How Students Work to Understand Their Group Mates

A dissertation submitted by

Elise Deitrick

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Education

Tufts University

February 2019

Adviser: Dr. David Hammer

Abstract

This dissertation conceptualizes student interactions in groups as intentional work to communicate and understand one another. In interdisciplinary education contexts, students use distinct types of listening and shared framings to understand their peers. The work presented in this dissertation develops a framework that illuminates evidence of students' listening within their discourse and illustrates how this listening can affect a group's shared framing. The data used throughout this dissertation is part of the CodeR4Stats project, which integrates the R programming language into a high school statistics class. The selected data were analyzed using qualitative discourse analysis.

The first empirical study (Chapter 4) illustrates that students shift epistemological framings to understand their peers during interdisciplinary group work. To switch epistemological framings to match a peer, students must be listening for their peers' framing. In Chapter 5, Van de Sande and Greeno's (2012) Perspectival Framing framework is modified to help illuminate distinct types of student listening, such as attending to framing. The use of Perspectival Framing also clarifies three dimensions of framing (epistemological, conceptual, and positional) which students are navigating. In Chapter 6, this modified Perspectival Framing framework is situated as a complement to the existing theoretical frameworks addressing the creation and maintenance of shared framings. Unlike previous frameworks which treat students' roles as static and assume they are equal participants throughout the group's work, Chapter 6's case study of a group over time demonstrates dynamic shifts in positional and epistemological framings.

All of this work together addresses the question *How do students work to understand their group mates?*

This work calls for the interdisciplinary STEM Education community to view student groups as dynamic systems where students do the work of listening and negotiating their framings over time. Additionally, it illustrates that listening happens and shared framings can be established even in asymmetrically positioned students. This means that in order to understand how a group negotiates framings over time, researchers must look at both moments where students are co-constructors and moments where they are asymmetrically positioned, as students flow between the two seamlessly and are working to understand one another in both.

Acknowledgments

I would like to thank the team of advisors I have had while at Tufts – Ben Shapiro, Michelle Wilkerson, and David Hammer. Each one of you taught me different skills and my journey at Tufts would not have been as transformative without the opportunity to work with each of you on different projects and papers. Additionally, I would like to thank Kristen Wendell and Merredith Portsmore for both serving on my committee and all the support you provided before then.

I would like to acknowledge all of the faculty, staff and students at Tufts who were with me for varying parts of my journey (and of whom there are too many to name). The discussions, feedback and support over the years have been an integral part to my experience, growth, and success.

Finally, I would like to express gratitude to my family, friends, and guinea pigs for always being there during the emotional roller coaster that is grad school.

Table of Contents

List of tables

List of figures

Chapter 1: Introduction and Motivation

While some earlier research has shown the promise of group work in education (such as improved learning outcomes), other work has pointed out the inconsistency of these results. These inconsistencies are complicated further by the field's current interest in interdisciplinary projects, where students must navigate both social and disciplinary negotiations. This chapter provides an overview of past work on groups in educational environments, introduces **one of** the gap**s** in the literature, and enumerates the intellectual goals of this dissertation.

Benefits of Group Work

Research has shown that having students work in groups leads to increased test scores, higher order thinking (Johnson & Johnson, 1981), better problem-solving outcomes (Cockburn & Williams, 2000; Williams & Upchurch, 2001), and student career preparation (Lewis, Titterton, & Clancy, 2012). Due to these promised benefits, stakeholders have included group work in standards. For example, the Next Generation Science Standards (NGSS) call for K-12 students to "plan and carry out investigations in the field or laboratory, working collaboratively as well as individually" (NGSS, 2013, p. 7). In higher education, listed student outcomes for undergraduate engineering programs include "an ability to function on multidisciplinary teams" and "an ability to communicate effectively" (ABET, n.d.).

As the number of students working in groups increases, a wave of research in the 1970s and 1980s asked *'when to use group work?'* Johnson and Johnson

(1974) discussed the results of a cooperative goal structure in a classroom as compared to competitive and individualistic goal structures.

