What Sarah referred to as “teacher trick” happened a lot, both in my observations of many other classrooms and as recorded in literature (Levin, Hammer, & Coffey, 2009). “There is no right or wrong answer” is often employed by teachers as a hook for pulling out misconceptions from students, in which case right and wrong answers would be revealed by the end and students would realize that they are “trapped.” Drawing this distinction was therefore a meaningful move. Not only did it help relieving students’ fear of “being wrong,” but it also contributed to the rapport between Sarah and the students.

While passing out scenario descriptions, Sarah suggested a discussion rule: “somebody's gonna put an idea out and we're gonna wait before we hear a new idea and hear anything related to that idea.” Later in this discussion, I saw students actively following this rule even when the teacher sometimes seemed to forget about it. One such example was when Jeff got the first chance to share his theory:

1. Sarah: Okay, go ahead Jeff. Here we go.
2. Jeff: My theory is that the snakes can be poisonous to eat and [*Inaudible*] you die.
3. Sarah: So the owl isn't eating them, they must be poisonous and that's why the owls not eating them.

4. Jeff: Did anybody else get that?
5. Sarah: Okay, Mina and then Acer.
6. Jeff: I thought we could talk about it?
7. Sarah: Yeah, I mean raise your hand to talk about it.
8. Mina: I wasn't gonna talk about it.
9. Sarah: Oh, Wait! Before you go do people agree or disagree with this?
10. Jeff: Did anybody-
11. Sarah: Wait, say that again.
12. Jeff: Did anybody have that theory also?
13. Sarah: I heard Tristan say it, Dennis did you think that also?
14. Dennis: Yes, he incurred it [*Pointing to Jeff*].

Sarah repeated to the class the idea Jeff offered—the snakes “must be poisonous” so the owl does not eat them, then continued to call on Mina, who had her hand up a while ago, without evaluating Jeff’s idea or requesting the class to talk about it. In reaction, Jeff not only took on the role of discussion facilitator, asking the class “did anybody else get this?” but also reminded Sarah about the rule they have set—“I thought we could talk about it.” Corresponding with Jeff’s effort getting his idea “talked about,” Mina also held on her idea, suggesting that she “wasn’t gonna talk about it (Jeff’s idea).” Sarah seemed to realize what she missed all of a sudden; she then invited the class to “agree or disagree” and gave Jeff the space to repeat his invitation.

Although the discussion on Jeff’s theory did not go further than identifying two other students who had similar theories (Tristan and Dennis), it contributed to the intersubjectivity of the classroom discussion rule that shared ideas should be talked

about. As this rule mediates how the class interacts in the rest of this discussion, every idea was afforded the opportunity to get understood and developed through interaction, even the ideas not considered by the teacher as serious ones at first. Considering the following example: after Deanna suggested the owl and snake phenomenon could be a case of “uncommon motherly instinct,” many students shared other such cases they knew. Taylor, among whom, came up with a related but different example:

1. Taylor: What about tiger and lion for a liger? [*A little bit of class laughter*] I may mispronounce that, a liger?
2. Sarah: I know, but that’s something completely different. I’m not talking about the animal breeding.
3. Taylor: But I’m just saying, maybe they are related.
4. Sarah: Um, the owl and the snake? Are related like cousins? [*Class laughter*]
5. Taylor: Yeah, I’m being serious.
6. Sarah: OK, go ahead, go ahead.
7. Taylor: Like my second cousin and my fifth cousin once was divorced [*Tristan makes an “owl” face and says “woo—”*]
8. Sarah: ‘Cause it is-, OK, all right.
9. Taylor: And they got remarried (class laughter.) I’ve been, I’ve been serious though.
10. Sarah: I got you, but I-, does anyone want to challenge Taylor?

Taylor analogized the owl and snake relationship to the rare breeding relationship between tiger and lion, suggesting the later as a possible explanation of the presented natural phenomenon. In her first reaction, by referring to Taylor’s idea as

“something completely different,” Sarah created little space for the class to follow this conversational thread. She also made fun of it, stretching “related” to “related like cousins” when revoicing Taylor’s comment. However, by picking on Sarah’s joke, drawing on examples from her personal life, and repeatedly claiming “I’ve been serious,” Taylor persistently pushed for an acknowledgement of her idea. As a result, Sarah finally stifled her initial opinion and invited the class to “challenge Taylor.” Although it is arguable why she replaced the more typical and neutral expression of “agree or disagree” with “challenge,” her action did allow Taylor’s idea to be treated in a way similar to the ones brought up before it: the class was invited to “talk about” it. This move, I would argue, went against the teacher’s initial reaction and reflected the mediational effect of the previously set and collaboratively reinforced discussion rule. The interaction also generated a positive meaning for “challenge:” for an idea, to be challenged was to be seriously considered and valued.

As this conversation went on, Tristan placed a challenge on Taylor’s idea by suggesting the phylogenetic distance between the two species (“but one is a reptile, one is a bird”); Deanna brought up a piece of evidence that supported the possible relation between distant species (“chicken and T-Rex, like they are relate”); Max counter argued Taylor’s idea by problematizing the analogy, pointing out where common owl and snake relationship (not that of the given phenomenon) violated the norm underlying common breeding relationship (“owls still eat snakes, and we don’t eat our relatives”). Taylor, again, provided a rebuttal by drawing on a rare condition in which the analogy can continue to work (“but don’t some people eat people”). Although these arguments went off the main topic of this discussion and into extremes, the way they were organized in

point to each other in terms of both disciplinary contents and argument structure still qualified for productive scientific argumentation practices.

Some scholars (Gutierrez, Rymes, & Larson, 1995) have suggested that, when students' seemingly unrelated questions/ideas are treated seriously and short departures from a current topic are allowed, a more comfortable joint space for knowledge construction can be created. This case, I would argue, provides evidence for this point, as it shows how attending to the substance of an idea appearing "off-topic" can actually afford productive inquiry.

With the setup of this activity emphasizing idea sharing and minimizing the role of the correct answer and with the class' collaborative effort in following the rule of "talking about" ideas, this discussion provided a platform for students to engage in productive scientific thinking. Students were eager to put their ideas out, and build on or challenge each other's ideas. Consequently, though Sarah still played the role of facilitator, her scaffolding moves were much reduced. While her effort promoting argumentation produced little effects and was even misinterpreted in last class, several times in this discussion students initiated argumentations on their own. For example, when Carla came up with the causal explanation that the snakes might "not realize it is owl egg" since they are blind, Jeff immediately made known to the class his "challenger" position by jokingly claiming "I'm challenging you...to a duel." Then both Jeff and Nick presented their challenges on the necessity of such causality: Jeff's argument was that the snake would still be able to tell their own eggs from owl eggs since "they can smell"; Nick suggested the snake could probably also tell by the egg sizes. During the time, Jeff and Nick both faced Carla rather than looking at Sarah as they normally did when

answering the teacher's questions, indicating that they were focusing on the idea from this fellow student.

Still, most of the argumentations in this discussion got started by Sarah's invitation moves. The discussion on Taylor's idea, for instance, started with the question "does anyone want to challenge Taylor?" and, in some other cases, Sarah simply invited the class to "Agree? Disagree? Build on?" following the statement of each new idea. In such situations, the students who came up with challenges or related ideas often faced Sarah and spoke to the class through her. Usually Sarah would repeat or revoice their ideas to gain the class' attention.

Sarah also frequently participated in this discussion through closely scaffolding students' specific arguments, such as probing for reasoning and evidence backing up a claim or making connections between different ideas. Such scaffolding moves not only contributed to the quality of immediate inquiry interactions, but also demonstrated to the class when and how one should ask for articulation on an idea in order to better understand it.

5.4.3 Is the sun alive?

The "philosophical chair" debate took place on the fifth class into the semester (right after the day of the owl and snake discussion), before the biological criteria of life got introduced. Students were given the question "Is the sun alive?" and several minutes to jot down a yes/no answer with some reasons or a "maybe" with questions for each side. They were then asked to line up according to their own positions and divided into three groups. After a five-minute group discussion, the "yes" group and the "no" group then took turns to debate, trying to win over the "maybe" group.

This transcript shows a typical moment of this debate. It was about one minute into the debate, after Carla from the “yes” group brought up several facts she considered as supporting evidence for “the sun is alive:”

1. Carla: The fact that it can't reproduce and it doesn't grow, and it has no organ system.

2. Sarah: Tell them. I'm not the [*Inaudible*].

3. Charles: Wait, time out. A liger can't reproduce.

4. Carla: A what?

5. Charles: A liger.

6. Candy: And donkeys [probably mean mule] can't reproduce.

7. Charles: Exactly, exactly but it's living, it's living, it's living, it's living, it's living.

[*Talking over Carla*]

8. Carla: Yeah, but they still have like cells. Cells. And they eat.

9. Sarah: Okay, hold on, it's not about who talks the loudest.

10. Carla: They have cells and organ systems. They breathe.

11. Tristan: Well not everybody needs to breathe.

12. Sarah: Max, what were you gonna say?

13. Max: It doesn't have any of the normal functions of like, of a living organism.

14. Charles: Define normal. [*Class laughter*]

15. Sarah: That's fine, go ahead.

16. Max: Sleeping, breathing, reproducing, cells...

17. Charles: First of all, not every living organism sleeps. For example: fish.

18. Tristan: Cells. [*Class laughter*]

19. Acer: Something is alive if it has...

20. Charles: Plants.
21. Acer: It can function and can make the choice to function. If it can like have, if it functions then it is alive.
22. Tristan: Can plants have decisions? No.
23. Carla: It has cells though, it has cells.
24. Acer: It has functions.
25. Tristan: The sun has a function.
26. Charles: So you're trying to say a plant has a brain?
27. Charles: You don't need a brain to function.
28. Acer: It's not alive, the sun has no function. It's a jumbo reaction.
29. Tristan: Can you prove that? [*Class laughter*]
30. Charles: The body could actually live without the brain.
31. Acer: Um, actually, can you prove that, can you prove that it is alive though? I mean...
32. Sarah: Go ahead. You don't need to raise your hand you just gotta-.
33. Candy: Yeah, yeah I was like nobody listens to me, I'm just listening to myself.
34. Sarah: Go ahead.
35. Candy: Um, like you know that little theory thing they have that when the world ends or something, the sun would like explode? So when it would explode it would come to its end; that means it's dead. So right now it's like alive.
36. Students: It's a chemical reaction. [*Students argue over each other*]
37. Acer: If you light a candle, and the candle burns out, does that mean that the candle just dies?

This snippet concentrated many examples that students were carrying out evidence and reasoning based scientific argumentation. On the “no” side, Carla (line 1, 8, and 10), Max (line 13 and 16) and Acer (line 21) brought up several arguments for their claim that “sun is alive,” which all got argued back at by the challengers from the “yes” side: Charles, Candy and Tristan. The argument made by the “no” side followed the same deductive logic: if all living things should be able to do (or should have) X, but the sun cannot do (or do not have) X, then the sun is not alive. The list of “X” they came up with included reproduction, growth, organ system, sleeping, breathing and having function. The “yes” side’s main strategy was to challenge the preconditions of living assumed by the “no” group by suggesting counter evidences. The underlying logic is: if there are things that cannot do (or do not have) X but are still considered alive, then X is not a necessary trait. Their counter arguments included: liger and donkey (probably means mule) countered the criterion of reproduction; fish, cells, and plants countered the argument that living things all sleep; finally, plants’ not being able to make decisions, and “body could actually live without the brain,” both countered Acer’s point that living things should have function and be able to choose to function. Candy then argued for the sun’s being alive by referring to scientists’ prediction that the sun would “die” one day— with the underlying logic that only something once being alive can die. Acer challenged her point by drawing an analogy to a candle that burnt out, trying to exclude such situations from the usual meaning of death.

Unlike the arguments popped up in the owl and snake discussion, arguments in this philosophical chair debate involved little mechanistic reasoning, but were mostly made through inductions, analogical reasoning, and extreme counter evidences. The

major reason for that, I think, is that the central discrepancy was not on how a natural phenomenon occurs, but on what characterize certain phenomenological category (alive), and accordingly, whether we should classify certain natural object or phenomenon (in this case the sun). While mechanistic reasoning is often taken as a central characteristic of scientific inquiry (Machamer, Darden, & Craver, 2000; Salmon, 1978), the lack of it in such case, I would argue, did not devalue the scientific meaning of this argumentation, since it is also part of scientists' practices to bound the phenomena being studied and clarify the criteria of scientific categories, in which argumentations were often involved as well.

In terms of general discourse structure, this conversation mostly consists of students going back and forth. The teacher's main role was to ensure everyone, rather than just the dominant talkers, got chance to speak. Examples here would be how she specifically assigned chances for Max (line 12) and Candy (line 32) to present their arguments. She also regulated the argumentation to ensure 1) that students were talking to each other rather than to her (e.g., she gestured and told Carla to face the "maybe" group); 2) that the students were focusing on each other's ideas (e.g., she reminded the class "it is not about who talk the loudest" when Charles talked over Carla); 3) that the argumentation was going in a proper, respectful way (e.g., when Charles challenge to Max caused class laughter, she claimed it as a proper move, permitting the conversation to continue.).

In this episode, there was no close scaffolding on argumentation from Sarah. In fact, through this whole debate, such teacher scaffolding moves were rare. Mostly the students articulated supportive evidence and reasoning (often embedded within the

evidence given) on their own when arguing for their side. In cases that an argument was not well articulated, the students from the other side would sense the obscurity, asking for elaboration or making counterarguments to that point. For example, when Max argued that the sun “does not have any of the normal functions of living organism,” Charles requested him to “define normal,” indicating that the word “normal” was too general for a precise definition. Also, when Charles argued against Acer’s point by suggesting that “the body could actually live without the brain,” Acer challenged him to base this counterargument on valid evidence and reasoning—“can you prove that it (the body in such situation) is alive?” On the one hand, such participation showed the challengers’ understanding of the quality of scientific argumentation; on the other hand, through such effort, the students actually guided each other to better articulate their arguments and provide stronger evidence or reasoning bases. In this sense, we could also say, the students took over Sarah’s role of scaffolding.

How, then, was such productive, high-quality argumentation afforded in Sarah’s classroom?

For one thing, the “philosophical chair” setup prepared students in a position that they had to defend their points. The “Yes” and “No” people were organized into two camps geographically, identified with the general claims they held, and since there were “maybe” people that could be persuaded into either camp, the debate activity motivated the students to win. In her instruction, Sarah also provided structural props: 1) “there is not right or wrong answer”; 2) “This is a discussion between educated persons, not a contest of who is louder.”

This activity structure, however, could not do all the work by itself. Although the “philosophical chair” is quite an efficient mental and physical setup for motivating debate, there are many different ways to make one’s point—nothing about this setup would ensure critical thinking as well as reasoning/evidence-based arguments. One could argue that Sarah's additional instructions oriented students' attention from looking for correct answers to focus on reasoning. However, as Sarah mentioned, and as I observed, in other classrooms, learning activities could still be about correct answers, even when a teacher asserts at the outset that "there is not right or wrong answer." Then, did the instruction on “educated discussion” alone lead to the critical thinking and productive reasoning shown here?

I would say no, since similar instructions did not have the same impact on classroom interactions in earlier discussion activities. Though this was only the fifth class into the semester, the students had already had two open-ended “educated discussions.” These two discussions did end up being productive to different degrees in terms of reaching the objects of putting out genuine ideas and arguing with reasoning and evidence, but they did take Sarah much more effort on scaffolding. As shown in my analysis above, in their first discussion on tea brewery, students would interpret the teacher’s push for argumentation as an indicator for that they were not getting the correct answer. It took Sarah turns of pushing and clarification for the first argument to emerge, and it was only after Sarah valued the idea and provided the space for better articulation that we saw other students starting to build on it.

In the owl and snake discussion, it was somewhat easier. For one thing, the problem was more “genuine” in that nobody would think they knew the “right answer”

and thus would be more willing to share their ideas. For another, they collaboratively constructed the discussion rule of “talking about the shared idea,” which afforded ideas to be better attended to and critically analyzed. However, in most of the times, Sarah had to send out her “Agree? Disagree? ” invitation, pushing students to go back and forth; the students still talked to the class through her; and there were still many situations that Sarah needed to closely scaffold the students’ arguments. There were student-initiated cases, but they did not last very long.

In addition, in this philosophical chair debate, we saw much longer snippets of students arguing scientifically on their own. The students provided supportive evidence and/or reasoning without being probed, and their arguments were usually to the point, which reflected their attention on and critical analysis of the substances of each other’s ideas.

Based on the changes in participation patterns observed through this series of three scientific discussions, I argue that the productive argumentation taking place in this philosophical chair activity was partially afforded by the learning goals, rules and values Sarah and her students collaboratively constructed during the previous two discussions. As I have suggested in my analysis, argumentation was set as part of the class’ learning goal both through the negotiation on what the teacher “pushed for” and through the teacher’s setup instructions; scientific reasoning and evidence was continuously focused on and valued, even in cases they were not immediately appreciated by the class; students’ moves to initiate “getting back and forth” was permitted and encouraged; “talking about every shared ideas” had been constructed into a classroom discussion rule; and “getting talked about”—even getting challenged—obtained the meaning of being

valued. When these resources gained intersubjectivity and exerted their mediational function in further classroom interactions, the need for the teacher's close scaffolding was largely reduced, as the students were afforded to critically analyze and directly comment on the substance of each other's ideas. Through this debate, I also saw new development in student participation: As students took on this role of scaffolding each other's arguments, they were better afforded to initiate and sustain high quality scientific argumentation on their own.

Here one may question how such goals, rules and values get established so quickly. Would similar interactions in other classrooms have the same effect on argumentation practices? There are two things I want to address. For one thing, I do not claim that everything is built from scratch just over these three classes. Students' previous experiences in school and everyday life gives rise not only to prior knowledge on scientific concepts (Sherin, 2006), but also to epistemological resources for pursuing understanding through reasoning (Hammer & Elby, 2003), and an intuitive sense towards the social practices of argumentation (Berland & Reiser, 2009). This work provided no data speaking to that aspect. However, it makes common sense that the students, in their life before Sarah's class, have experienced the rational ways to present and defend their claims, as well as to challenge other's claims. They knew in an everyday sense how to argue, what they really needed were signals that such participation was welcomed in this class and scaffoldings for it to better align with the ways of arguing scientifically in a classroom. That, I would argue, was the nature of classroom affordance for argumentation.

For another, comparing the participation patterns constructed through this series of scientific discussions with that of the predation and parasitism argumentation, which occurred about a month into the semester, we see both coherency and differences. In both student-initiated argumentation with few scaffolding moves from the teacher; and in both the participants challenged the substance of each other's ideas scientifically and respectfully, defending their claims with evidence and reasoning; finally, in both we have observed collaboration between students in constructing arguments. However, the most significant differences were: first, in predation and parasitism argumentation, the teacher participated as an argument maker, and her argument was treated equally with arguments from other students, which did not happen in any of the three discussions analyzed here; second, the predation and parasitism argumentation occurred without a general setup for argumentation; so it was entirely initiated by the student rather than something the teacher planned and expected to happen; last, while both the owl and snake discussion and the philosophical chair debate were framed to be on "genuine questions," in the predation and parasitism episode, what the students challenged was the repeatedly confirmed "correct answer."

In the following sections, I investigate the same interactive history, but focus on resources affording the features that differentiate the class' participation in the predation and parasitism episode and the teacher-planned scientific discussions.