> *"The authors conclude that* ***almost all instructional activities should take place within a cooperative goal structure.*** *Individualistically structured situations may be productive in learning specific material and skills, but the lack of interaction among students precludes the widespread use of such goal structures. Competitive goal structures should be the least frequently used" (Johnson & Johnson, 1974, p. 232).*

While Johnson and Johnson's article makes a bold claim that almost all instruction should be in a cooperative context, it also discusses "the importance of all students being specifically taught cooperative skills" (p.233).

Webb notes, about a decade later, that in small cooperative group settings, "only in a few cases do students have prior experience working in groups" (Webb, 1985, p. 32) meaning they have not had a chance to develop these 'cooperative skills.' Webb finds…

> *"When these [small group instructional] methods are compared to conventional instructional methods (typically whole class instruction), they are often, but not always, found to produce greater learning…Because the research findings are not consistent,* ***it is important to understand the conditions under which small group settings are beneficial for learning****" (Webb, 1985, p. 32).*

The lack of consistency in research findings leads us to consider what is causing some groups to work well, while others do not.

Why Some Groups Work and Others Do Not

Webb's early work (e.g., 1982a, 1982b, 1984a, 1984b, 1985) tries to explain these discrepancies between performances in groups by using group composition. Webb's survey of the literature (1982a) concluded that "that an individual's role

in group interaction is an important influence on learning, and that interaction can best be predicted from multiple characteristics of the individual, group, and setting" (p.421). However, when attempting to use junior high mathematics classroom data to predict group outcome by group composition, comparing uniform and mixed ability groups, Webb (1982b) found no direct relationship between the group composition and outcome. Instead, Webb (1982b) stated that despite the strong relationships found in previous studies between group composition and outcomes, "the effects of group composition may be better understood by examining the influence of group composition on interaction" (p. 483).

Webb (1984a) investigated how sex[1] played a role in interaction by conducting a study of almost 80 middle school mathematics students in groups of 3 to 5.

> *"The breakdown of achievement and interaction by sex … shows that males scored higher than females on the achievement test even though females and males had similar ability… In short, male students experienced most of the interaction that was beneficial for achievement (receiving explanations) and female students experienced most of the interaction that was detrimental for achievement (receiving no explanations and no responses to procedural questions)" (Webb, 1984a, p.35-36).*

This illuminating study signaled a shift from looking at how group composition affected interaction, to looking directly at group interactions.

Webb's work into the 1990s became sharply focused on verbal interaction (e.g., Webb, 1989; Webb, 1991).

---

[1] While discussing Webb's work, I use the word "sex" to match her terminology but today we would use the word "gender"

> *"Based on previous empirical research, critical features of peer interaction include the level of elaboration of help given and received, and the appropriateness of responses to requests for help." (Webb, 1989, p. 21).*

In the early 2000s, Barron continued this focus on student's verbal interactions (e.g., Barron, 2000; Barron, 2003). Unlike Webb (1989; 1991) whose focus was on help-seeking and the subsequent explanations of traditional math problems, Barron studied groups in a messier context. The messier context resulted in Barron's conceptualization of proposals and engagement (Barron, 2000; Barron, 2003). Barron (2003) developed a coding scheme "to capture the responses of peers to the correct proposals generated. Three categories of responses were used: accept, discuss, and reject or ignore" (p. 322).

Both Webb and Barron's conceptualizations look at the smallest grain-size of two turns of talk (help-seeking and explanation-giving, and proposal and engagement), where each turn of talk comes from a different individual. Using this conceptualization of discourse on data, both Webb et al. (1995) and Barron (2003) noted differences between groups in their studies. Webb et al. (1995) noted that the level of help received - the content of the student giving help's discourse - was not directly predictive of achievement.

> *"Overall, these results show that, although* ***receiving highly elaborated help was not sufficient for achieving high post-test scores****, receiving highly elaborated help encouraged or enabled students to work constructively on the problems, which in turn helped them achieve high post test scores" (Webb et al., 1995, p. 414).*

Barron's (2003) work concluded that it was not what the students were proposing but how their peers were *responding* to proposals that made the successful groups productive.