5.5 Construction of the peer-like teacher-student relationship

5.5.1 The first day

Sarah's first class had the same activities many first day biology classes would have—introduction, discussion on the definition of biology and then a lab safety quiz. Sarah started the introduction:

1. Sarah: Here is what I want to do first: introduction, getting to know each other. I'll go first. I'm Ms. Henson. I went to school in, up in New York, up at a college called St. Rose. I got my degree in marine biology. Wait, Tim, my life isn't interesting to you?
2. Tim: Sorry.
3. Sarah: I got my degree in biology. I thought I wanted to be a scientist in a lab so I did that for a little while. I got really bored and so I went back to school at University of Maryland and I got my Masters in Education and this is my third year at Northwood. And myself and Mr. Perry and Mr. Roberts who also teaches with us sometimes, we've been teaching Biology all three years so we've got bio on lockdown. Um, what else? I played soccer in college, we were really good. Three and two, usually we ranked in the top ten, top twelve in the country. I talk really loudly, like you'll go to the bathroom and you'll hear me in the bathroom 'cause I talk that loudly. And, I'm not a big fan of homework, and that's all. Yay! You don't have to applaud.

The way Sarah introduced herself has already distinguished her from many other teachers. She did not just routinely talk about her working experience and educational backgrounds, but also shared many personal details in a language teenagers would

employ when talking with friends, such as describing how she “got really bored” about lab work, mentioning proudly her college soccer team, joking about how loud she can talk—so they can even hear her in the bathroom, and announcing by the end that she “is not a big fan of homework.” These stretches closed the common gap between teacher and students, and identified Sarah, rather than the only adult and authority in this room, more as a whole person to the students, who also thought science could be “boring,” caring a lot about sports, willing to make fun of herself and disliking homework. Research on affective learning suggested that self-disclosure is an effective teaching strategy for promoting psychological and physical closeness between teacher and students (McBride & Wahl, 2005) and encourage classroom participation (Goldstein & Bernassi, 1994). Here as the teacher’s initial move, Sarah’s self-disclosed statements opened the classroom as a suitable place for such personal details to be brought on the table.

In concert with how she talked about herself, Sarah also interacted with the students in a peer-like way. She got Tim to turn off a side conversation by asking, “my life isn’t interesting to you?” in a half joking way. Later, she attended to what students shared about themselves in the same manner, especially when their sharing contained more personal experience. For example, when Jeff shared his skill of flipping the pen, Sarah let him perform pen-flipping for the class, expressed her admiration by the comment “that’s pretty cool,” and also picked up a pen and tried it herself. When she failed, she earnestly asked Jeff for guidance, spending five turns discussing the mechanism of the pen-flipping with him. This serious learning attitude led to class laughter, as the scene of a teacher trying to learn something from students contrasted with

the traditional teacher image. Through the laughter, I would argue, it also suggested to the class what kind of teacher-student interactions were allowed in this classroom.

Another case was when Azar shared that he had learned “dimmak” lately. Sarah first did not get what it was. After Azar explained how it worked--“it's like massaging your body but instead of massaging it, you're doing the opposite and disrupting it,” Sarah showed much curiosity, making Azar explain to the class how dimmak works and why he was learning it. The conversation ended like this:

1. Azar: One time, I was like walking down the street in New York City and all of a sudden someone threatened to kill me so it's like.
2. Sarah: Yeah.
3. Tim: That was me. [*A little bit of class laughter*]
4. Sarah: No it wasn't. No, wait, time out, that's not funny, that's cool. And you know what? My sister you can tell her so, she got mugged on Halloween once for her candy. She needed some self-defense moves. [*Class laughter*]
5. Student: Some robber?
6. Sarah: Yeah.
7. Azar: How old was she?
8. Sarah: You know at Halloween people go crazy. I got you, self-defense that's cool. That's cool. I'm gonna take a self-defense class also.
9. Azar: You could probably do kickboxing.
10. Sarah: Yeah, I think I could be a kick boxer. Okay.

When Tim joked about the life-threatening experience Azar shared, Sarah acted seriously, confirming Azar what he said was “not funny” but “cool.” But then she half-

jokingly suggested that he could tell her sister about it, since “she got mugged on Halloween once for her candy” and “needed some self-defense moves.” The contrast between the self-defense against killing threat and the candy robber caused a good amount of laughter. Moreover, Azar did not appear to be offended either, since he continued to ask about how old her sister was and suggested that Sarah do kickboxing.

This half-joking way of talking gained a dominant position in their later interactions. The way Sarah played jokes signaled to students that jokes were welcomed and even valued in this classroom. They soon started to play a joke on Sarah and their fellow students. For example, when they were doing the lab quiz that everyone “has done for millions of times,” Sarah asked Tim to read the questions and let the whole class do it together. A few questions into the test sheet, with one question with the answer “tell the science teacher,” Tim accidentally pronounced “science” as “tience,” which caused some giggling. He then caught the chance to modify that mistake in a funnier way—directing the tease to Sarah by pronouncing another such answer as “‘sell’ the ‘tience’ teacher.” While this remark successfully caused a class wide laughter (including Sarah), Tim put on a straight face and claimed “it’s not funny!” and “I did it on purpose.” This pretended seriousness strengthened the joking effect.

When playing jokes on certain students, Sarah assumed that the student would find it funny rather than offensive, the same as when students played it back on Sarah. As suggested by many scholars who studied humor’s influence on social relationships (Gibbs & Colston, 2002; Graham, 1995), such mutual acceptance of jokes would help reduce social distance and build bondage between speakers and listeners.

Being the first communications between a teacher and a new group of students, the scenarios I draw on have a “set-the-tone” kind of significance. Through these interactions, Sarah showed that she shared a lot with the students: their teenager language, their sense of humor, as well as their values attached to being cool and funny. Also through these interactions, types of participations acceptable to this classroom got implicitly negotiated: that an interesting sharing can temporarily lead the class conversation off track; that joking and serious conversations can go side-by-side; and that playing jokes in class is not the teacher’s prestige, but that the students have the same right. Here the interactions between Sarah and the students were less formal than teacher-student interaction in traditional classrooms, but resembled how friends, especially teenager friends, would socialize with each other in everyday settings, which provided a good starting point for building closely bonded, peer-like relationships.

5.5.2 Relationship building in the long run

The work on building up such relationships did not just get done on that first day but became a routine for Sarah’s classroom. She continuously brought in everyday a type of fun when interacting with students: she would make a class deal for showing students a YouTube video of an anaconda throwing up a hippopotamus if they promised that “only one person is going to talk at a time” in a later scientific discussion; and she would ask “does anybody want to have Jerry Springer final thoughts on this?” at the end of a discussion or debate.

Besides, the class would also spend time on something Sarah called “family bonding,” sometimes at the beginning of a class, sometimes at the end when they have five minutes extra. Such activities took place with high frequency in the first few classes.

Usually a question that every student can answer would be posed and the class would volunteer to share. At first it was the ice-breaker type of questions, such as, What did you do in the passing long weekend; If you were a vehicle, what would you like to be? And why?, etc. Later when the students got more comfortable talking with each other and the class got into more specific topics, the sharing shifted to be related to the topic of day. For example, the day they had the owl and snake discussion, the students shared interesting facts they knew about owls and snakes; and before they talked about the energy pyramids in the biological system, they shared ideas on “How do human beings get energy?”

When I interviewed Sarah about the purpose of the family-bonding activity, she told me it was founded on her previous experience of getting a silent class to “blossom” by first engaging them by talking about their own lives. The great outcome from such teaching experience led Sarah to believe that, being willing to talk and having closely-bonded relationships would somehow contribute to productive learning. Therefore, the purpose was not on science learning, but on building up friendly relationships so that students would feel comfortable communicating, first through sharing with each other things that “have nothing to do with school,” and then by bringing in the rules and norms of sharing that students were already familiar with and were participants of in their daily lives.

Among students as well as between teacher and students, the non-judgmental, comfortable-to-share classroom relationship led the class to value authority less, but everyday experience more. A message possibly conveyed was, science is not that far

from everyday life. It was expected that if students felt comfortable sharing everyday life like this in class, they should also feel comfortable to sharing scientific ideas as well.

The family-bonding strategy used by Sarah can be aligned with the morning meeting strategy suggested by the literature for elementary school (Kriete, 2003; Kriete & Bechtel, 2002), as both were aiming to provide space for the construction of a caring classroom culture. Sarah's family-bonding activity, however, was much looser in structure. It did not happen regularly at the beginning of each class. The students were not asked to communicate with specific language or tightly bounded by turn-taking rules (Whereas the morning meeting would ask students to first greet each other, then take turns sharing and conclude their sharing with statements such as "I'm ready for questions or comments.") but offered the right to improvise. Plus, there was much less concern on the appropriateness of students' sharing contents and comments.

Such conversation with more active speakers, teasing and joking comments was closer to teenagers' everyday sharing out of the classroom. It allowed students to see the classroom as a real sharing site rather than performing the sharing to please the teacher. Being loose in conversational structure and formality, in this case, helped to ensure the genuineness of the friendly relationship and sharing norms building up through this family-bonding routine.

In the same interview, Sarah also talked about the funny way she interacted with students:

(joking about how she tried to pin down her friend next door as the nerdy one)...
so like that's why I go around and make a fool of myself, and everybody laughing
and stuff, like, *I think it kind of sounds like this idea, like people feel more*

comfortable. It is OK to, like, it is OK to do things, like, people laugh at. It is OK to say things that don't make sense or sounds ridiculous. I hope it helps, I don't know if it does. I don't know if it is all very consciously thought out, or I'm just like a huge nerd.

Though it may not be “very consciously thought out” and Sarah did not know if it did work, she did expect that the goofy way she interacted with students would make them “feel comfortable” to do things and talk, especially to say things “that people laugh at” and “that don't make sense or sounds ridiculous.”

When the sharing shifted to relating to the content topic of the class, such patterns were maintained while some new patterns emerged. For example, consider the following exchanges that took place when the class shared what they knew about owl and snake:

1. Tristan: The most poisonous snake is the river snake and it can't go on land.
2. Sarah: Is that true?
3. Tristan: Yes it is true, I learned it from Wild boys.
4. Sarah: Does anybody know the little saying about how you know if a snake is poisonous or not?
5. Tristan: If it bites you and you die, it's poisonous. [*Class laughter*]
6. Sarah: True, but it's not a little saying.
7. Nick: Snakes have two heads?
8. Sarah: I don't know I always mess it up, but I think it's something like-
9. Student: How can you tell if they like bite you?
10. Sarah: 'Cause it's a saying that goes something like, red against yellow, kill a fellow; red touching black, friend of Jack, or something. But I don't

know if I have the color right so don't follow that. It's this little rhyme about what, the pattern of their stripes.

11. Mina: That's only for those two different snakes, though, that have the red, black, and yellow pattern. Not all of them are red and black, some of them are grey and [*Inaudible*]

12. Sarah: Yeah, you're right!

13. Nick: It's only for those, to distinguish those two types. There're two that look different.

14. Sarah: Oh, that's not helpful then, 'cause what are the chances you're gonna run into them. Anybody else? Owls or snakes. Yeah, Azar.

15. Azar: There are different types of snakes, including some of them called pythons, constrictors, poisonous, and spitting. Spitting being like spitting cobras, poisonous snakes meaning sea snakes, constrictors meaning boa constrictors, and pythons meaning they're not poisonous.

16. Sarah: Azar, I think you win some type of award for like, talks the fastest. [*Class laughter*]

In this snippet, when Sarah asked if anyone knew the saying for distinguishing poisonous snakes, Tristan played dumb by making up the saying of “If it bites you and you die, it's poisonous.” When Azar quickly went through the types of snakes, Sarah did not comment directly on what he shared but joked on his talking speed. Both humor practices successfully got the class to laugh and reduced the seriousness of the conversation.

But there is something more to this sharing. As Sarah shared the little saying on poisonous and non-poisonous snakes, Mina and Nick challenged that it could only be used to “distinguish those two types (red against yellow and red touching black)” while there were many other types of snakes (“some of them are grey and...”). This challenge got immediately accepted as Sarah admitted “that’s not helpful then,” articulating the practical limitedness herself: “‘cause what are the chances you are gonna run into them?” Such exchanges carried some flavor of student-initiated scientific argumentation. The student’s reasonable argument against what teacher shared showed that they were attending to and critically analyzing the substance of what she said. This interaction pattern ran parallel to that of the predation and parasitism argumentation, as in both students brought up arguments against something from the teacher in an activity that was not particularly set up as one about argumentation.

I argue that the emergence of this new participation pattern cannot be separated from the class’ participation patterns constructed though the general, not learning-targeted interactions. The class’ continuous encouragement of sharing and talking about what they shared, the relaxed atmosphere constructed through half-joking, half-serious sharing discourse, and the peer-like way the teacher interact with the students, all afforded the students to see this classroom as a place for sharing and making sense of whatever got put on the table, from the students or from the teacher. As I have suggested earlier, sharing and arguing are not new to students in everyday settings (Berland & Reiser, 2009; Lave, 1988), the key is whether such interactions are allowed and valued in science classroom.

What I denoted as peer-like, comfortable-to-share relationships may align with what the literature refers to as affective components (Pintrich & Groot, 1990; Weiten 1997) of learning. At the core, relationships are about how people feel about each other and the context of their activities; these feelings contribute to their actions and interactions. However, most research in the area of affective learning attends to individual students' feelings towards general or specific disciplinary learning tasks, exploring how such feelings correlate with students' cognitive learning behaviors (Aslop & Watts, 2000; Thompson & Mintzes, 2002) and their academic achievements (Ames & Archer, 1988). Few studies attend to issues about classroom relationships. The work that does (e.g., literature on teacher self-disclosure), typically focuses on how teacher's relationship-building strategies affect students' perceptions of teacher and of learning (Goldstein & Bernassi, 1994; Mazer, Murphy, & Simonds, 2007; McBride & Wahl, 2005). There is little close analysis on how classroom relationships, as interpersonal feelings distributed among classroom participants, get gradually constructed through interactions, and in turn, what those ensuing relationships afford in terms of classroom learning interactions. My analysis of relationship in this section suggests this as a meaningful direction for affective learning research, in ways similar to recent work looking at the affective components of cognition (Lee, 2008).

5.6 Epistemic resources for challenging the "authority"

The above section showed how the students were afforded to initiate argumentation with the teacher in their sharing activities. While the argumentative participation in that episode aligned with the predation and parasitism episode, their

argument contents were distinctive in nature. In the sharing activity, the arguments focused on whether the little saying presented a way of distinguishing poisonous and non-poisonous snakes, and the main point was on its limitation in practice, which the teacher did not insist on from the beginning. In the predation and parasitism argumentation, however, the challenge was directed to a definition repeatedly confirmed by the teacher as a canonical one, and it was about its correctness—if the definition did not apply to the situation the students brought up, then they faced the question of how to treat it: should they still take it as it is, or should they modify it, since it was problematic? To initiate and sustain an argumentation like that, the students needed to place a reasonable idea not only ahead of the authority of the teacher but also ahead of the authority of canonical knowledge.

In this section, I reflected on what resources this class constructed that would contribute to the affordance of such *epistemic practices*. The term was brought from Sandoval & Reiser (2004), who used it to emphasize epistemological perspectives embodied in practice, distinguished from literature suggesting how students' epistemological framework guided their performance.

As the philosophical chair debate on “Is the sun alive?” continued, both the “yes” and “no” groups constructed powerful arguments for their claims and against the other side's claim. Sarah then came in and invited the “maybes” to participate by posing questions. When she called on Avilene, the discussion went in a slightly different direction:

1. Sarah: Now Avilene, did you have a question?
2. Avilene: Um, I just want to know like, to know what do they like constitute as

- being alive or dead? Like what characteristics fall under each category?
3. Sarah: Okay, let's start with the yes side. What do you think something has to have or be or do in order to be alive?
 4. Tristan: Have a function.
 5. Sarah: Have a function.
 6. Charles: Have a purpose.
 7. Sarah: Have some kind of purpose.
 8. Tim: Dead things have functions too.
 9. Sarah: Hold on, hold on, hold on, it is not your turn yet. Have some kind of effect.
 10. Charles: It affects you!
 11. Sarah: Guys.
 12. Tristan: It's not dead though.
 13. Jeff: It's not alive.
 14. Sarah: Okay, so they're saying, my friends. The yes side just said it has to have a purpose or a function or an effect on something.

Structure-wise or content-wise, the arguments here did not differ that much from what I demonstrated earlier, however, the meaning of the arguments and the object of the activity did shift. What Avilene recognized as “characteristics” and what the students pulled out and argued about (e.g., “have a function,” “have a purpose” and “have some kind of effect”) were the criteria, or in scientific terms, the assumptions embedded

in one's theory. This request for clarifying the criteria matched how Sarah concluded this debate:

Sarah: Okay. So the whole, the question that's being posed to you guys is: Is the sun alive? And the reason why here there's nobody here who's really right or wrong at any point is because it depends on what you consider to be alive.

Before introducing the canonical criteria for "alive" in biology Sarah also said:

We are gonna talk about one definition for things that are alive. There is, different people can argue different things, I'm just going to give you three criteria for life we are going to use.

Calling these criteria what they "are going to use" in this class, Sarah maintained the position that "it (whether the sun is alive) depends on what you consider to be "alive" and "different people can argue different things." Framed this way, the criteria of life were shaped as canonical but are left arguable. Although the class did not talk about scientific epistemology in any of its terms, the debate activity did allow the students to experience the muddiness of science (biology). They did not learn in words that scientific knowledge is problematic and theory-directed, but through interactions, they constructed this unspoken view into a shared resource that guided their epistemic practices. From arguing for one's side to pulling out their own assumptions and challenging each other's assumptions, the students gained understandings not only on this epistemological perspective, but also on how they could act correspondingly in their future inquiries.

Much of the class' later interaction showed patterns aligning with such epistemic resource. One routine phenomenon I observed was the class' combined effort

on identifying “exceptions to the rule.” For example, after the class defined producer and consumer, Sarah asked the student to “think of a challenging question”:

1. Sarah: Okay? Does anyone know, can anyone think of a challenging question?

2. Nick: Challenging question?

3. Sarah: Can anyone think of an exception to this rule of where something-, [*Nick raises hand*] You don't even know what I'm saying yet. Woah [*Charles raises hand*] Wait, hold on. Danny's got it, go ahead. [*To Charles*] You're next.

4. Danny: The mushroom.

5. Tristan: Venus flytrap.

6. Charles: Darn you! [*Class laughter*]

7. Sarah: Okay, what I was gonna say was an example of something that is both a producer and a consumer.

Before Sarah had a chance to finish her question, Nick and Charles put up hands, indicating that they had guessed out what the teacher was trying to ask. Their answers—“mushroom” and “Venus flytrap” (Tristan shouted it out, but obviously Charles had the same thought as well.) suggested that they did get the question, as these are both reasonable exceptions to the rule bounding producer and consumer. Venus flytrap, as Sarah agreed with and explained later, gets energy through photosynthesis as producer while it catches and digests other organisms as consumer. As the discussion continued, it was revealed that a mushroom does not directly use sun energy, and therefore does not count towards an exception. But still, mushrooms share many traits with plants rather than with other consumers (usually animals), such as growing from a spore and standing still in one place for its whole life, which qualifies it as a reasonable candidate for such

exception.

Such discussion conveyed the message that biological categories are not perfect “rules” but have exceptions, which runs parallel to the “criteria we are going to use” view on the definition of life. They both emphasized the man-made, theoretical aspect of biological concepts. For something to be a canonically defined does not exclude its arguable status. Students’ participation in such discussions not only required an understanding of the problematic nature of science, but also required a conceptual understanding of the canonical content, as thinking of reasonable exceptions to the rules or constructing reasonable arguments against a certain set of criteria indicates that one can comprehend and critically analyze the substance of such “rules” or “criteria.”

As the class continued, it became a recurring theme for the class to dig out “exceptions to the rules” while learning about canonical knowledge, even without probing from the teacher. For example, when the class was introduced to the definition of carnivore and herbivore, Tristan conjectured the situation of someone that “eat[s] only fungi” and asked where that would fall. As the discussion went on and the class verified that fungi is neither plant nor animal, revealing its undefined nature within the common categories, Sarah admitted that she “don’t know what you count those as” and that she, as the teacher, was “tested on.” This move confirmed the value of the challenge.

Tristan’s challenge showed his conceptual understanding of carnivore and herbivore as well as fungi’s special status in the taxonomy system, and Sarah’s valuing this challenge encouraged this path of thinking and this type of discussion. In a long run, the view that there are always “exceptions to the rules” became an epistemic resource for the class and the identification of exceptions became a routine practice, which, I would

argue, also contributed to the affordance of Acer's challenge in the predation and parasitism episode. In parallel to the situations analyzed above, what Acer challenged was a canonically defined boundary between two types of relationships, and what he employed to support the challenge was an example qualified as a candidate of exception.

5.7 Research findings and implication

Since this study aims to provide a picture of how classroom argumentation "norm" that grew out of sequential classroom interactions, I go beyond evaluating and boosting certain argumentation structures, moving into the construction and functioning of argumentation-related classroom mediational resources.

Through analysis, I have identified the following resources the class constructed through their interactive history before the predation and parasitism episode:

- The peer-like, comfortable-to-share classroom relationship.
- General goal towards argumentation and values assigned to the substance of ideas.
- The classroom norm of "talk about shared ideas."
- The "exception to the rule" epistemic stance.

As demonstrated in analysis, these resources contributed to the formation and shifts of the class' discourse and participation patterns along that timeline. For example, as argumentation was set to be the learning goal and as it became the norm to talk about shared ideas, the students were afforded to critically attend to the substance of each other's ideas, which reduced the need of teacher scaffolding; also, along the epistemic

stance they constructed on exceptions, the students were afforded to realize the limits to canonical correctness, preparing them for making argument based on exceptional counter evidence. Together, I would argue, such resources could have afforded the productive features we see of the predation and parasitism episode.

The work done in this chapter also revealed the significant role that non-disciplinary learning activities may play in constructing the affordance of productive disciplinary learning. The peer-like, comfortable-to-share classroom relationships were first built up through sharing of everyday experiences in the class' introduction and family-bonding activities. Continuing into their scientific discussions and debates, such relationships afford lower thresholds for students to share their ideas, caring less about being wrong or being laughed at. More thoughts along this line are shared in the final chapter (Chapter 7), where I reflect on my analytical work and suggest why it matters.

Chapter 6: The constraints on the argumentation practices

6.1 “That’s another day, my friend”

In last chapter I demonstrated how students in Sarah’s class were able to initiate productive scientific argumentation on their own against canonical knowledge that has been agreed on, and how Sarah the teacher could participate in such argumentation as an arguer, since the students focused on the substance of her idea rather than taking it as an authoritative answer. Through reflection on the class’ interactive history, I pointed out mediational resources constructed through previous interactions that could potentially contribute to the productive features of their later argumentation practices, including classroom norms for participation, values assigned to the substance of ideas, comfortable-to-share and whole-person-respected relationships as well as the repeatedly conveyed epistemic message that biology concepts “always have exceptions.”

Sarah’s class, as I have argued, constructed significant affordance for their participations in scientific argumentation. However, looking through the semester, it was not the case that they would value and pick up any chance for initiating and developing scientific argumentations. There were many situations where buds and threads of argumentations were ignored or dropped, and still more where few ideas got shared or “talked about.” How should we understand the uneven distributions of the class’ scientific argumentation practices? This is the question I aim to explore in this chapter.

To illustrate the type of phenomena that raised such concerns, I continued to draw on the parasitism-predation argumentation episode. What I presented as a typical student-

initiated, productive argumentation lasted for only a few minutes and did not develop to its fullest. The excerpt below showed how the conversation was called to an end when students started to challenge the “iffy status” of virus:

1. Sarah: Well but then isn't malaria caused by the mosquito bite, no. The malaria kills the person, not the mosquito. Starvation kills the person, not the tapeworm. I would argue. It's kind of like, OK, OK, yeah Azar. [*To Tim*] Wait hold on 'cause I can't even hear him.
2. Azar: Uh, I can kind of relate to what you're saying by um, you've heard of the Human Pamplona Virus right?
3. Sarah: True, yes.
4. Azar: It affects people who have it, in different body parts. So I would say it is probably is an alive organism cause if it wasn't alive. So that means that what reproduces it?
5. Sarah: Wait, sorry, say it, I'm sorry, what?
6. Charles: [*laugh*] I know. I'm lost too.
7. Sarah: [*laugh*] Okay, say it again. Human Pamplona Virus. So you want to argue that viruses are alive?
8. Azar: Yeah.
9. Sarah: Oh, that's another day, my friend.
10. Charles: Another day, we've gotta get back on topic.

Between this excerpt and the excerpt presented in the previous chapter, the conversation has left Acer's virus example and Sarah's counterargument based on the virus' not being alive, but engaged in the previous arguments on if the parasites or the

diseases caused the host's death with different parasite examples. This is when Azar threw in his different thread of argument. Knowing that HPV can affect "different body parts," Azar revisited and rebutted the teacher's "virus is not alive" argument, suggesting that "it (the virus) is probably alive" or else "what reproduces it?" Here the reasoning embedded synthesized his prior knowledge on HPV with the definition of "alive" that they have made early on: since viruses can spread onto different body parts, it has to be able to reproduce; and since "reproduction" is a criterion for being alive (among the set of three, see page 88 in last chapter), viruses should be considered as alive. Applying the requirements of formal logic, one could argue that this argument was structurally deficient, as it treats a necessary condition (one criterion out of three) as a sufficient one. But such focus would fully miss the potential of this argument. Had the class taken it up, there were several directions the conversation could have gone. For example, they could have gone back to the criteria of life and discuss how "iffy" a case virus really is regarding being alive or not; or they could have reexamined the example of virus in the spirit of their ongoing argumentation—if the virus can be treated as living organism, and how is it different from or similar to other types of parasites? Also, they could have looked into whether reproduction of virus is a similar idea to the reproduction of cell-based organisms. In this sense, Azar's argument could be seen as a potential start for productive inquiry conversations in multiple directions.

The actual conversation, however, did not follow any of these routes. Sarah's initial reaction ("I'm sorry, what?") and Charles' comment that "I know, I'm lost too," showed that, at first, the teacher and other students both did not catch what Azar exactly argued. Right after offering Azar the space to rearticulate and before Azar had a chance to reply

yet, Sarah seemed to sense what he could be trying to argue in reflection, as she added the question “So you want to argue that viruses are alive?” Azar’s confirmation immediately led to Sarah’s move of dropping the thread, not through counterargument or explanation but through stating its lack of relevance at the time: “that (whether virus is alive) is [the topic for] another day, my friend.” Charles immediately interpreted this move as a signal for ending the argumentation conversation and to “get back on topic,” where the “topic” referred to their routine activity of reviewing biotic relationships. Indeed, Charles’ prediction was right. That was what took place after another few turns, in which the students kept throwing out new examples of parasite “killers” (including virus examples such as HIV) and the teacher kept drawing back on the same piece of reasoning—“what kills the host is (the disease), not (the parasite)” —as the counter argument. The productiveness of this inquiry faded away, as little new insights were developed in terms of either argumentative content or ways of reasoning.

What this excerpt demonstrated was a typical way argumentation got constrained in this classroom. The earlier excerpt (see the beginning of last chapter) showed how the class was afforded to go on a tangent, initiating and sustaining argumentation in an activity not particularly framed for scientific debate or open-ended scientific discussion. The class focused on demarcating the concepts of parasitism and predation. The exchanges between Acer and Sarah, though relating to virus, were still arguments centering on if there is an overlapping zone between the two types of relationships, which was what the review activity was checking on. Azar’s argument was different. As a challenge to the teacher’s eligibility setting move, it was solidly built on the ongoing argumentation; as a step looking into virus’ status of life, it did not maintain a direct

connection with the review activity's focus on understanding biotic relationships. It was, in this sense, a slightly more tangential thread of argument to follow. As I have pointed out, this move had the potential of shifting away from the demarcation between parasitism and predation, but towards reexamining the definition of life or looking into virus' mechanism of reproduction.

In the class' previous activities framed as an open-ended discussion or pure pursuit of scientific argumentation, I have observed situations where more tangential arguments got accepted and followed. For example, in the owl and snake discussion, argumentation at one time took on whether the blindness of the snake would influence their ability of distinguishing their eggs from owl eggs. This argument largely spoke to a presumption underlying a student's reasoning that if the snakes "don't realize that it is owl's eggs," then they would "not like pose a threat." Additionally, this piece of reasoning is part of the student's chain of reasoning towards why the owl would not see the snakes as dangerous, which in turn formed her explanation for the teacher's question on "why this (the owl and snake) relationship exists the way that it does?" The objects of that activity were loose and multifaceted: at one end, the teacher set it up for everyone to participate; at the other end, they were trying to come up with reasonable thoughts on what was going on in the given scenarios, rather than focus on labeling the owl and snake phenomenon with a fixed relationship category. Such vague objects allowed in-depth explorations into details of ideas.

In contrast, the unit review activity has a much more specific object and therefore a clearer boundary between the main topic and tangent. Time devoting to "tangential" conversations was often restricted, since there was a more to-the-purpose "topic" to get

back on.⁸ Also, in preparation for quickly returning to the topic, the tangents needed to maintain a direct connection to the current object.

How, then, should we understand the presenting phenomenon? While the first half of this episode showed how the argumentation was afforded to emerge naturally in service to the class' sense-making processes, in this second half we certainly see the argumentation being suppressed. As the constraints play out, Azar lost the chance of rearticulation, yet neither the students nor the teacher herself seemed to understand what exactly his argument was. Does this conversation conflict with the resources identified in last chapter? Does the norm of sharing ideas and valuing the substance of ideas by "talking about it" suddenly lose its power? Does the affordance of argumentation practices suddenly collapse? How should we understand the constraints? What contributes to where and when they present, and what determines the strength of their effects on ongoing conversations?

In this chapter, tracing the interactive history of this class, I focus on identifying mediational resources constructed by this class that could constrain their argumentation practices, in this episode as well as in the rest of the semester.

6.2 Defining "fun" verses "boring"/ "serious"

A classroom is a complex activity system evolving in a nonlinear, multidimensional way. Even from the beginning of this semester, there were clearly multiple overarching goals organizing their class activities. For example, on the first day of school, when introducing to the students to the course syllabus and unit exam dates, Sarah had been

⁸ One might argue that time could be the whole reason that the class did not take up Azar's argument, but noticing how the conversation continued for another minute following the previous argumentation pattern, I think it is more reasonable to synthetically consider the influence of timing and going off on a tangent.

very explicit about how this course was confined by external requirements:

Sarah: We're on a schedule cause it's an HSA class and that's kind of the serious side of things like I like to think that I'm kind of a fun teacher. Like we're not real boring in here we don't take things too seriously. But the serious side is we have a test to get ready for in May and then everyone has to pass it in order to graduate... Having said that, this is my third year teaching Biology and we've been taking the HSA each year and my students, Mr. Carig's students, everybody's students here at Northwood tend to do, have done well on the Biology HSA. So on our end we've got it figured out. We know our timing, we know our vocab that needs to be gone over, we know what topics we have to cover. So on our end we've got it set. Which means you guys on your end, you just need to really show up and be ready to work in class.

As I have argued in previous chapters, starting from the opening introduction, and continuing into their later “family-bonding” activities and scientific discussions, the class valued being cool and having fun, which referred to how teacher and the students should interact in a way that respected everyone as whole person, so that they could bring into classroom everyday experiences and playing every day type of jokes on each other. Such interaction patterns matched what Sarah identified here as her preferred teacher image and class image: she wanted to be “a *fun* teacher;” and she wanted the class to be “not really *boring* in here” and “not take things too *seriously*.”

When I interviewed her later, Sarah also drew on the same idea, suggesting that she “tries to be like a little bit goofy,” since “if they (the students) think I’m crazy they are *not going to take everything so seriously*.” When asked to elaborate on this, Sarah said that the main goal was to make people “feel more comfortable,” seeing that “it is OK

to do things, like, people laugh at” and “it is OK to say things that don’t make sense or sounds ridiculous.” Therefore, the emphasis on “not take things seriously” was ultimately about removing the constraints on the behavior codes traditionally assumed in a science classroom (such as focusing on getting to the correct answers and avoiding “being wrong” or “sounding stupid”), so that a broader set of “suitable” content and ways of sharing could be afforded.

However, here Sarah pointed out to the students that the class also has a “*serious* side,” since “it is an HSA course” and they “have a test to get ready for in May (HSA).” Mentioned both before the description of preferred classroom atmosphere and after it, and following the adversative conjunction “but,” the “serious side” of test preparation was both framed as an opposite goal of “fun” and implied as the reason why the class could not be organized in the “fun” way all the time. The importance of this test generally came from its critical role in the students’ schooling process—the requirement to “pass (the test) in order to graduate.”

The pragmatic use of personal pronouns played a significant role in addressing and balancing the “fun” and “serious” goals for this course. As the literature (Halliday, 1995; Kamio, 2001) suggested, when a speaker uses first-person, plural personal pronoun “we” to address the audience, interpretation following grammatical rules would help shorten the conversational distance between the two, creating an inclusive relationship. Here Sarah started by introducing the “serious side” as the reason “*we* are on schedule,” by “we” she referred to the whole class, including herself. When shifting to describe the ideal form of the class, she first spoke in first person, emphasizing her wish of being “a fun teacher;” then quickly switched back to “we,” connecting her role of “a fun teacher”

with the class' preference on "not real boring here" and "not take things too serious." Continuing with the same plural subject, she explained the "serious side" of the course as rooted in the reality that "*we* have a test to get ready for" and "*everyone* has to pass in order to graduate." Strictly speaking, Sarah does not actually have a test to take and is not one of the "everyone" who needed to meet graduation requirements. Grammatically, it is more precise for her to use "you" to refer to just the students instead of "we." But, by positing herself with the students, she avoided being associated with this "serious" goal and kept her identification with the "fun" goal for the class. The test was then framed as an external pressure that the class—Sarah and her students—as a whole has to deal with.

Such a "comrade" relationship continued to stay as a shared assumption even when Sarah changed her pronoun again, using "we" to address the biology teachers of Northwood, and using "you guys" to address the students. In this part of her talk, Sarah acted as the representative of teachers, affirming the students that "on our end we got it set," and then asking them to take care of their end. Put in this way, passing the state assessment is not a goal set for the students by the teacher, but something that the teacher and the students, as partners have to collaborate and fight for on a united front (each party is responsible for their own "end"). The conflict between the "serious" side and the "fun"/ "not take things too serious" side, as well as the need of balancing them, became reasonable in light of institute imposition. In this way, the teacher-students alignment was strengthened rather than attenuated while different behavior and participation codes got set for different purposes.

The language of "fun" verses "serious"/"boring" has been continuously employed by both teacher and students in their later interactions. As different activities took place

and as actual timing conflicts emerged in classroom interactions, the “fun” and “boring” discourse gradually gained more elaborated meaning.

For example, their second class started with the following conversation:

Sarah: OK, we have a little bit of tedious, boring stuff to do, I say we do it first and get it out of the way. Then we have some fun stuff to do. And then it's a long weekend!

Nick: Yay!

Sarah: Okay, so tedious boring part first?

Nick: fine with me.

Charles: Great!

In this snippet, Sarah told the students that they are going to have both “fun” and “boring” activities and suggested that they got the boring one “out of the way” first. The “boring” part turned out to be setting up their notebook for Cornell notes. For about 20 minutes, Sarah gave very specific directions on how to make a title page, number their pages, and arrange room for notes and assignments, so the whole class could have the same thing on the same page as they went along and the students could easily “catch up” if they missed a class. Sarah made PowerPoint slides showing these setups, and the students simply copied things down into their notebooks following her directions. Except for side conversations among those who finished their copying faster than the rest, the class was generally quiet, and there was no need to ask questions or comment on anything.

The “fun” activity, in contrast, was three rounds of a game on “following procedure.” In each round, one student was kept out of classroom while everyone else was showed a picture made of a combination of geometric figures. Then, when that student was let in, other students took turns giving single sentence instructions on

drawing the picture. In between rounds and at the end of the game the class discussed how to write precise procedures and why it was important.

In the “boring” activity, the teacher was the only talker and the students were assigned the role of passive instruction follower. In the “fun” activity, however, not only did the students do most of the talking, but they also actively participated—commenting on the quality of each other’s instruction, laughing at how different the outcome drawing was from the original picture, asking for permission (which was allowed) of adding “delete it” instructions so that they could remove the previously made errors and improve the instruction quality on site, and suggesting, based on what happened, how to be more precise in giving instructions. Such dramatic differences in the participation patterns, again, denoted “boring” and “fun” in concrete terms.

6.3 “Fun” and “boring/serious” playing out in class activities

For the rest of the semester, both teacher and the students frequently employed the same discourse construct in shorthand reference. For example, the teacher would call a day containing just notes and BCR assignment as “such a boring day.” The students would complain that “today is boring” when much class time was devoted to note-taking; they would also make requests for discussing something “on tangent” by half-jokingly saying “don’t you want us to have fun?”

Linguistically, “fun” and “boring/serious” have opposite meanings. When used in this class, the learning goals and participation patterns they were associated with were also somewhat contradictory. However, most learning activities were not clear-cut into one or the other, but shifted back-and-forth between interactions towards “fun” and

towards “boring/serious.” Such phenomena, I would argue, showed the class’ commitment to both goals and therefore to their efforts of blending them together. For instance, on the day after the owl and snake discussion, Sarah introduced an activity of matching phenomena with biotic relationship categories:

Sarah: We already have these notes, we already have these words in the definition and you guys left some space to fill in examples right? So what I'm gonna do is I'm gonna put up a picture and it's gonna have some relationship. Some of them you may be familiar with, some not. If you think you know what's going on, then I want you to raise your hand and tell us about it and then we'll label it and we'll put it back with one of the definitions, okay?

The activity was oriented towards “fill in examples” for relationships defined in previous class. As Sarah suggested, every picture she put up would finally be labeled with a certain relationship. This object was clearly different from that of the open-ended owl and snake discussion, which had “no right or wrong answer;” also it was distinguished from direct note taking, as the students were invited to share their ideas rather than simply following the teacher. Correspondingly, the expected student participation was restricted compared to that of the owl and snake discussion, as the students were only encouraged to share if they think they know “what’s going on,” and were asked to do it formally with hands raised; but at least, unlike occasions where the teacher was the only speaker, there was space set for student ideas.

The following exchanges took place as this “blended” activity started:

1. Sarah: Okay, so here's the first one, this is an easy one 'cause we've probably all seen Finding Nemo. [*Female student: Nemo!*] The relationship between a

clown fish and a sea anemone is? Azar?

2. Azar: Mutualism.
3. Sarah: Mutualism, how come, what's going on?
4. Azar: Cause they're helping, they're benefitting from each other. [*Lots of side talk*]
5. Sarah: OK, time out, I don't know, wowowow!
6. Tim: I can't find the-
7. Sarah: OK, Azar, how are they each benefiting?
8. Azar: Well, the clown fish, um, helps clean the anemone, the anemone provides food and shelter.
9. Sarah: OK! What the clown fish gets out of it is food and shelter, which is obviously a plus [*writing a "+" sign on the board*], and the sea anemone is saying, it gets cleaned, so that's a plus [*writing another "+" sign*]. Acer, what do you want to add?
10. Acer: um, I said it was commensalism, because the clownfish gets the protection but the sea anemone doesn't really get anything because they eat like, whatever is left out, like organisms that are living in the water whatever, so I mean it is not like its getting cleaned is a benefit.
11. Sarah: Good argument also. I would add this point in. Clown fish can become territorial, so some other things that may try to come and nibble on the sea anemone, the clown fish actually gets territorial with them and would try to scare them off. I'm not saying it can scare off, you know, a seal or a shark or anything, but it can keep some other fish that might nibble on the anemone

away. So GENERALLY, this relationship is GENERALLY thought to be one of mutualism. You can CERTAINLY argue other relationships for each of these, for many of these things, but I'm going to give you the one that's kind of the GENERAL belief, that this one is mutualism. So under your mutualism definition, I want you to go back and add, this is an example [*students taking notes*]. Example: clown fish and sea anemone, OK?

With Sarah's scaffolding probes, Azar articulated his full explanation on why the relationship between the clown fish and the sea anemone should be classified as mutualism: the clown fish gets "food and shelter" while the sea anemone gets cleaned up. By repeating his idea to the class and representing it with symbols on the board, Sarah supported this idea in an affirmative way. This seemed to be a good point to shift to another example, since the object on labeling examples has been finished. However, Acer threw in a thread for argumentation. Knowing that sea anemone eats "organisms living in water," he challenged the position of taking clown fish's cleaning up as a benefit, and argued for commensalism.

Sarah's response showed an effort of balancing the goal of note taking (representing the "serous" side) and the goal of argumentation (representing the general pursuit of "fun"). She first gave the evaluation remark of "good argument," and then took on the arguer role, suggesting another benefit for anemone in this relationship: the clown fish can be territorial and protect the anemone from being bitten. At this point, Acer's argument has been valued and accepted, and the conversation contributed to the goal of argumentation.

But, the goal of argumentation soon yielded to the goal of "fill in example:"

without pausing or posing any question for the whole class, Sarah directed the students to note down this phenomenon besides the definition of mutualism. While drawing this conclusion, she also emphasized the classification as a “GENERAL” belief and confirmed that one can “CERTAINLY” argue for other relationships. This interweaving effort buffered the conflict between the “fun” and “boring/serious” goals and saved some space for uncertainty. Further, the activity continued following similar interaction patterns: when the students raised disagreements on how a phenomenon should be classified in terms of relationships, the teacher would probe for reasoning, evaluate arguments and occasionally play the role of arguer, and she would have the final word on what a “general belief” was for the case.

This episode also represented how this class went through many of their note-taking activities. Sarah’s move in such situations resembled what the literature recorded as *rational authority* (Norris, 1997; Peters, 1966), in which the teacher did more than telling, supporting knowledge claims by reasoning and evidence rather than their institutional status. The tension between students’ emergent engagement in valuable argumentation practices and the activity object of reaching fixed classifications created the need for the teacher to play such a role, which in turn, limited the growing space for argumentation.

Interestingly, as this activity went, I observed situations in which a student initiated the shift back to task from an ongoing “fun” discussion. For example, when they came to the relationship between a candiru and the host fish, the conversation once went sideways into the myth that a candiru could go up the urine stream and enter people’s urethras. The class, including the teacher, was attracted by this piece of prior knowledge

from an episode of *House M.D.* There was a lot of laughter and side conversations while the discussion stayed on this topic. As Sarah summarized the phenomenon, the class got curious on why a candiru does this⁹:

1. Sarah: OK. It only lives in the Amazon River. For some reason I read, that it is, it happens more often to males than females, that it would follow kind of the stream of urine, back up and actually inside. It happens, it has happened to females before, doesn't happen very often. But, if you are ever on Amazon River, probably don't want to pee. There's scam inside, OK?
2. Charles: why do they attract to pee?
3. Sarah: I don't know. They want something in the pee. It is warm, or they need the salt, or... I really don't know. [*class giggling*]
4. Jeff: probably they think it is from some sort of fish.
5. Taylor: I wouldn't stand it.
6. Sarah: yeah, or maybe it just...they know there is a host at the end of that trail, who is peeing somewhere [*a lot of side conversations going on*]. Acer? Guys!
7. Acer: Um, I guess you can say it is commensalism or parasitism, because-
8. Sarah: Oh, wow, I didn't even, OK, sorry.
9. Acer: well, I mean, you- it is-, the barnacles aren't really doing anything to the whale.
10. Sarah: True.
11. Acer: arguably it would slow it down, so it is not really [*inaudible*].
12. Sarah: right. I got you. But besides the fact it is going to be slowed down, do

⁹ According to Wikipedia, this phenomenon is more of a rumor. There was only one case claiming such accident actually happened.

you think these barnacles will have much of an impact on this huge whale?

13. Students: No.

Acer raised up his hand while students (Charles and Jeff) as well as the teacher were trying to make sense of what “motivates” candiru to swim up the urine stream. Within such discourse contexts, Sarah probably took it for granted that he had something to share about the candiru phenomenon that they have not understood yet, which would explain her “unprepared” reaction—“oh, wow, I didn’t even...” –when realizing that Acer has already shifted to the next phenomenon on the board (a picture of barnacles on the tail of a whale that was next to the picture of a candiru and its host fish.).

Their exploration into the candiru phenomenon simply got cut off this way. Though Charles’ question of “why do they attract to pee?” (Sarah guessed it could be attracted to urine, and Jeff thought that it could mistake it as from “some sort of fish”) was not officially closed, and argumentation could have been developed if different reasons got critically examined. Sarah, though she could not help her surprise at first, quickly shifted her role, attending to and evaluating Acer’s reasoning on the whale and barnacle relationship. By the time Acer finished his whole explanation and Sarah made a reflective toss, posing the question on barnacles’ impact, the class’ unanimous response showed that their attention was also shifted towards this new thread of conversation.

Unlike how Sarah structured her shift proposal with value attached to and space saved for argumentation, Acer’s move gave no explanation on why he just started to talk about the next phenomenon. I had no evidence whether he, or the rest of the class were considering the incompatibility between the “serious” object driving this activity and the tangential goal of fun. One could argue that Acer simply got bored of the candiru

discussion and found it more fun to explore the new phenomenon. But functionally, the fact that the activity had a serious object and the fact what Acer talked about was as more on the “serious” side helped justify his action for the rest of the class, and might partially have explained why such a sudden shift, while unexpected, was quickly accepted. This topic shift, I would argue, was afforded by the class’ shared understanding on the need for balancing the “fun” and “serious” goals of learning.

In the focus group interview I conducted at the end of the semester, “fun” was also the word the students used to evaluate their class activities. For example, after we watched the philosophical chair debate episode, they gave the following answers to my question of “how do you think about these kinds of activities in your class?”

1. Nick: It is more fun than [*inaudible*] and writing on paper.
2. Kitty: it is more fun than what?
3. Nick: it’s more fun than sitting in front and writing on paper.
4. Kitty: Oh!
5. Charles: It is always fun interacting with people. I had a lot of people join the side I was on.

In Nick’s comment, the “fun” of the scientific debate activity was relative to “sitting in front and writing on paper,” which referred to “serious” activities such as taking notes and writing answers for BCR questions. In Charles’ comment, “fun” was associated with “interacting with people,” which also matched what this word characterized when used in class interactions. When I later showed the students another snippet of a warm-up discussion, Charles found that he was absent from class that day:

1. Charles: This was a fun day. And I wasn’t there.

2. Charles: Wait, it could possibly be me...behind Sarah.
3. Nick: it is not your shirt.
4. Dennis: It's Jeff.
5. Charles: It's Jeff. Shoot, I miss the game that day.

Charles first called it the “fun day” and was trying to find himself in the video. After being confirmed by others that he was indeed absent, he showed his pitiful feeling about “missing the game.”

Later when others explained to me what specific ideas from them meant, Charles also commented that “*If I were there on that day of class, I would have totally intelligent answers to share,*” Which well matched his “game” idea, conveying how he looked at such activities—that these are almost like games of competing to share “intelligent answers.”

This is probably how students, especially the more talkative ones (students recognized them as the “characters” of the class) see their participations in such open-ended discussions, which significantly differed from how they participated in the “sitting there and writing on paper” type of activity. That, I think, revealed what the class shared as the definition of “fun.”

In the educational research literature, the “fun” of learning is often connected to the use of certain curriculum material or teaching approach. Implementing educational computer games (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005) or multimedia resources (Stoney & Oliver, 1998), giving song composition assignment for remembering periodic table (Pettus & Blosser, 2002) are among the fun making strategies. And the argument for making learning fun mostly resorted to its physiological and cognitive

effect on individual learners, such as activating students' intrinsic motivation, reducing learning stress, and creating a state of relaxed alertness (Malone & Lepper, 1987; Bisson & Luckner, 1996). Framed that way, the "fun" part seemed to be a facilitator to the real learning process. The construct of "fun" in Sarah's class, however, seemed to bear some different meanings. Over time, the teacher and students used it to refer to classroom participation patterns that stressed direct interactions with people on specific topic, such as sharing intelligent thoughts and challenging each other's ideas based on reasoning and evidence. "Fun" of this kind, I would argue, was critical to how learning got organized in this classroom.

In conclusion, I would argue that the discursive construct of "fun" verses "boring"/ "serious" was a classroom mediational resource built and intersubjectively shared by this class. While the students and the teacher explicitly preferred "fun" over "boring"/"serious," they also understood the necessity of the "boring part" or "serious side." As a class (including the teacher), they did not have the full right of choice since the conflict was between the goal to the class' favor, which emphasized the fun of idea-sharing and interacting, and the goal set to meet the requirement of systemic assessments, which emphasized following instructions, listening to the teacher and note copying. Taking into consideration the mediational effects rooted in the need of balancing the two goals, it makes sense that affordances of productive argumentation practices would stand side-by-side with the time and content constraints in the parasitism and predation episode. The resources identified in last chapter allowed such argumentation to occur and sustain in certain topic range for a certain amount of time, which satisfied to some extent the "fun" goal for the class. The goal towards preparing for their unit exam (which served

as a preparation for HSA) required the class to switch back to the “serious” task of unit review, making sure that all students had the test acceptable knowledge of their scientific terms. The effort of balancing these two goals, in this case, formed the constraints on the width and length of the students’ argumentation practices.

6.4 The timing issue

While the freedom of pursuing “fun” at the price of “serious” tasks was locally determined in specific activities, there were some general tendencies when looking throughout the semester. First, as suggested in this chapter’s opening analysis and the analysis of the examples above, it depends on how compatible the “fun” or “serious” goals are with the specific activity object: open-ended discussion or debate could surely afford more “fun” while note-taking activities, bearing the responsibility of test preparation, were limited in how far a tangent can go, how “undetermined” the conclusions can be, and how much conversational space can be devoted to argumentation or other inquiry practices before a topic gets closed. Second, as argued below, there was the issue of timing. As the semester moved towards the semester exam, and as each content unit moved towards the unit exam, the class has less freedom to go on tangents, and the space for argumentation practices shrank.

A third factor has to do with the nature of various subject areas within this biology course and how the teacher perceived them differently. This will be addressed in the next section.

At the beginning of the semester, Sarah told the class that their unit exams and semester exams were both preparation steps towards and good indicators of their

performance in the final state assessment:

“If you can pass the unit exams, that usually means you’ll pass the semester exams. And the semester exams are closely correlated to how you would do on the HSA. So if you're passing all the unit exams with A's and B's, that's likely what you'll get on the semester exams and that's likely the range you'd be looking at for the HSA.”

In the spirit of getting prepared towards HSA (the state assessment), the class had to make sure that they met the requirements on timing, coverage of vocabulary, and the coverage of certain content topics (see page 99 for the quote from the transcript). While Sarah put these three in parallel, they often mingled as the “serious” factors that organized classroom learning goals. Through their classroom interactions, the effort on meeting the two coverage requirements often raised the issue of timing, which I identified as a common constraint on the class’ argumentation and other inquiry practices.

The effect of such timing constraints became more and more salient as every exam date got closer. Usually, at the start of a new unit, there would be more activities involving open-ended discussions and more room for the class to go on tangents, but towards the end of the unit, the “discussion” often lost such freedom, becoming just another approach that serve the test preparation objects. For example, consider the episode occurring at the end of October, two classes before their exam on the Chemistry unit.

In the first 50 minutes, the class took a mid-unit quiz, reviewed the definitions and types of major organic compounds, and filled in the corresponding part on their study guide. Since this was the last content coverage class before unit exam (the next class was

an exam review), Sarah had to finish during the rest of the class (40 minutes) all the notes on what inorganic elements (e.g., potassium and calcium) and organic molecules (e.g., carbohydrate and protein) were needed by our body and why. After the class spent 10 minutes noting down functional roles of necessary inorganic elements and talking about diet, Sarah suggested that they did a “really gross discussion about poop in a minute.” This suggestion stirred up much laughter and side conversations. However, even from the very beginning of this “discussion,” Sarah made a great effort to limit the students’ participation and keep the conversation strictly staying on topic:

1. Sarah: Guess what I think, you guys get to hold your tongue until I finish what I got to say about it, OK? If you don’t wanna own up to ever looked at poop before, that’s fine. Some people in my other classes were saying, oh, they noticed this when they were helping with the potty training their little sisters. That’s fine. If you don’t, if you wanna pretend like you never look at your own poop, and you’ve never seen someone else’ poop, that’s fine. [*class giggling*]
2. Tim: I honestly did not-
3. Sarah: stop!
4. Nick: you just walk into the toilet-
5. Sarah: Stop! You guys I’m getting a little frustrated. I need to be able to finish sentences before you guys throw out your crazy comments. Crazy comments welcome; let me finish my sentences first, OK? So here is what I am saying. We are not capable of digesting every single thing that we eat. Like-
6. Taylor: [*whispering*] like corn!

7. Sarah: [*make "hold on" gesture*] [*pause*] well, we talk about when we talk about owls and snakes, we talk-
8. Tim: Pellet! [*class giggling*]
9. Sarah: Tim, can you please stop? [*pause*] We talk about owls and snakes, and they will eat like a whole rodent, they won't be able to digest the bones and the furs, so what do they do?
10. Taylor: pellet.
11. Dennis: they cough up the-
12. Sarah: [*cut off Dennis*] they coughed up those pellets that have that stuff in it.

While Sarah would encourage everybody to participate in open-ended discussion like the owl and snake one, and would give students space for sharing ideas even in emerging argumentations such as the parasitism and predation episode, here she was doing the opposite—directly asking students to “hold their tongue” until she finished and cutting their comments off by shouting “stop!” and making the “hold on” gesture. One could argue that she did so to avoid students’ unscientific jokes on this “gross” topic, or to train the students being respectful while others were speaking. I would agree that this might explain why she stopped Tim and Nick on line 3 and 5 respectively. But it would not be able to explain why she stopped Taylor on line 7 and Tim on line 9. As the comments on line 6 and line 8 were very reasonable guesses on what she would look for several turns after. Tim jumped onto “pellet” from the hint of “owl and snake” (in that previous discussion they had addressed owl pellets). Right after calling his comment to a stop, she described the source of owl pellets and asked students to provide that word. What was gained through holding such comment then? A possible impact, I think, was

that the students would not be able to go anywhere on a tangent from the ongoing “discussion,” but had to strictly keep to Sarah’s storyline.

In the “discussion” following, there were only several short slots that students could give Sarah the answer she needed for completing the stories. For instance, she did ask for examples of “things we can’t digest:”

18. Sarah: OK, since everybody has a million things to say about this, does anybody wanna take a step at some of the things we can’t digest?

19. Students: corn!

20. Sarah: corn is one.

21. Nick: Really? Our stomach doesn’t know what to do with it?

22. Charles: certain types of beans.

23. Azar: fiber!

24. Sarah: beans have a lot of fiber in them, so I can see why. I can see what you are saying. [*students keep throwing in examples*] The bottom line is a lot of plants, we can’t digest all parts of plants. Other animals are really good, cows are better at digesting plants, they got all those stomachs. And they can digest a lot of parts of plants. We can’t digest all parts of plants, we don’t throw it up, so it comes out from the other ends. So this is what I’m saying. Some things go undigested by [*inaudible*], we get some of it. Like corn, we got some nutrients out of that, but a lot of it goes undigested. So within your stomach, even with the acid in there, even with the water you drink in, it doesn’t dissolve or break down or get digested. It goes straight into intestine and comes out.

Confirming corn and beans as acceptable answers, Sarah quickly went back to continue her story. While the students obviously had more examples to share, their comments were ignored. Sarah also made no effort to probe for why the students considered the examples they shared as indigestible, instead she provided the reason for Charles's bean example—"beans have a lot of fiber in them, so I can see why." As the story went on, she also gave the main point: that fiber does not get digested but "goes straight into intestine and comes out." After explaining fiber's role as intestine cleaner and having a few exchanges with the students on "getting more fiber in our diet," Sarah finally revealed her goal for doing this:

25. Sarah: so, here is the whole reason why I'm going through this whole poop story, OK? Fruits and vegetables fall into the carbohydrate category, which means fiber falls into the carbohydrate category. This is always, always, always a question on the HSA, OK? The question said something like, what is the source of fiber in your diet, or where do you get your dietary fiber from, and the answers would be like A, carbohydrates; B, lipid; C, protein; D, something else, and you should know that the answer should be?

26. Students: A/ carbohydrate!

It turned out that "the whole reason" for "this whole poop story" was to emphasize "fiber falls into the carbohydrate category," which was "always, always, always a question on HSA." This poop discussion could surely be organized in a way that afforded more student participation and encouraged scientific reasoning; even if they looked into Nick's doubt that "our stomach don't know how to deal with it?" there could be productive argumentation developed on possible reasons for why fiber does not get

digested in our body. However, as the time for content coverage was very limited, and the requirement associated with this piece of content was shallow, the most important thing here was to ensure that the students could correctly answer one specific question on HSA, the conversation was purposefully kept short and fully under the teacher's control, which constrained every chance for the students to participate in reasoning and every possibility for tangents. The content coverage and the shortage in time both turned into an issue of timing for this "discussion."

Such constraint of "timing issues" got more and more in the way as the semester went on. While the ecology unit lasted for more than a month, the cell structure unit and the reproduction unit only lasted for about half of that time each, but with much more terms and details that had to be covered. The timing issues then became prominent earlier in the unit. For instance, on the third class into the cell structure unit, Sarah went through the list of different organelles, identifying them on the diagrams of plant and animal cells and explaining their functions. As she talked about plant vacuoles, students raised up many questions: some were clarifying questions on whether certain shapes on the diagrams represented vacuoles; however, some others were more on the challenging side. Consider the following exchanges:

1. Sarah: OK, if you had, this is how big the vacuole is supposed to be, and you don't water it for a day, it used up this part of it. And the next day let's say it used up this part of it, and now the vacuole only takes up this much space, what do you think is going to happen to the shape of the cell?
2. Students: shrink.
3. Sarah: it is going to start to shrink and hence the plant starts to shrivel up.

4. Nick: how does it shrink if the cell wall is like, rigid?
5. Sarah: it does have a cell wall that is a little bit rigid, but they kind of work together—the cell wall and the vacuole. The cell wall would start to collapse in on itself, if it is not been held out by that full vacuole, OK? So that, that is why, a cell would start to shrivel up a little bit when it is using up its water. So this is what the vacuole is for. Its job is to hold water.

While Sarah and many students agreed on that the cells would shrink if water in the vacuoles were used up, Nick posed a challenge—how can the cell shrink if, as they have just learned a few minutes ago, that plants have this rigid structure on the outside called “cell wall.” This possible initiation move for argumentation was not explicitly valued or picked up. Giving no time for other students to respond, Sarah explained this challenge away by providing the mechanical detail that “cell wall would start to collapse in on itself;” reconfirming that the cells “would start to shrivel a little bit” and claiming the role of vacuoles to be holding water. Similarly, when Tristan expressed his doubt on if bananas also have vacuoles (which made sense, since if the role of vacuole is to hold water, then it was reasonable to guess that the less juicy plant parts, such as banana, would have smaller or no vacuoles.) Sarah’s response provided an authoritative answer without any reasoning: “every plant cell has vacuoles.”

While the conversation stayed on the topic of vacuole, many students seemed to have all kinds of curiosities as they continued to throw in questions. It finally came to a point that Sarah realized how tight time was for her coverage goal:

1. Sarah: Oh my God, it is [*start to talk very fast*] you guys, I know that this is a lot, we have, literally we have two more to do after this one, OK? And then you guys

are gonna have plenty of time to talk.

2. Charles: [*loudly*] Oh, my God!!! [*looking frustrated*] [*slapping on the table*]
3. Sarah: I know it is Friday, I know everybody's ready to be done. We are almost there, OK? What we need to add here is the vacuole [*labeling "vacuole" on the board*], OK, this helps in the structure thing we are talking about, because if it is not full, it shrivels up.

Until this moment, the class had been taking notes for 40 minutes, on five different organelles. They were mostly looking alternatively at the board and their notebooks, listening to the teacher and trying to copy everything down. It was only during this questioning period (about three minutes) that they started to actively participate and interact with the teacher. It was therefore not a surprise to see how students, like Charles, were so frustrated that this "boring" activity has to continue as they "have two more to do after this one."

Snippets like this shed light onto both the affordance and constraints of the class' argumentation practices. On the one hand, it was impressive how common the students felt entitled to raise arguments, which showed the strength of the argumentation norm in this classroom. Like when discussing how lodging resistant genes allowed crops to stand in the wind, the previously constructed, intersubjectively shared resources afforded students to think critically, bringing up questions and challenges, even when the activity required much focus on the "serious" task. On the other hand, it was pitiful that, constrained by such a "timing issue," the students' participation in argumentation was cut short; their buds for in-depth explorations and argumentation were sacrificed for accomplishing the goal of content coverage. In the long run, such lasting constraints

might have the potential of discouraging students from productive inquiry thinking.

6.5 “Personally I don’t like this unit”

As I have suggested at the beginning of the above section, the level of freedom to pursue “fun” also has to do with the nature of subject areas within the discipline of biology as well as the how the teacher perceived them.

Much educational literature has addressed the disciplinary influences on teaching and learning. It has been suggested that different disciplines favored different learning styles (Kolb, 1981, 1994), different individual beliefs about learning (Hofer, 2000), different pedagogical ideas (Healey, 2000), as well as different teaching approaches (Lueddeke, 2003; Lindblom-Ylänne, Trigwell, Nevgi, & Ashwin, 2006). Such variations were considered to be rooted in intrinsic disciplinary differences in primary tasks, nature of knowing, disciplinary criteria and research methods (Kolb, 1981; Becher, 1987). This branch of research has made much effort in characterizing disciplinary knowledge structure, identifying requirements for disciplinary expertise and drawing implications for disciplinary learning and teaching. There are also great limitations: For one thing, most of the research in this line focused on higher education. While different disciplines were taught as separate courses in current secondary school, there was little research focusing on the effects of disciplinary differences within that setting. For another thing, the term *discipline* was often a broad construct in this type of research. For example, Hofer (2000) compared students’ epistemological beliefs associating with the disciplines of “science” and “psychology;” Lueddeke (2003), Becher (1987) and Lindblom-Ylänne et al.’s (2006) research all addressed the difference between “hard” disciplines (such as

physical science, medication, etc.) “soft” disciplines (such as social sciences and humanities) and those in between (including many application sciences). There was little research closely attending to the differences of lower level disciplinary categories. Are “science” or “biology” small enough units for thinking about disciplinary learning then? Would the specific characteristics of lower level units (for example, in biology, there are subject areas such as ecology, cellular biology, biochemistry, molecular biology, etc.) play a role in classroom teaching and learning?

My research cannot provide data to address these questions. However, some of my observational data did speak to the possible influences from such sub-disciplinary differences and raised the need for further research in these directions within the secondary school settings.

For example, in Sarah’s biology course, the chemistry unit was located right after the unit on ecology, which lasted for more than one month since the beginning of the semester. In the ecology unit, we saw much evidence of students’ active participation in scientific inquiry, especially argumentations. Besides the three open-ended discussions purposefully launched by the teacher over the first five classes, I had also observed multiple argumentation episodes initiated and sustained by the students. Besides the parasitism and predation episode that I chose as the representative case and closely analyzed within these two chapters, the class has also engaged in arguing about whether any animal can get energy without eating other plants and animals, how strict the boundary is between carnivores and omnivores, and how to deal with the situations in which one could argue for population changes in both ways through the analysis of a food web, etc. Their argumentation practices distributed over the whole unit, from the

introduction class to the unit review, serving the needs of many at-the-moment sense-making processes.

I thought by then that such frequency of and participation in argumentation practices would last into the unit of chemistry. It was frustrating to see how much time the class spent on memorizing the structure of water, which monomer made up which polymer, or which macromolecule carried out which functions, etc. It was even more frustrating to see that few buds of argumentation were generated during this unit, and even when those did generate, they often got put aside and never picked up on again.

Part of the reason, I would argue, was embedded in the way Sarah perceived the content of this unit, which she explicitly told the students in their unit review:

Sarah: So this, part of your study guide, just the bottom part is the organic molecules. There are four of them. It is kind of suck, it is something that I don't... I personally don't really like this unit, 'cause I feel it is not as interesting. **This is not something I can show you** and then you're gonna be like "oh, amino acids made up proteins!" **That's not something we can like see or touch into. It is a little difficult. This kind of information is something you just kind of have to sit down and go through until it is kind of like sucked into your head. You need to know** that amino acids made up proteins or the nucleotides made up nuclear acid. OK?

Sarah's main point was that she viewed this unit as one unlike other units, in terms of the science contents involved. In the ecology unit, they often pulled on phenomena they have seen or heard of in real life as the placeholders for understanding different relationships, producers and different types of consumers. In the chemistry unit,

however, it was hard for her to use or pull from the students' lives examples that would intuitively explain the structures of chemical molecules: "This is not something I can show you and then you're gonna be like 'oh, amino acids made up proteins!'" Without a way to connect such required topics to life examples that the students "can see and touch into," Sarah found it difficult to pursue sense-making with the contents; instead, she labeled them the kind of information that "you just kind of have to sit down and go through until it is kind of like sucked into your head." Being it the unit goal to memorize this information, it was unsurprising that there was little chance for argumentation practices, but much need for note-taking and triadic dialogues that checked on memorization.

While the teaching and learning of macromolecules and their functions focused completely on memorizations, there had been several student bids for inquiry when the topic was on water property (which was in the same unit), but they all got dropped pretty soon. For example, when they talked about the universal solvent property of water, Sarah made an analogy between the water molecule and magnet: "We said, like, a magnet is polar 'cause it has a north end and a south end. A water molecule is polar 'cause it has a positive end and a negative end." Following this analogy, Acer raised a question several turns later, right before they move on to the next water property:

1. Acer: Um, if you drop like a magnet into water, would it like, move the water into order?
2. Jeff: Acer!
3. Sarah: You mean because it is also polar?
4. Acer: yeah.
5. Sarah: I don't know, I am not, like, I'm kind of a life science person, and I

don't really understand magnets very well, it is kind of like physical science to me. You might have to ask your physics teacher that.

6. Deanna: Um, is it like because the electrons are all moving one way? Um, so that determines, like, the way they are going is one polar and the opposite end, like the way they are moving around-

7. Sarah: right, and that's how you can do this electromagnet also, but I don't know what the effect is on water. I don't know. Um, so this is true, water doesn't mix with oil because water is polar and oil is non-polar.

While Sarah's analogy probably pointed to the similarity between water and magnet's polar structure, Acer might have taken it as that their polar property meant the same thing and therefore reasoned forwards that dropping a magnet into water would be able to "move water in order." Understanding where this idea came from, Sarah admitted that she did not know the answer and avoided to step further into it. Claiming the question to be "kind of like physical science," she identified herself as a "life science person" and emphasized her lack of knowledge in the discipline of physics. Even though Deanna tried to jump in with a mechanism of magnet, Sarah pushed this discussion aside by stating that she did not know "what the effect is on water."

One might argue that the reason Sarah tried not to pursue a discussion along this line was that she did not know how to handle the absence of a correct answer. But then it would be hard to explain why, in previous classes, Sarah purposefully set up classroom discussions on topics with "no right or wrong answer." The owl and snake discussion, for example, is one on a genuinely unsolved problem in the field, to which neither the students nor Sarah has a "correct answer."

An alternative explanation on why Sarah chose to not pursuing this line of inquiry, I would argue, could have something to do with her perception of knowledge in this unit and its intrinsic affordance of inquiry. Acer's question got at molecular/ atomic level phenomena, such as the electron movements in magnet and the effects on water molecules. Similar to ideas like "amino acid made up protein," this question tried to look into something "imperceptible." While Sarah found ideas that could not be "see or touch into" hard to get hold of through sense-making, Similar perception might also prevent her from considering the mechanism behind polarity as something they could inquire into.

Sarah's perception of chemistry unit did illustrate some characteristics intrinsic to micro-level biology. Indeed, reasoning and arguing in any subject areas without being a pure reductivist, one would have to accept a set of fundamental, unproblematic "bottom out" components (Machamer, Darden, & Craver, 2000). For subject areas such as biochemistry, atomic mechanism of water polarity and magnet polarity, the identification of monomers and polymers, and many other content coverage requirements of this unit, were probably among such "bottom out" structures. Sense-making activities on such objects would resort to the type of inquiries in inorganic and organic chemistry, which most students in this class, and even the teacher, might not be familiar with.

The dilemma of the chemistry unit in this biology course, I would argue, called for more close studies focusing on the issues of sub-disciplinary variations, especially to inform what learning contexts we need to construct in a secondary biology classroom to afford inquiry into such areas.

6.6 Argumentation as performance

In the final section of this chapter, I would like to address a piece of constraining resource that has been concealed under the table. My identification of other mediational resources was mostly through analysis of classroom interaction data. While explicit references are not necessarily made, the intersubjectivity was often evidenced from the alignment of participation and discourse patterns. This piece of resource, however, functioned so “implicitly” that I would be unaware of it if the students had not mentioned it in my focus group interview.

In the previous chapter, I have used the class’ philosophical chair debate on “Is the sun alive” as an episode demonstrating productive, high-quality scientific argumentation. In terms of argumentation structure, the arguments students collaboratively constructed in this debate were mostly supported with warrants and evidence; in terms of the class’ participation pattern, the debate was mostly sustained by students on their own; besides the setup of the activity, the teacher made few close scaffolding steps during the conversation. Also, as I have argued, while the “yes” and “no” groups went back and forth, the students actually guided each other to better articulate or modify their arguments, providing stronger evidence or reasoning basis. In my focus group interview with the students, I let students watch and reflect on a five-minute excerpt from this debate, asking whether they liked such activities and what they learned from it.

Charles, the main speaker on the “yes” side in that debate, was among the group of students I interviewed. He made great contribution arguing for his side during the debate, especially through challenging the “no” side’s points with counter evidence. For

example, he used “liger” as the evidence that something alive does not necessarily need to be able to reproduce. Even when the debate was closed and Sarah put out “being able to reproduce” as one of the criteria “generally used in biology,” he continued to remind the class of his earlier argument: “Not always true. Think about a hybrid—a liger.”

In the interview, after I announced the snippet we were going to watch and right before we started the five-minute video, Charles said “don’t pay any attention to what I was saying, because I think I was just trying to persuade them.” and then “’cause I’m on the other side, just to help these kids and I’m good at argument.” After the video, I particularly asked him to elaborate on this comment, and he explained to me with four of his classmates sitting around:

1. Kitty: So I just, so, um... Charles, you said that you were actually on the other side. You just said these to help this group to argue.
2. Charles: Yeah.
3. Kitty: Could you say more about that?
4. Charles: Um, ‘cause, every time activities like this, sometimes everybody goes like one-sided. So that... I believe there were only two people on that side, on, um about sun being alive. So I was saying to her, OK, Ms. Henson, I’ll help you out. I’ll go over there, just to create argument. Of course.
5. Kitty: Did she know that?
6. Charles: of course I created an argument. (Nodding) Yep.
7. Kitty: But you did really well at arguing on this side. Like the liger idea, is it?
8. Charles: I was good at creating arguments.

Both in his first comment and elaboration, Charles made it clear that he was “actually on the other side.” His arguing on the “sun being alive” side was just “to help these kids” and help Ms. Henson out, since “there were only two people on that side” (both of them were not in the focus group I selected) while a debate needs two sides, and since he considered himself as good at “creating arguments.” Sarah, as Charles suggested, knew this right from the beginning.

Later on, in reply to my question for the whole group—“do you feel like this is more like a game, or it’s something to take seriously,” Charles and three other students agreed that they considered it “as a game” while Deanna being the only one who held a little bit different position:

1. Deanna: I don’t know. I think that it is kind of both like it’s serious and something you can throw off your way. So like-
2. Charles: That you can enjoy something you learned best because of me.
3. Deanna: [*chuckling*] Yeah.
4. Kitty: So do you think you learn anything from this kind of discussion? Since Deanna said you don’t know what other people would say. Do you finally think this is a right or wrong answer to this kind of question?
5. Deanna: No, I don’t...as right now, I don’t think there is. I mean, well obviously I’m going to believe in my opinion, but there is not definitely a right or wrong answer, I guess, so...
6. Kitty: [*to the boys*] How about you guys?
7. Charles: Yeah, I honestly believe the sun is not alive. It is just chemical reaction. [*the other two boys nodded.*]

8. Kitty: OK. [*to Christine*] How about you?
9. Christine: Um, I, well, I think since it doesn't really-, it is not. You know, all these rules about how something has to be alive. Since it doesn't meet all the rules, the sun is not alive.

Taking this activity not just as a game, Deanna was also the only one explicitly agreed that “there is not definitely a right or wrong answer.” Charles firmly repeated his belief that “the sun is not alive” but “just chemical reaction.” The other two students, Nick and Dennis nodded to Charles’ agreement.¹⁰ Christine was originally a “maybe” student in that debate. She hesitated a little bit, but finally decided that “the sun is not alive” since “it doesn’t meet all the rules (for being alive).”

While this "behind-the-scene" story came from just five students, which might not be able to represent the opinions of the whole class, it is worth reflection what could be made different if such was the way the students experienced this debate episode. Initially, I have showed through analysis that, as the debate continued, the students and the teacher together suggested the importance of “criteria” in deciding whether the sun is alive. They agreed on the uncertain answer to such question; in a “criteria” language, the problematic nature of scientific theory was emphasized and started to be constructed into an epistemic resource for the class’ later learning interactions.

However, based on the above interview data, while the students could create argumentation in a criteria-dependent spirit, they could still “believe in” the existence of a single correct answer. The interview situation could certainly be a contextual issue— that is, the students might hear the question to be judgmental and assumed that the interviewer, unlike their teacher, might be checking on if they have learnt the correct

¹⁰ Unfortunately, this “nodding” part was not recorded on camera but in the interviewer’s field notes.

answer. But the way Charles jumped to clarifying his position without any probe, the fact he confirmed to me that Sarah knew he was just helping out, and the manner in which the two other students aligned with him, made it hard to deny that, these students could hold similar thoughts back by the time they engaged in this debate.

Considering how the students managed to argue without truly disagreeing and how their positions might not have changed though the language of “criteria” was introduced and accepted at the moment, I would argue that there could be another message conveyed through the philosophical chair debate: that “arguing for the sake of arguing” was allowed, even encouraged in this classroom. Argumentation in such case became a “game.” The students apparently understood the rules, enjoyed the game, and showed their ability of playing it well; but they might never have seen the need of this particular debate. They would not sense the discrepancy had it not been set as the argumentation theme. For the majority (four students out of five in this focus group interview), the positions on whether the sun was alive, and more important, on whether there was a correct answer to such question were not influenced by the activity at all.

If the whole purpose of argumentation practices was for students to become “good at making argument,” in Charles’ words, then this activity was definitely successful and productive. But if our overarching goal was to foster argumentation into a useful discourse tool the class could draw on in their daily learning activities, arguing without the presence of real discrepancy could be problematic and dangerous: when simply treated as a game, argumentation lost its original function that made it so important to the historical development of science and the practices of science community. Such

allowance of performance-oriented argumentation, if developed into a norm, might constrain how purpose-serving argumentations could be in classroom.

Consider the following example, which happened at the beginning of the day after, when they started a discussion on “where human beings get energy from?” The students were given five minutes for writing down their ideas and then shared with the class. This snippet took place when Acer suggested that “you get energy by eating plants and animals that eat other plants and animals.”

1. Jeff: There are plants and animals that have not eaten other plants and animals, ‘cause [*inaudible*].
2. Sarah: hmm, you had better ask Acer.
3. Jeff: Wait. OK, Acer, if I eat a plant or animal that had not eaten another plant or animal ever, would I get energy or strength?
4. Acer: Um, could you show me an example of a species of plant that doesn’t exist off other species being eaten?
5. Tristan: Plankton!
6. Tim: A new born camel. [*class laughter*]
7. Tristan/Nick: Plankton! [*more people shouted out plankton*]
8. Nick: Is that right?
9. Sarah: Who eats camel? I won’t have that for lunch.[*class laughter*]
10. Dennis: Asian people.
11. Sarah: Really? Nah. OK, wait, what is-, wait a minute. Acer, what was the challenge you presented, tell me or what?
12. Acer: Oh, um, like, show me a species has not eaten other species, or does

not exist off other species?

13. Sarah: Show me a species that does not live off other species. Oh, that's a challenge, Tristan?

14. Tristan: worms.

15. Sarah:[*laugh*] [*inaudible*]

16. Nick: Yeah, it does. That's true.

17. Sarah: OK. Dennis?

18. Dennis: a sea cucumber. [*class laughter*]

19. Sarah: what?? Sea cucumber, OK.

20. Tristan: fungus.

21. Tristan: worms are animals.

22. Students: How about cactus? /Plankton

23. Sarah: OK. What is plankton?

24. Nicole: swamp bug !

25. Nick: it's that little thing.

26. Dennis: they are mean.

The argumentation here was started by Jeff's challenge to Acer's claim, that instead of getting all energy from eating, there could be plants and animals back by asking for a piece of evidence—"a species of plant (should mean that "have not eaten other plants and animals." Sarah directed this challenge to Acer, and Acer argued animal that doesn't exist off other species." At this point, the whole class started to shout out answers. The evidence they provided included only one or two words, without any explanation on why those were considered as supporting Jeff's challenge, assuming that

the reasoning embedded could be easily pulled out given the specific contexts of this conversation. In my later interview, when asked, students have suggested reasons for some of their answers. For example, Nick explained that “those (planktons) are like microbes in the water, and in water, like on water, would you have anything to eat?” In comparison, “a new born camel” was a more obvious idea. The immediate class laughter was probably resulting from realizing that a “new born” would meet the condition of not literally eating anything yet but being alive as animal. Sarah also entertained this example, jokingly commenting that she “won’t have that (camel) for lunch.” Although Sarah made effort to value Acer’s challenge and offered space for the argumentation to grow, the conversation following that ran more and more into sharing laughable idea, and it never got returned to Acer or Jeff, who raised the issue at the first place.

The “new born camel” idea, while being trickily acceptable, was not something that really served the needs of argumentation at the moment. Students might honestly have no idea what plankton or sea cucumber eat, but as a class consisting of mostly 10th graders, I doubted if there would be of any real confusion over where new born mammals get their energy from. Arguments like this, I would argue, was more for the sake of performing argumentation and making an “intelligent answer,” rather than oriented towards solving a real discrepancy among students’ ideas. While Sarah’s class was often filled with jokes and class laughter, and as I have suggested in last chapter, the teacher and students’ being able to play jokes on each other’s ideas were signs of their peer-like relationship, and, in many cases, actually facilitated their inquiry learning interactions. But jocular arguments like this one was played out at the cost of dropping the really arguable, exploration-worthy stuff on the table.

In the present research, because of the data limitation, it is going to be too much of a stretch to pin down through analysis how “argumentation as performance” would constrain the development of classroom argumentation practices. However, through analyzing the above case, I would like to suggest the necessity of looking into this issue in the future. As for argumentation to function in object-oriented classroom learning activities, creating or seeing the authentic need for arguing should be considered at least as important as understanding the ways to argue.

Chapter 7: The roles of humor

7.1 Why humor now?

One phenomenon I observed in Sarah's class was class laughter. Mostly, the laughter emerged in ongoing conversations among teachers and students. For example, consider the following snippet that occurred in the middle of the semester, immediately following a discussion on the differences between observations and inferences:

1. Sarah: So if you saw me-, if you guys walk into the room, you saw my faces-, if I-, you guys walk into the room, and I look like this. [*arms held together; head tilted to the left, mouth widely open; eyebrow raised and frown.*] What observations would you make?
2. Students: {Um, you're paralyzed?}
3. Jeff: {Um, your face gets-}
4. Sarah: OBSERVATION! [*Class laughter*]
5. Nicole: Um, your arms' crossed!
6. Sarah: My arms' crossed.
7. Jeff: Your face looks weird.
8. Sarah: YOUR face looks weird! {[*Class laughter*]}
9. Jeff: {My face isn't weird.}
10. Sarah: Like my eye brows {are like-}
11. Charles: {Oh! Oh! Oh! I got one. You are wearing a red undershirt. {[*Charles laughing loudly*]}[*Class laughter*]}

12. Sarah: {That
is true. I AM wearing a red shirt [*Laughing*]. Ok? What inference would you
make if you came into the room and I was like this?
13. Taylor: {You had a bad day.
14. Charles: {You are {[*Inaudible*]
15. Nicole: {There is some-
[*Students all speak at once.*]
16. Sarah: I had a bad day. I'm what?
17. Tristan: Playing {sports. }
18. Azar: {You're} worrying. [*Class laughter*]
19. Tim: You are Republican!
20. Sarah: [*saying while laughing*] I'm Republican. My shirt would fit in. [*Class
laughter*]
21. Sarah: {Um- }
22. Tristan: {Are you-} Are you an independent?
23. Sarah: That is not politics class.
24. Jeff: Sure it is.

In this episode, Sarah attempted to check on the students' understandings about observation and inference, which they just discussed about. She made a strange face and asked the students to first make observations and then draw inferences. In this less than one minute snippet, the class burst into laughter four times (line 4, 8, 18, 20). Many of their exchanges on observations and inferences were integrated with humor. To understand learning in laughter-rich snippets like this, unavoidably, we would run into

the need of understanding what led to class laughter and how that influenced the flow of their ongoing conversations.

The laughter following Charles' statement about Sarah's red undershirt, for example, could be triggered by his pick of an unexpected observation: it is reasonable to say that Sarah meant to get the students to focus on her facial expression and pose, since those were what she changed to set up the situation for them to observe and make inference of. However, this focus was not explicitly stated, which makes it unexpected but legitimate to extend observation onto descriptions of other features, such as the color of her undershirt. That Charles ended this comment in loud laughter indicated his intention of making fun. Based on such interpretation, we could argue that Charles not only had a good sense of what counted as observation, but also understood the task so well that he was able to find a hole and joke about it. The class' getting this joke suggested that they were on the same page and shared the same understandings. Had there been no laughter involved, Charles' comment could be taken as evidencing the opposite—that the students did not understand the task and has no idea what to attend to in their observations.

This jokingly stated observation also affected their later interactions. Mainly, it broadened the ground of inferring, leading to humorous inference building on the same line of joke. In laughter, Sarah treated Tim's statement of "you are Republican" as a sensible inference, commenting that "my shirt would fit in," which obviously drew on Charles' red undershirt observation and linked it to the well-known fact that Republican camp is represented by red (this might also be where Tim's inference came from, but there was not direct discourse evidence).

As demonstrated by the above analysis, humor (as indicated by laughter) appeared to be such a structurally and functionally significant component of the class' discourse that it would be irresponsible to leave it out of an analysis examining the development of this classroom activity system. Therefore, I devoted my last analytical chapter to exploring how humor became significant for this class and the roles they played in ongoing learning interactions.

7.2 Understanding the “elephant” of humor

Many researchers have suggested the essential roles humor plays in human communication (Bateson, 1953; Foot & McCreddie, 2006; Norrick, 1993); some even suggested that “there are probably no contexts, however dire, in which humor is not a potentially appropriate response” (p. 297, Foot & McCreddie, 2006). Humor practices have been recognized by many as a collection of phenomena marked by laughter, in which cognition, emotion, physiological paths, and social interactions all have important roles (Bateson, 1953; Chapman & Foot, 1996; Foot & McCreddie, 2006; Meyer, 2000). Studies on humor came from multiple disciplines—psychology, philosophy, sociology, anthropology, and cognitive linguistics, sharing the research goals of explaining the origin and effects of humor.

Recent reviews suggested several major theories on where humor stems from (Foot & McCreddie, 2006; Meyer, 2000). The incongruity theory suggests the unexpected, in some sense inappropriate events, as a shared cognitive basis of humor (Berger, 1976; McGhee, 1979). The relief theory argues for a physiological common ground, claiming humor experience either as resulting from sudden reduction of arousal

(Berlyne, 1972), or as caused by the release of tension, which was arguably formed through socially repressed desires (Christie, 1994; Freud, 1928, 1938; Rothbart, 1977). Finally, the superiority theory (Gruner, 1997; Zillmann & Cantor, 1976) emphasizes the involvement of “self,” stating that humor stems from making one favoring oneself over others in a certain way.

These theories offer different perspectives rather than competitive models for explaining the complex phenomena of humor. For example, an extremely optimistic/confident but unlucky cartoon figure can make people laugh, but it would be hard to pick out whether (or how much) such funniness came from the unusual pairing of personality and experience, or a sudden release of the audience’s tension accumulated through a frustrating life experience, or a superior feeling over the misfortunate character.

Strong arguments have been established that these theories can also be applied to phenomena other than humor. For example, it has been pointed out that incongruity could cause anxiety or curiosity instead of humor (Foot & McCreddie, 2006; McGhee, 1979); certain forms or amounts of crying could result in tension relief (Cornelius, 2001); and superior feelings over others might lead to aggressive behaviors rather than a humorous experience (Baumeister, Bushman, & Campbell, 2000).

What limited the scope of these theories—which may also partially explain their insufficiency in characterizing humor—is the focus on individual experience of humor and the assumption of universal mechanisms underlying such experience. Humor, especially the everyday sense of humor, is, above all, occurring through interactions embedded in immediate and historical contexts. As many have argued, decoding humor required much reading into the unsaid, what was humorous in one situation might not

produce the same meaning at all in another (Douglas, 1968; Duncan, 1982; Goffman, 1974). Assigning the whole story to an individual trait or cognitive skill would underestimate the complexity of the humor phenomena and lead to oversimplified conclusions. For example, combining personality tests and humor rating, many cognitive psychologists successfully associated individual taste of humor with personality traits (Cattell & Luborsky, 1947; Mindess, Miller, Turek, Bender, & Corbin, 1985). However, research priming humor rating with photos of arousal and non-arousal contents (Goldstein, Suls, & Anthony, 1972), or manipulating prior exposure to high arousal communication and tone of humor telling (Cantor, Bryant, & Zillmann, 1974), found that such immediate contextual elements could also significantly influence the participants' appreciation of humor. Still, what was left out of concern was such experimental setting itself: rating written (or told) humor presented by psychologists in a lab is a very different kind of interaction from chatting with an old friend in a café and sensing something humorous in the ongoing conversation. It is reasonable to doubt, then, to what extent these lab test results would reveal how people appreciate humor in real-life situations.

Scholarly work looking at humor emerging from naturally occurring human interactions worried less about the origin of humor, but mostly focused on its social functions in diverse settings, especially how humor practices reflected and affected social relationships (Colston & Gibbs, 2002; Duncan, 1985; Fine & De Soucey, 2005; Sanford & Elder, 1984). Many agreed on humor's role in establishing, strengthening and sustaining close relationships between interaction participants (Colston & Gibbs, 2002; Fine, 1984; Fine & De Soucey, 2005; Sanford & Eder, 1984). On the one hand, people have to share much understanding of the situation and of each other's identities to assume

that their remarks would be interpreted as funny rather than offensive (Fine & De Soucey, 2005). On the other hand, as people laugh together about the same thing, it creates strong group feelings that can shorten social distances and add to the common ground of interpretation (Colston & Gibbs, 2002; Fine & De Soucey, 2005; Lorenz, 1963). Researchers also suggested humor's effect in sustaining hierarchical social relationships—when only certain people may initiate humor-involved conversation and play jokes on certain others (Fine & De Soucey, 2005), or in erasing the social gap—when there is no humor monopoly associated with the high-status members in a group (Duncan, 1985). Finally, some research argued that humor could cause conflicts and lead to relationships redefining (Colston & Gibbs, 2002; Martineau, 1972; Meyer, 2000), in case people “have strong disagreements with a subject of humor (p. 318, Meyer, 2000).”¹¹

There were also studies looking at humor's various functions in organizing ongoing conversation. They found humor practices to be an effective tool in multiple aspects, including attracting attention (Foot & McCreddie, 2005; Long & Graesser 1988), increasing the frequency of turn-taking (La Gaipa, 1977), conveying verbally aggressive messages while maintaining the potential of role distancing (Fine & Soucey, 2005; Graham, Papa, & Brooks, 1992; Infante, Riddle, Horvath, & Tumlin, 1992), and legitimizing or delegitimizing proposals of conversational thread (Bonaiuto, Castellana, & Pierro, 2003).

¹¹ In my opinion, it is arguable whether such divisive effects could be counted as the function of humor, as in such case, at least one of the communicative parties doesn't find it “humorous” but actually takes something in it as offensive.

7.3 Communicative functions of humor in classroom

Traditionally, classroom humor was considered distracting since the main teaching goal was to focus student on specific subject matter (Morreall, 1983), and teachers were trained not to “smile before Christmas” as to maintain control of their classrooms (Wallinger, 1997). Many scholars, however, suggested that humor can be productive teaching tools for multiple purposes. A major line of research in this area focused on humor implementation in college level courses (Berk, 2000; Bryant, Comisky, Crane, & Zillmann, 1980; Gorham & Christophel, 1990; Wanzer & Frymier, 1999). In alignment with the tension relief theory (Christie, 1994; Freud, 1928, 1938; Rothbart, 1977), they argued that teacher’s use of humor can help reducing anxiety associated with difficult subject, improving confidence and positive perception of learning. Besides, there were also work revealing other roles of humor practices in classroom, such as narrowing the status gap between teachers and students (Bowers & Flinders, 1990; Monroe & Obidah, 2004), binding learning community (Kryston, Smith, Collins, & Hamilton, 1986), and stimulating students’ creative and critical thinking (Korobkin, 1988).

While there is a rapidly-growing, multi-disciplinary literature on humor, research on classroom humor was largely limited to its effects when employed by teacher. There were few close investigations into the roles of humor practices emerging from classroom interactions. In this study, I conduct close analysis on some laughter-rich cases from Sarah’s classroom, exploring how various types of humors were generated through interactions in Sarah’s classroom and the various roles they played in organizing classroom learning. The episodes employed in this chapter were convenience sample selected to represent the different roles I perceive of humor interactions in this class.

Through this rough, primary exploration, I made no attempt to systematically characterize the functions or development of classroom humor interactions.

Since the interpretation of humor went deeper into the muddy water, I found it useful to pin down possible interpretations by attending to fine discourse details, such as the exact locations of class laughter, the tones applied, and the words stressed. The episodes in this chapter were therefore transcribed more carefully to retain such details. The transcript work followed the standards and employed the legends set by Engle and Conant (2002).¹²

7.4 Humor that accompanied classroom sharing interactions

Humor occurred in Sarah's class ever since their introduction activity. For example, their first class-wide laughter was triggered by Tim's introduction:

Sarah: Tim, THE Tim.

Tim: I am THE Tim. And, I'm gonna drop out and get sponsored for snowboarding! [*Several students giggling*]

Sarah: Cool! [*Class laughter*] Ok.

¹²Legend (Engle & Conant, 2002)

. = falling/end intonation contour

? = rising/questioning intonation contour

! = an exclamation

, = anything else, usually a slightly falling/continuing intonation contour

[inaudible] = word cannot be identified

[description] = transcriber's description of nonspeech moves or other behaviors

(word(s)) = transcriber uncertain that the word(s) has been correctly identified

((word(s))) = transcriber especially uncertain about correct word identification

(word1/word2) = either word1 or word2 could have been spoken

wor- = word or intonation unit cut off midstream

exte:::nd = vowel lengthened, with more colons indicating more lengthening

{ =where remark overlapping starts

} =where remark overlapping ends

There are several possible explanations that may count for what led to the laughter here. First, Tim was addressed by the teacher as “THE Tim,” and then introduced himself in the same way. The addition and emphasis of definite article labeled Tim as someone special, which might indicated what Sarah (and probably some other students) heard about him prior to this class. (Tim turned out to be a character of this class: he was one of the most talkative students, who often played jokes on the teacher and attracted attention to himself.) Second, the way Tim shared about himself was more personality-bearing than the several students going before him, who plainly said that “I played guitar,” “I have a sister and a brother,” etc. Instead of stating “I love snowboarding,” Tim claimed that he was “gonna drop out (of school)” and “get sponsored for snowboarding.” The “drop out” part, in particular, while aligning with role model of sport elites, was more likely to be taken as a joke in the context of this honored biology class. Third, by calling it “cool,” Sarah took no issue with Tim’s openly-stated preference of not attending school but identified with the students, which might violate teacher’s alignment with academic values and contribute to the humorous effect.

Another case was when Jeff shared that he could flip his pen. Jeff’s sharing was not found funny in itself. While caused class laughter was the way Sarah interacted with him afterwards: she immediately picked up a pen, tried, failed, asked Jeff for detail instructions on what to spin with, but failed again. The amusing incongruity in this case resided in the uncommon roles the teacher and the student took on. Sarah the teacher acted as the learner rather than the authority, while Jeff the student was in the authority place, demonstrating a skill and explaining the way to do it. The effect was enhanced as

the teacher looked clumsy and failed the little trick again and again, which contrast with the “authority” image often associated with teacher.

A common ground underlying these laughter-generating scenarios is the ongoing reconfiguration of classroom relationship. One would not find Tim’s statement humorous had it not been made in a classroom setting; likewise, Sarah’s learning pen-flipping from Jeff would not appear to be so abrupt had she not being the teacher or this not being during the class time. Though there was no direct proof from the data, I think it was very likely that the class members all have experienced, and, besides Sarah’s class, were probably still experiencing the more serious type of classroom, in which interactions were organized in a way that maintained academic orientations and teacher’s authority status. Such experience, I would argue, founded shared configurations about what was allowed to be brought up in classroom and how teacher and students should behave in such classroom sharing settings. The personality-bearing, peer-like sharing interactions violated such configurations, which would also contribute to laughter, and in turn, legitimized and encouraged sharing of similar kind in the future.

Laughter generating sharing interactions gradually became common for this class, not just in activities devoted to relationship building, but also continued into their science learning activities. In this way, more personal experiences were allowed to be brought up and attended to in relation with the scientific content they were talking about. For instance, at the beginning of the DNA unit, when they talked about the distribution of traits, Sarah showed students her rare trait of having both second and third toes longer than the big toe. The rareness of that trait, and uncommon scene that the teacher stood in the middle of the class with a bare foot, revealing such trait to her students, together

caused much laughter. With the vivid sharing experience it bore, the long second toe also became a major example of dominant trait they would refer to.

Students also brought up their personal experience in similar ways. Consider the following snippet as an example:

1. Sarah: Ok, when you guys hear scavenge, what does it make you think of?
2. Charles: A scavenger's {hunt. }
3. Deanna: {Like a } Scavenger's {hunt. }
4. Sarah: {THANK} YOU! Do you say Scavenger's hunt?
5. Charles: Yeah, I did.
6. Sarah: Oh! THANK YOU! Because I've been saying that all day and everyone is like, no, it doesn't make me think scavenger hunter. I was like, are you SERIOUS?! [*Class spoke all at once*]
7. Charles: My mom has this thing what she calls when she doesn't cook at night, she will call it, like, scavenger's night, and like- [*Saying while laughing*] [*Class laughter*] what kind of food do you eat.
8. Nicole: [*To Deanna*] My mom did that too.

This exchange took place when Sarah first introduced different types of consumers to the students. It was a norm for the class to pull out their previous knowledge on a term or words relating to it before talking about meaning in biology contexts, which, as Sarah suggested in interview, was “to make sure they have something to connect to.” In this case, the first link students made with “scavenger” was the game of Scavenger's hunt, which many might have played as kids. Charles, however, did not

stop there, but continued to share a piece of personal experience from which he understood how this word could be used: when his mom did not cook at night, it was called “scavenger’s night,” indicating the kind of food they eat (leftover). The class, including Sarah and Charles himself, burst into laughter. This sharing offered a good connecting point for understanding the idea of scavenger: scavenger as a consumer category and scavenger as a metaphor in the example Charles gave shared the trait of eating leftovers.

In this case, what made Charles’ remark humorous was not only the unexpected analogy between scavenger behaviors and an occasional dinner of leftover, but also the unexpected reference of self-humiliating personal experience in a science classroom. The class laughter did not embarrass him, but reflected and further contributed to the comfortable-to-share relationship continuously constructed in this classroom. As class laughter got allowed, pursued and even taken as the signal of acknowledgement in this classroom, the threshold of sharing was lowered and the class were afforded to put more of their personal experience out.

In summary, humor that accompanied sharing interactions influenced Sarah’s class from at least two aspects. For one thing, it greased the interactions, affording the type of class participation that would not be traditionally afforded, with teacher taken as the authority figure and classroom conversation aligned with formality and seriousness. The peer-like teacher-student relationship constructed through such informal, playful conversations, as I have argued through previous analysis, was a supportive resource for the class to comfortably share and challenge ideas, especially for the students to treat

teacher's ideas as ones from their peers, focusing on the substances rather than looking for cues of correct answers.

I would also argue that this type of humor played an important role in broadening up topics for science classroom, and shortening the distance between science and everyday life. For a class to keep their conversation formal and serious, much information and prior knowledge might be blocked out, simply because their content can be easily connected with laughable or sensitive issues—which would be considered inappropriate and might even create embarrassments. Sarah's class, however, solved the problem by constructing a humor-enriched learning environment, in which the common rules of appropriateness have been repeatedly violated; and laughter following student comments became a reward rather than served as the signal of being ridiculed. On that basis, sensitive, seemingly irrelevant, or even self-degrading (like Sarah's toe showing and Charles' sharing about scavenger night) experience could be brought into scientific discussion with less restraints—as the meaning of laughter changed, the risk of being laughed at is reduced.

Hawkins (1974) has emphasized the importance for educator to understand student's "working relationship with the world around him," as how much you can see of a person is determined by how much of him is allowed to be involved in the learning environments. Here humor facilitated the involvement of the part of teacher and students that would commonly not be involved. The class, in such case, could engage in interactions more as full persons, and were better afforded to connect science with everyday life in their learning interactions.

7.5 Arguing scientifically with humor

The above section focused on how humor practices contribute to the growth of classroom relationships. Many humor interactions in Sarah's class were less related to the incongruity caused by presenting topics or part of selves that did not usually have the chance of being presented on class, but more rooted in particular ideas or argumentative moves. Cases of such were most salient in the contexts of scientific argumentations, when the major focus of interaction was on defending and challenging substances of ideas. Here, I drew on some examples from the "Is the sun alive?" debate to illustrate the kind of situations I talked about. (For more background information about this debate, see Chapter 4 page 45.)

One argument from the "No" side started with the original statement that the sun "doesn't have any of the normal functions of a living system." Within ten turns after this statement, Class laughter occurred three times:

1. Max: It doesn't have any of the normal functions of like, of a living organism.
2. Charles: Define normal! [*Pause*] [*Class laughter*]
3. Sarah: That's fine, go ahead!
4. Max: Sleeping, breathing, reproducing, cells, {and-}
5. Charles: {First} of all, not every living ORGANISM sleeps. Uh, for example, fish?
6. Tristan: Cells. [*Class laughter*]
7. Acer: Something is alive if it has-,if it-, {it-
8. Charles: {Plants.

9. Acer: If it can function and can make the choice to function. If it can like ha-, { i-, i-, if it functions then it is alive. }

10. Charles:

{Ok. Some animals are (in plant) forms) or {[*Inaudible*]

11. Tristan: {Can plants have decisions? No! [*Class laughter*]

The first laughter came after Charles' request of "define normal," from the "yes" side and the "maybe" people first then the "no" side as well. There was a short pause (for about two seconds) between this remark and the laughter, in which the class stayed completely silent. I have two guesses on what was humorous in this situation: first, in their argumentation prior to this point, all the arguments were conventional, either presenting reasoning and evidence supporting one side or challenging the claims from the other side with counterevidence or reasoning. Charles' move here did not follow such pattern but probed for a clarification. This unexpected change in argumentative strategy might be what caused the delay in response as well as a source of incongruity. Second, since it was usually the teacher who would ask for clarification question through an imperative sentence, the way Charles used it here indicated a higher authoritative power over their debate opponent. This "pretended" authority might also contribute to the laughter from the "yes" side. Through the comment "that's OK, go ahead" Sarah legalized Charles' request. Later in the debate, such clarification questions have been widely used as a way to argue, but no more laughter was generated by them.

I would therefore argue that the laughter facilitated the establishment of a new

interaction pattern. The alignment with humor covered the aggressiveness of such an imperative move, relieving the offensive feeling it could have possibly caused in peers and appropriating it as an acceptable argumentative strategy. The establishment of such pattern allowed the students to closely scaffold each other's arguments for better quality.

The second and the third class laughter occurrences were similar in terms of position: they both followed the presentations of "yes" side's counterevidence. The second laughter occurred as Charles and Tristan brought up "fish" and "cells" respectively as evidence supporting their counter argument that "not every organism sleeps;" and the third laughter happened when Tristan employed a rhetorical question to present plants as an instance that is alive but can't make decisions, which counter argued Acer's point that living organisms should be able to "make choices to function."

Humor in both cases seemed to rise from how the original the "no" side argument was made ridiculous by the presence of the "yes" side's counterevidence. Further, the construction of humor and the construction of exception-based counterargument shared the same trait of pushing a statement to its full generality and then picking on where it leaked to show the incongruity. (Colin, private conversation) This typical way of arguing against definitional statements is at the same time a significant way of creating humor. Since humor and powerful arguments were both valued in this classroom, such argumentative moves were particularly favored, as they accomplished two goals at the same time. The popularity of these types of arguments could be seen in this debate as well as many of the class' later argumentation episodes.

Near the end of this debate, when Sarah asked both sides to present their "Jerry Springer final thoughts," the following exchanges happened as Kathy presented the "final

thought” for the “no” side, which illustrated another type of humor function relating to argumentation:

1. Kathy: So, the reason why the sun like technically DIES [*Making a “quote and quote” gesture*] is because it has the energy up until that point. That's like, if you have a cell phone it's ALIVE [*Making a “quote and quote” gesture*] because it had that much battery. But when you LOSE that energy it's DEAD. [*Making a “quote and quote” gesture*]
2. Tim: { [*Standing up and making the “yes!” gesture*] [*class laughter*]
3. Kathy: {So that doesn't mean it's like a human being or an animal or plant. It's ALIVE [*Making a “quote and quote” gesture*] because of the energy {it has.
4. Tristan: {That may be true?
5. Jeff: Your cell phone is not alive.
6. Kathy: Exactly.
7. Sarah: {That's what she's saying!}
8. Deanna: {That's what she's saying.}
9. Taylor: She's trying to agree with us, {be quiet! }
10. Max: {Dead is a} figure of speech, dead doesn't {always have to mean [*Inaudible*]
11. Charles: {How's your cell phone not alive then?
12. Christine: Wait! Well you-
13. Charles: It's fully functional [*Saying while laughing*]. It tells me

my missed calls [*Saying while laughing*]. [*Class laughter*]

14. Tim: Haha, that's funny!

Kathy's analogical argument through cell phone (that the sun "dies" from using its energy up similar to how cell phone dies from running out of battery.) was found quite powerful by many. Not only did she gain great support within the "no" group—Tim's overdone "yes!" gesture even caused laughter; and both Deanna (and Sarah) and Taylor spoke for her when Jeff seemed to not getting her idea right—but even Tristan, who was at that time sitting with the "yes" table showed a tendency of buying it, as he said "that may be true" on line 4.

When I interviewed the students about this debate at the end of the semester, Charles still remembered that "somewhere in there someone gave a cell phone idea, which I thought was brilliant." This reflection indicated how he perceived Kathy's argument. But at that moment, as the main speaker of the "yes" group, he chose to continue defense rather than surrender. Using a similar "figure of speech," he presented his argument in laughter: that even the cell phone should be considered alive since it is "fully functional," which was a criterion of living suggested earlier by the "no" group. The "functional" here was then concreted into "tells me my missed call."

The class burst into great laughter in response to this argument. Stating that a cell phone was alive totally went beyond scientific argumentation but into a violation of common knowledge; what made it even funnier was how Charles pushed the meaning of "functional" out of the biological context in order to return to the ridiculous "cell phone being alive" statement at the "no" group's fault. This irrational but smart "counterargument" was presented as a joke and treated as a joke. The laughter generated

this way lubricated this conversation, relieving the tension between the two parties involved and shifting attention away from which group actually “won” the debate, but onto the critical reasoning about each other’s ideas.

In a word, the cases above demonstrated some roles humor interactions could play in affording the class’ scientific argumentation practices:

- It can facilitate the establishment of a new argumentative strategy, especially the type of interactive strategy that would sound aggressive if taken seriously;
- Since the presence of incongruity characterizes both humor and counterargument through exception, the goal of arguing and the goal of making people laugh can merge; and it is reasonable to expect that the classroom value attached to humor can lead to enhancing use of exceptional counterevidence in argumentation.
- Humor can help release the competitive tension that can be caused by ongoing scientific argumentation, avoiding embarrassment of being the “loser,” and refocusing participants’ attention on the reasoning behind ideas.

7.6 Incongruity resolution and conversational flow

Incongruity was the most widely accepted necessary condition for humor (McGhee, 1979). However, there has long been the debate on what type of incongruity would lead to humor. Suls (1972) suggested that an incongruity has to be resolved in order to be perceived as humorous. In contrast, Rothbart (1976) argued that incongruity itself can

initiate humor if perceived through a playful lens. Some other scholars suggested that the two sides should be brought together based on the agreement that resolvable incongruity and non-sense incongruity represented two different types of humor (Ruch & Hehl, 1998).

What the literature referred to as “resolution” to incongruity was “finding a cognitive rule reconciling the incongruous elements (p. 966, Pien & Rothbart, 1976).” This has been exemplified by the function of a punch line in a joke: it gave an unexpected but reasonable explanation to the incongruous situation presented above (Pien & Rothbart, 1976). When humor emerges in group interactions, there is the similar concern of whether incongruity gets resolved or not. Resolution in this framework was less a process for an individual to recognize a cognitive reconciling rule, but more of a group decision on whether and how to pursue a reconciliation of the presented incongruity. Employing this modified construct of resolution, I analyzed two selected cases of classroom humor interactions, one with the pursuit of resolution and one without, looking specifically at how such differences influenced the conversational flow that followed it.

The following example came from the class discussion on “where do human beings get energy from?” As Acer suggested that we get energy from eating “plants and animals that eat other plants and animals,” Jeff challenged the point by asking whether energy can be gained from “eat[ing] a plant or animal that had not eaten another plant or animal ever.” In response, Acer asked for examples of such species, and the class started to shout out answers:

1. Tim: {A new born-}
2. Volya: {Plankton! } [*Class starts giggling*]

3. Tim: A new born cam {el! }
4. Volya: {Plan} kton! [*Class laughter grows louder*]
5. Mina: [*To Tim*] No one (can win {that }).
6. Volya: {Plank {ton! }
7. Nick: {Is that} right? Is that {right? {Is that} right?
8. Sarah: {Who eats CA{MEL?}}
9. Sarah: I wouldn't have that for {lunch.} [*Class laughter combining with some "Wow" sound.*]
10. Tristan: {Asian} people.
11. Sarah: REAlly? [*Class laughter grows louder.*] Nah. Wait! Ok, what is- wait a minute. Acer, what was the challenge you presented? Tell me a what?
12. Acer: Oh, um, like, show me a species that has not eaten other species, or does not exist off other species?
13. Sarah: Show me a species that does not live off other species. Oh! That's a challenge. Tristan?
14. Tristan: Worms.
15. Sarah: [*Say in laughter*][*Inaudible*]
16. Nick: Yeah, it does. [*Dennis raises his hand*] That's true!
17. Sarah: OK. Dennis?
18. Dennis: A sea cucumber.
19. S1: What?! [*Class laughter*]

20. Sarah: A sea cucumber?! OK.
21. Max: Fungus
22. Tristan: [*Playing with his shirt*] Worms are animals.
23. Sarah: Worms.
24. S2: Oh! How about cactus? [*Tim laughs*]
25. Nick: Plankton! [*Side conversations*]
26. Sarah: Wait a-, what is plankton? [*Many speak at once.*]
27. Jeff: It is like the swamp {bug. }
28. Nicole: {swamp} bug. }
29. Sarah: {I can't- I can't} hear.
30. Nick: it's that little things. It's like algae right?
31. Dennis: They are mean. [*Some students giggling.*]
32. Sarah: Ok. They are MEAN? Wow! [*Class laughter*] [*To Deanna's table*]

What do we say up here?

Laughter in this case started first when Volya shouted out “Plankton!” and grew louder when Tim threw out the idea of “a new born camel.” Though the whole class laughed, there might be various reasons why they laughed, as the funniness of the ideas could reside in at least two aspects: for one thing, shouted out with no explanation provided, they sounded as randomly picked funky answers that one could not reason about; for another, if thought about deeply, they did have the potential of fitting the “have not eaten other plants or animals” requirement through unusual paths: plankton, as “the little things” drifting on the water, sounds too small to have the ability of eating any other organism; the idea of “new born camel” took the “eaten” part literally on purpose—

though the species of camel indeed needed to get energy from other species, a new born camel has not physically eaten anything yet. Sarah did not respond to the idea of plankton, but played with the idea of camel by making the comment “who eats camel? I won’t have that for lunch!” she did not seem to understand the possible reasoning behind these funny but reasonable exceptions, as in her comment camel was in the food role rather than the eater role. She also seemed to be aware of her lack of understanding, as she quickly turned back to Acer, checking for his original question.

Sarah’s joke, however, brought significant impact to the flow of this conversation. By introducing the out-of-place situation of “have that (camel) for lunch,” it led to class laughter by emphasizing and building on the absurdity of the “new born camel” idea, without any effort pursuing possible reconciliation. This teacher’s move, with its success on raising laughter, seemed to justify the situation as one for talking nonsense.

Flowing from there, the class never provided any explanation on why their funny-sounding examples might count as exceptional counterevidence. Even though the teacher tried to clarify the original challenge by letting Acer repeat it, students directly ran for the goal of throwing out weird, laughable answers. When Sarah probed one of the popular answers by asking “what is plankton,” Dennis made the completely irrelevant comment of “they are mean,” which signaled Sarah that the conversation has digressed too far from the topic. While the thread of conversation was started by Jeff’s original challenge and Acer’s request for specific counterevidence, it never went back to follow their line of reasoning, but slid into one dominated by nonsense jokes.

The following episode set an example in slight contrast:

This took place when the class was having a discussion on “where in our body

can we find our DNA.” While Sarah tried to address Azar’s question on the mechanism of tumor’s unregulated growth, Tristan brought up the idea that fingernails were also growing cells without DNA:

1. Sarah: So, if a cancer cell gets into something on you, and they don’t separate, they just keep replicating, replicating, the tumor starts to grow, the mass of cell doesn’t stop growing, just growing, growing, growing.
2. Tristan: Like fingernails!
3. Sarah: But our fingernails are actually like, proteins.
4. Tristan: Well, it keeps growing when you are dead. [*Several students giggling*]
5. Sarah: [*Pause*] Is that true?
6. Students: Yeah! [*Class laughter*]
7. Tristan: Your fingernails {and your hair would grow longer when you are dead.}
8. Dennis: {Can you search that right now?}
9. Sarah: Grow when you were dead?!
10. Tristan: [*Nodding*] {Yeah.
11. Dennis: {Yeah, search it on Yahoo or something!
12. Azar: Yeah, like. I heard that your hair will grow a little bit longer [*Gesturing “a little bit longer”*] when you are dead, and then like parts of your body would grow Little little bit longer when you are dead, and then it is like {it all stops [*Making the “stop” gesture*]}.}

13. Nick: {Then why isn't it in bones, like, why isn't it grow in bones? You know what I mean?
14. Sarah: Yeah. I don't get this id-, why would your skin, why would your hair and fingernails keep growing after you die?
15. Nick: It would have like a very COGNITIVE-like minute, like [inaudible][laughing], you know what I mean right?
16. Tristan: 'cause that's when you made it.
17. Sarah: OK, what, Charles?
18. Charles: your hair is also not alive. Also [Inaudible].
19. Sarah: I can't, I cannot hear Charles talking.
20. Charles: [*pointing at his own hair*] Not necessary living cells. So hair cells like, continue to die, like [*grabbing his own hair*], basically dead.
21. Tristan: Doesn't it sound like that it resists to die? [*Tim starts singing*]
22. Charles: It is like, your hair is all dead cells, um, the only part that's alive is the root part. It died gradually and that made the growth.

In this conversation, the idea that fingernails and hair would “keep growing when you were dead” first raised laughter. The funniness of this idea could reside in its intuition-contradictory feature—that some part of body would still grow while the body was dead. The humorous effect was enhanced since Sarah appeared to have never heard of it and was at a loss for words.

Sarah clearly found this idea weird, as she repeatedly asked for confirmation from the students in suspicious tone: “Is that true?” “Grow when you are dead?!” However, she did not joke about the absurdity of idea but treated it as something that one should be

able to reason through. By posing the question “Why would your hair and fingernails keep growing after you die?” she invited the class to generate causal explanations for such phenomenon.

The conversational flow that resulted was therefore quite different from that of the previous example. Students were trying to come up with a reasonable explanation instead of competing to amuse the class. Among the three ideas Nick, Tristan, and Charles presented, Charles’ idea was best articulated. Based upon the fact that only the root part of a hair is alive, he suggested that the way cells die gradually rather than all in a sudden may contribute to the hair (or fingernail) growth after death. Such explanation helped resolve the incongruity between the death of a body and the continuous growth of specific parts.

In summary, when following a comment combining amusing incongruity with a reasonable idea, it then becomes critical whether it gets taken up just as a funny remark or also an idea worthy of being “talked about.” The immediate response (here in both cases coming from the teacher) can greatly influence the direction of the conversation that follows. Humor can better afford scientific inquiry practices if the class does not just focus on constructing and getting amused by the nonsense type of humor, but also pursue explanations that can reconcile the presented incongruity.

7.7 Implications

The cases analyzed above illustrated the various ways humor can afford or constrain scientific inquiry learning, especially scientific argumentation. Such exploration suggested humor’s great potential as a type of resource (or different types of resources)

for classroom science learning. In one sense, it bears similarity to the resources mentioned in the previous chapters. Since classroom humor and the classroom allowance of humor are both constructed through classroom interactions, and the way they afford or constrain the class' inquiry learning was also through influencing the patterns of ongoing interactions.

In another sense, humor can also be seen as cognitive resources that individuals hold, as students often engage in humor practices outside the classroom, and they come into the classroom knowing how to construct and appreciate humor. When they get the signals on what types of humor are allowed in what types of classroom situations, they can draw on such resources to accomplish various communicative purposes. This is similar to Lee's (1995) argument on how signifying can be a resource for African American students' learning of literary interpretation. For those students, signifying was something they practiced in everyday social interactions, which, once allowed into classroom and made valuable, would enable the students to engage in critical thinking about literature.

As a primary exploration, this chapter gained no insight into how humor practices evolved in an activity system. Still, with the limited data collected from this study, even the understandings on the possible types of humor and humor's possible roles can be very limited. Also, the roles of humor are revealed through investigations of individual cases, with little power of generalization. Further study along this line is therefore needed on multiple aspects: First, there should be more thorough investigations into the possible ways humor interactions can influence learning; second, we need to better understand how humor interactions change over time through interactions; third, when data and

related research accumulates in this area, we may expect deeper insights into how humor interactions can be integrated in organization of inquiry-affording learning environments.

Chapter 8: Reconsidering the lens: A move for classroom culture

In previous chapters, I have demonstrated how classroom inquiry practices, especially the practices of scientific argumentation, evolved through the interactive history of Sarah's classroom. In this chapter, I reflected on this preceding analytical work and explored the embedded implications as I attended to the question of "in what ways does this matter?"

8.1 An overall message

My analysis attends to classroom data often not considered as relevant to students' science learning. My first analytic chapter, for example, showed that the way Sarah's class interacted through their introduction and "family-bonding" activities set the tone for interactions throughout the whole semester; and as such, peer-like, "comfortable-to-share" relationships continued into disciplinary activities. These relationships afforded the students to focus their arguments on the substance of the teacher's ideas, rather than accepting whatever she said because of her authority status. Similarly, while exploring constraints on argumentation practices in the second analytic chapter, I found the class' discourse constructs of "fun" and "serious" as something closely associated with different learning goals and played into the organization of participation patterns. Finally, sensing the prevalence of humor practices in this classroom, I devoted a chapter to exploring various humor-involved classroom interactions. While the data collected does not allow systematic investigation into the development and function of humor practices, I showed

through a series of discrete examples the significant roles humor played in classroom science learning, such as lowering the threshold for classroom sharing and reinforcing “going to extremes” as an argumentation strategy.

Together, my analysis suggests that classroom scientific inquiry practices do not just live in their immediate contexts; their productiveness or limitations in width, length and depth cannot be solely counted for by the disciplinary interactions they occur through. A classroom is a continuous, organic whole developing through prior interactions, including disciplinary interactions as well as interactions that have no direct connection with disciplinary contents.

Too often, in our efforts to understand and organize science teaching and learning, we focus almost exclusively on disciplinary activities, extracted from the broader, historical contexts in which they sit. Such moves make sense, as learning in a discipline is most easily marked by the involvement of disciplinary content. There are also many practical reasons for doing so: first, it allows clear boundaries on phenomena and therefore precise identifications of analytical subjects from a complex classroom system; second, it reduces variables and breaks down the complexity, so that classroom activities can be designed and implemented in manageable pieces. Finally, such simplifications make it possible to characterize different types of learning behaviors (such as scientific argumentation, mechanistic reasoning, causal explanation and so on) and develop evaluation criteria accordingly. For example, research on scientific argumentation helped us see how students’ argumentation behaviors could be very different from formal argumentations with regards to their intrinsic logic structures (Dawson & Venville, 2009; Jiménez-Aleixandre, et al., 2000; Kuhn, 1991, 1993), create structure-based criteria for

measuring argumentation quality (Dawson & Venville, 2009; Erduran, Simon, & Osborn, 2004), and showed the possibility of guiding students argumentation practices towards improved structure through local interventions (Erduran, Simon, & Osborn, 2004; Kuhn & Udell, 2003; Zohar and Nemet, 2002). While acknowledging the valuable insights we gain from such studies, my work shows that we should also proceed with caution. When boundaries are set too clear and tight, we may not be studying what it is we want to be studying, and what we try to improve or take as improved may not be as meaningful as we think they are to students' needs of sense making. What has been cut off from the complexity, such as teacher-student relationships and humor practices, may be of great importance for our understanding of how affordances of productive learning gets constructed in classroom. If we work on building learning environments, but have little understanding and consideration of the influences from all these factors on disciplinary learning in a classroom, whatever we build risks little staying power.

This situation is analogous to how molecular biologists used to think that once the human genome was sequenced we would understand everything about our hereditary information. However, as the research moved ahead and accomplished the goal, the field started to see how much was left unexplained by focusing on genes alone, and how what we used to consider as meaningless could actually be critical: for example, nuclear RNA and what was labeled as “junk” DNA (noncoding DNA, up to 95% of the whole genome) both play key roles in regulating gene expression, which introduce much complexity into the picture and need to be better understood.

Through doing this work and considering how science learning unfolds in a classroom, I realized the need of a more holistic and dynamic perspective on learning

environments, which can bear the ongoing, multi-layered processes that an activity system develops through. Driven by this goal, the following section starts with a revisit of my theoretical framework, suggesting its connection with what some scholars take as “culture.” After expounding upon my view of culture, I lay out what “classroom culture” offers as a theoretical lens for understanding classroom teaching and learning.

8.2 A view of culture

The analytic work in the preceding chapters was guided by the framework of activity theory (Engeström, 1987, 1999). The expanded mediational triangle (Engeström, 1987) drew my attention to aspects of activity that mediated individual activities. Following Engeström’s (1999) argument that an activity system evolves and expands through internalization and externalization, I explored the ways a classroom activity system changes through interactions over time.

While activity theory provides the vision that the participants in an activity system actively contribute to the creation of what mediates their interactions, concrete research drawing on activity theory focuses primarily on the internalization part, that is, how existing artifacts and sociocultural contexts shape ongoing interactions, but rarely touch the externalization part, that is, the transformation of such artifacts and contexts (Daniels, 2004; Engeström, 1999). Even in work that did include this later aspect, analyses usually focused on comparing the output differences in mediational effects, which treated internalization and externalization as two steps rather than locally integrated processes (Engeström, 2000).

Part of the reason, as Daniel (2004) pointed out, is the lack of a language that describes the processes of change, especially when such processes are not happening in clear stages. In Engeström's (2000) work on the redesign of workplace, the identification of internal contradictions within the activity system and the corresponding revision of rules took place in specified activities separated from the hospital participants' daily tasks. The type of analysis he conducted fit well with the level of organization with which he worked, but would not be directly applicable to organizations of much lower level and with smaller populations of participants (such as a classroom). Transformative processes on such level are often inexplicit and indirect, which rarely, if ever, occur in planned, separate space-time. When do innovations actually happen? What counts as the evidence of that? How stable are the changes? Such questions push the bounds of activity theory. How to address them remains somewhat unclear. While some indications can be pulled out from the theoretical emphasis on the mediational roles of history-bearing, interdependent elements, we can also turn elsewhere for help.

As I illustrated through close discourse analysis, in the activity system(s) of Sarah's classroom, mediational resources such as learning goals, norms, teacher-student relationships or epistemic resources emerged from ongoing interactions; they gained intersubjectivity and afforded discourse and participation patterns living in future activities. Specific moments of classroom interactions were mediated by previously constructed resources, and at the same time, modify the existing resources as well as giving birth to new resources.

Such local, simultaneously bidirectional evolving processes resembles what some scholars (Cole, 1996; McDermott, 1993; Varenne & McDermott, 1993) describe as

“culture.” Culture in this sense is not a fixed set of characteristics that can be attributed to a specific group of people, but is continuously shaping and getting shaped by its participants through ongoing interactions. This type of cultural theories share the Vygotskian cultural-historical tradition in which activity theory is rooted, emphasizing the intrinsic transformative momentum of a social group, and considering the interactions (internalization and externalization) among participants as sites where transformations take place.

8.2.1 Culture as continuously mediating and constructed

Cole (1996) suggests that culture is *mediational*, which means that it is both external “material manifestation of human action (p. 124)” and internal “sources of intersubjectivity and coordinated action (p. 124).” This argument knocks down the clear division between culture and mind that has been long debated¹³, emphasizing the bidirectional role of culture and mind. Culture in this sense cannot be taken as static traits of people or static factors that influence human mentality or behaviors, but as dynamic processes that reserve the potential to be constructed and changed. Cole’s idea about culture aligns with Vygotsky’s (1978) description of learning as the interactive processes happening between social and individual planes, as well as with Engeström’s (1999)

¹³ Traditionally, there is a major debate between anthropologists and psychologists on the relationship between culture and mind. Briefly, many anthropologists (e.g.: Morgan, 1877, as referred to by Peblissier, 1991; Lévy-Bruhl, 1923/1966; Malinowski, 1939; Lévi-Strauss, 1983/1958) considered culture as attributes identified with certain group, and took it as the dominant power that explains the group’s social behaviors and associated social phenomena. Psychologists who concerned about culture (e.g.: Dilthey, 1923/1988; Whiting, 1968; Berry, Poortinga, Segall, Dasen, 2002) took it as external factors that need to be taken into account in the process of generating valid mechanisms of mental processes. Despite their different perceptions of the relationship, both camps treated culture and mind as separate entities, and considered culture as relatively static in local time and space. The present discussion on culture did not try to contribute this philosophical debate, but aimed to clarify the position on culture this work aligned with.

emphasis on social interactions (internalization and externalization) as the primary sites for the evolution of an activity system to take place.

Such dynamic view of culture does not reside solely in the cultural-historical psychology line of thought. French anthropologist Boas (1912, as quoted by Pelissier, 1991) criticized the tendency of corresponding personal mental characteristics with collective beliefs (i.e., Levy-Bruhl), redefining the task of anthropology as investigating how collective thoughts, rather than the individual minds, were formed in specific social environments and with specific historical accounts. With a primary research focus on history, he promoted the research focus on how such collective thoughts, or say, culture, change over time. Through his investigations of cultural changes happening in a large time and structural scale, he attributed the momentum for such changes to “the history of the people, the influence of the regions through which it has passed on its migrations, and the people with whom it came into contact (p. 64. Boas, 1887/1982).” The larger-scale dynamics of culture as he wrote about it, however, stayed at the macro level and posed less of a challenge to the idea that, within a local area and a local time frame, cultural traits would stay relatively static and could be attributed to certain group of people.

8.2.2 Culture as locally constructed

A more radical challenge to the static view of culture was made by Varenne and McDermott (1993) in their book *Successful Failure*, in which they recorded how learning disability, as an American school culture, was shaped by all participants in school through interactions, and how such cultural product shaped its participants’ identities and actions as well as their group organizations at the same time. Through a fine grain-size comparative analysis of interactive moments in school and out of school, they vividly

demonstrated that most difficulties “Learning Disabled” students encountered in terms of learning at school was not internally originated from their being disabled to learn, but emerged from the local interactions—the school culture was “well organized to label and disable” them. What was generally taken as an individual trait (learning disability) was therefore not belonging to individuals but to culture, in the sense similar to how Cole (1996) would define it: as both the artifacts a group produced, and what counted for the interaction patterns we see in this group.

The major contribution of this piece of work is the idea that culture is continuously built *on microscopic scale*, that the construction of culture was not just on the level of a nation, an ethnic population, a history or a general professional community, but could be realized through local interactions.

I am not the first to connect the dynamics of classroom learning with cultural construction on this grain-size. In the book *The Culture of Education* (Brunner, 1996), Bruner asked the question “what does it take to create a nurturing school culture that empowers the young to use effectively the resources and opportunities of the broader culture?” (p. xiv), and then drew on Brown’s (1994) work on Fostering a Community of Learners (FCL) as an example of how collaborative learning culture got successfully constructed by and for its participants. In that work, classrooms were described as communities of learners that developed through classroom discussions their shared goals, values, criteria for evaluating evidences, ways of argumentation as well as diverse expertise. These community features worked together and supported better collaborative learning. While Brown did not use the term “culture” or the lens of activity theory, what she promoted as FCL was in core a particular form of cultural construction processes: the

class made themselves into a unique community, in terms of how they learned, through minutely and continuously constructing all the specifics (goals, values, norms, etc.), which, I would argue, constituted their “classroom culture.”

The nature, functions and values of culture on micro level, as demonstrated by such studies, suggest the necessity of understanding learning through understanding the local processes through which culture gets constructed. Theoretically, this micro, interaction-rooted view of culture fits the analytical space of activity theory (Engeström, 1987, 1999). Methodologically, this focus on micro-level dynamics and microscopic construction processes requires ethnographic observations and close discourse analysis of continuous classroom interactions.

8.2.3 Culture as locally integrated

A major significance of activity theory for this work resides in that it points to key aspects that mediate how an activity system interact, including artifacts, rules, community norms and values as well as relationships. While my analysis of Sarah’s classroom illustrated various resources that would fall in different mediational categories, it also showed that such resources should not be understood in pieces only. As the class engaged in specific activity within specific local settings, pieces of resources were interweaved and functioning in a balanced and integrated way, bringing on specific interaction patterns. Through such play-outs, resources also develop, gaining new meaning to themselves.

For example, as I have suggested, the parasitism and predation episode could not be well understood without simultaneously considering how the class has constructed through their interactive history the learning goal of “disagreeing about stuff,” the

participation norm of “talk about” every idea brought up, the peer-like relationship, and the “exception to the rule” epistemic stance. As that argumentation episode took place on that particular topic within that particular activity, the previously constructed resources were weaved together and their meanings were renewed: not only should one “disagree about stuff,” but the “stuff” could also be something confirmed by the teacher as canonically correct; and, not only should ideas get “talked about” in open-ended scientific discussions, but such participation could also happen without the teacher’s setup, in activities where the primary object was for the teacher to check on whether the students “got it right.” Finally, the class was allowed into argumentation, but at the same time their argumentation practices were restrained in the range of topics and in length because of the “serious” review task in the background. From a researcher’s perspective, we are more likely to identify that as the result of conflicts in goals, but for the teacher and that group of students, this was typical of how their learning activities unfolded. During their interactive history, they pursued both the goal of “fun” (such as disagreeing with each other and talking about every idea on the table), and goals more on the serious side. Discrepancy, if it existed, was resolved early on, and by the time of this review activity, limited space for fun had already been set as something reasonable, expectable and to a certain degree, negotiable.

Culture as a construct reserves this holistic view towards resources and the locally-integrated flavor of their mediational function in local activities. An apt analogy on this feature of culture came from Geertz (1966):

The appropriate image, if one must have images, of cultural organization, is neither the spider web nor the pile of sand. It is rather more the octopus, whose

tentacles are in large part separately integrated, neurally quite poorly connected with one another and with what in the octopus passes for a brain, and yet who nonetheless manages to get around and to preserve himself, for a while anyway, as a viable, if somewhat ungainly entity (page 66-67).

8.2.4 Classroom culture as a lens

Following from above, I propose “classroom culture” as a theoretical framework and analytical unit for understanding how a classroom, as an activity system of teaching and learning, evolves over time. Grounded in the literature, central features of classroom culture include:

- continuously shaping and getting shaped by the participants as the classroom activities accumulate (Cole, 1996; McDermott, 1993);
- being locally constructed through the class’ interactions (Brunner, 1996; Varenne & McDermott, 1993)
- consisting of locally integrated resources (Geertz, 1966)

As I said above, activity theory falls short of emphasizing how mediational resources get constructed in a micro-level activity system. Obviously, symbolic tools (language), rules, norms and values held by community, and labor division cannot come from nowhere. They are constructed through activities and interactions. Furthermore, the coexistence and interdependence of multiple mediational resources imply no simple correlation between changes in mediational resources and the perceivable changes in interaction patterns from moment to moment. While a specific resource can be seen as a thread, what affords particular interactions of a particular activity is an instantaneously formed web, resulting from the interplay of threads.

The gist of classroom culture as proposed makes the idea of such a dynamic “web” more explicit: first, being continuously shaped, classroom culture catches the dynamics of mediational resources, underlining the active role of participants; second, classroom culture points out the bidirectional role of local interactions, especially its being the construction site for mediational resources. Third, culture bears the sense of complexity and multidimensionality, emphasizing the interplay between various mediational resources.

An analogy can be drawn to the feedback loop of our body’s metabolic process. Blood sugar level, for example, is a dynamically changing index. We can measure it at a given time, but the measurement we take is produced by the interplay of many hormones, enzymes and chemical substances over time, and is conditioned by the current bodily activity—whether being just having eaten a hamburger, running for miles or taking a nap. In addition, if traced further back, the hormones and enzymes do not always exist. They are also the historical products of the biochemical reactions occurring in the same body. Such biological molecules of specific types and amounts work together, shaping the local reactions and therefore the blood sugar level from moment to moment; at the same time, the dynamics of blood sugar level also feedback and shape the gene expression processes, changing the amounts and types of enzymes and hormones created.

Similarly, classroom participation varies from moment to moment. What we see at a specific moment reflects the interplay of many different resources conditioned by the local settings. Tracing back, we could see how the pieces of resources are also, historically, constructed through interactions among the participants of this class. The resources work together, shaping the local interactions; but at the same time, through

local interactions, pieces of resources are continuously generated and modified, which would contribute to the class' interaction patterns in the future.

To understand learning in a classroom therefore requires an understanding of a complex system. A doctor can hardly make a responsible diagnosis based on high measurements of blood sugar only, since that would not allow insight into the processes generating such measurement. Indeed, he could use treatments just addressing that symptom. But, to design effective therapy targeting at the roots, he needs to synthetically consider the specific conditions in which the measurements were taken, the patient's medical history, eating habits, amounts and activity levels of specific enzymes, as well as certain hormone levels in his body. Similarly, to study classroom affordance of productive inquiry learning, it is not enough to assess the quality of inquiry in separate activities only according to some external criteria. From the classroom culture perspective, one should look at the classroom as an organic whole, investigating how shared mediational resources get constructed through its interactive history, and how these resources balance and interplay in local settings of specific activities.

8.3 Practical implications

I chose to write about this classroom, not just for the distinct scientific inquiry practices it affords, but also for the weight of realness it bears. *Realness* here has two folds of meanings. One points to the institutional pressure this classroom has to deal with—since classrooms cannot always be experimental sites in vacuums. In order for the goal of scientific inquiry to organize classroom learning in a meaningful way, it has to coordinate with many other objects that orient classroom activities. The other points to

the goal of promoting inquiry in science education: if what we want is a useful way that affords students' sense-making process, then we, as the researchers need to better situate inquiry practices in the broader fabric of schooling.

8.3.1 Understanding and designing learning environments

In this work, I identified mediational resources that contribute to the affordance and the constraints of argumentation practices in Sarah's classroom. Since the effects of many resources (e.g., peer-like teacher-student relationship, humor practices) have much to do with who Sarah is and who the class of students are, the study is not intending to provide a list of specific resources that can or should be replicated in other science classes. The message for educational research on learning environments tends to be general: In order to understand or design learning environments that afford scientific inquiry practices, we need to look beyond just what we want to see happening, but extend our consideration to resources from broader contexts, especially those regarding classroom norms, values, teacher-student relationships and features of classroom discourse. In other words, the goal of organizing learning environments should reside in forming and transforming a classroom culture, so that it is both affording and sustainable.

8.3.2 Teacher education

For teacher educators, this study suggests the necessity of attending to continuous classroom discourse and the long-term consequence of interactions. Considering classroom interactions as the process of constructing learning related, shared mediated resources may help teachers and teacher educators reflect on teaching practices and understand teaching effectiveness from a more constructive, long-term perspective.

While activity theory has established theoretical account of how activity system can evolve locally on itself, little work has been done to illustrate such process with data. Through thick description on the construction and functioning of shared mediational resources in science classroom, this study also provided a concrete account corresponding with such theoretical processes.

8.3.3 Future research

Due to the limitations in time and data collection, much worth examining and understanding about classroom culture was left out of this investigation. For example, possible roles and the development of humor practices in science classrooms have not been systematically studied. While individual students' class identity may contribute to the class' participation patterns (the students knew who the "characters" of their class were), I have left it mostly unaddressed. Also, since my primary focus is on understanding one sample case, the study does not hold much generative power. In future works, I would like to extend this work to a greater number and more varied learning environments. One possible trajectory is through comparing discourse and participation patterns in inquiry practices across different classrooms, preferable when there are some parallel learning activities taking place (e.g., discussing the same question; debating on the same issue; implementation of the same instructional interventions) in the middle of their learning processes. Tracing back each class' interactive history while attending to their immediate situations, may provide a better opportunity to identify different sets of classroom mediational resources that count for why and how one classroom differentiates from another in terms of how they afford inquiry learning.

Appendices

Appendix A

Interview Questions for Students

These questions will be used in semi-structured group interview with students. Such interviews will be conducted when it is mutually convenient. Further probing questions may be asked in order to get students further explain their ideas on these basic questions.

1. Select specific situations in class (e.g.: a scientific argumentation) and ask “could you describe for me what was going on at that time?” “What do you mean when you say ...” (if the student expressed certain idea in class) or “What do you think your classmate meant when s/he said...”? (if the students does not express any idea in class)
2. Select a certain classroom activity and ask students “can you tell me about what you were doing in this activity?” “do you understand why you are doing this? ” “did you enjoy it? ” “what did you get out of/learn from the activity?” “Is it helpful?”
3. “Is that class different from the science classes you have taken before? If yes, how?” “What do you expect to get from this class? ” or specific: “When Ms. X said that in class today, what does she means?”
4. Ask students about their understandings of certain biological concepts.
Sample questions: “Does photosynthesis make sense to you? Could you explain it to me?”
“What’s your understanding of energy?”
5. Ask students about what they want to learn and what they need to learn.
Sample questions: “Is there anything you’re particularly curious about in genetics?”
“What about twins that’s so intriguing?”
“What do you think is important to understand about evolution? Why?”
“How are you going to prepare for the unit exam?”
“Do you have any idea how to do well in this test?”
6. Ask students if they think what they learn in the biology class is related to their real life.
Sample questions: “Have you heard of inheritance before?”
“So do you have any idea now why your cat has two different color eyes?”
“Give me a life example of adaptation.”
7. Ask students to “think aloud” biology problems related to the topic they are learning about.

Sample questions: "Can a dominant trait be rare? Why? "
"Is it possible to get an extra finger at like 12 years old?"

Appendix B

For each statement below, please circle how strongly you agree or disagree

YOUR OPINIONS ABOUT SCIENCE AND LEARNING

1. Learning biology/life sciences is easy if you can remember everything you see or hear.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

2. I learn biology/life sciences better if I figure it out for myself, rather than hearing the teacher explain it.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

3. What I learn in biology/life sciences helps me understand things in everyday life.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

4. When something in biology/life sciences class doesn't make sense, I accept it and move on, because not everything in biology is supposed to make sense.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

5. The best way to learn biology/life sciences is by taking notes in class and remembering them word for word.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

6. What we learn about in biology/life sciences class doesn't help solving most real-world problems.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

7. Using common sense is helpful while learning biology/life sciences.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

8. Most people can learn biology/life sciences well if they try hard.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

WHAT YOU EXPECT FROM THIS CLASS

9. The most important point of doing labs is to test whether what we learn in class is really true.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

10. If I answer a test question differently from how the teacher showed us, I'll still do well if my answer makes sense.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

11. The main reason for homework is so the teacher can grade how well we understood what we learned in class.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

12. To do well on a test question, it's more important to get the *idea* right than it is to get the *words* right.

Strongly disagree Kind of disagree Agree/disagree equally Kind of agree
Strongly agree

Please answer the following questions.

Would you take this biology class if it was not required? Why?

Is there anything you are especially interested in biology? Explain what about that you find interesting.

What kind of work do you expect to do in this class? And how much time do you expect to spend outside of class time on studying and class related assignments?

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