> *"There were three times as many accept responses, twice as many discuss responses, and less than half as many reject or ignore responses in more successful groups… these results suggest that there is a significant difference between more and less successful groups in the way that partners respond to correct proposals" (Barron 2003, p. 323).*

One possible reason these studies did not find a direct relationship between utterance and achievement but instead found a relationship between peer response and achievement is because of what happens between two turns of talk: listening. Whether between a request for help and an explanation, or between a proposal and a response, the students in the group were listening.

The Challenge of Interdisciplinary Settings

Interdisciplinary settings add a layer of complexity to the social negotiation of group work. English (2017) discusses the many challenges of STEM education – including differing perspectives on whether "STEM education" implies the integration of these disciplines.

> *"Several arguments are offered for the advantages of STEM integration including as a means for adding meaning to and linking students' learning across the STEM disciplines, its relevance to tackling real-world problems and the increasing use of multidisciplinary teams across many professions" (English, 2017, p. S7).*

Many research projects have investigated discipline integration, including infusing STEM into non-STEM disciplines. Novel Engineering integrates engineering into literature to provide a rich context and clientele for engineering

problems in elementary education (McCormick, 2015; Deitrick, O'Connell, & Shapiro, 2014). BlockyTalky integrates music and computer science to create authentic situations for students to explore the challenges of synchronizing across a distributed network (Deitrick, Sanford, & Shapiro, 2014; Deitrick, Shapiro, Ahrens, Fiebrink, Lehrman, & Farooq, 2015) CodeR4Stats integrates computation into statistics to give students the ability to engage with real-world data sets while using authentic disciplinary tools (Deitrick, Wilkerson & Simoneau, 2017; Thoma, Deitrick, & Wilkerson, 2018).

While these are compelling examples of integration, there are also concerns. For example, we found on the CodeR4Stats project that the R programming language we used as a tool to help support statistical learning also created barriers for the students to access the statistical content (Thoma et al., 2018). English (2017) echoes this concern.

> *"I do not advocate total integration. It is questionable whether such an approach would do justice to students' learning of core disciplinary content and processes" (English, 2017, p. S9)*

In addition to this pedagogical challenge of ensuring enough space for students to engage meaningfully with the different disciplinary aspects of interdisciplinary projects, we are also asking students to navigate between these different disciplines (e.g., McCormick, 2015). We are asking students to negotiate this navigation between disciplines so that they can still effectively communicate with one another (Deitrick et al., 2017). In this dissertation, I will illustrate how listening is both key to groups in general and how specific types of listening are essential to help students work together in these interdisciplinary spaces.

In the following chapters, I review recent research on listening and introduce some methodologies to look at student listening. Before reviewing research on listening, which is all from about the past decade, I want to point out that it makes sense that this previous work focused on student discourse instead of student listening. Student discourse (talk, gesture, tone, etc.) is readily available to see and hear. To study student listening, researchers must address a challenging methodological hurdle: How can we "hear" or "see" student listening?

Intellectual Goals

In this dissertation, I contribute to interdisciplinary STEM Education literature both theoretically and methodologically. Regarding theory, I contribute a framework that helps researchers notice nuances in discourse that provide evidence of students' work listening to their peers. This framework, built on Perspectival Framing and discussed in greater detail in the next chapter, is developed and situated in the literature over the course of the three studies that make up the body of my dissertation. My first empirical study builds on previous literature that names the work and skill students need to navigate group contexts by illustrating the work of complex epistemological shifts needed in interdisciplinary group work. In study two, I identify Perspectival Framing as a useful starting point and modify it to help illuminate student listening and attending to framing. In study three, I refine the methodology for identifying evidence of student listening and situate this framework as a complement to the existing theoretical frameworks which treat students' roles as static, assuming they are equal participants throughout the group's work.

This work calls for the interdisciplinary STEM education community to reconsider how we think about groups. Researchers should view student groups as dynamic systems where students negotiate their framings and positioning over time. While much of previous work on groups consider short segments chosen to exemplify the equal contributions of the students, we need to start looking at these groups over more extended periods of time with both previous frameworks which can explain these symmetrical contributions, and my proposed framework or future frameworks which can explain asymmetrical contributions. By looking across the lifespan of a group, we will be able to understand how the group converges and diverges – and the fantastic work students do to synthesize after a divergence or maintain a convergence. I summarize and discuss these contributions and their implications in greater detail in the closing chapter of this dissertation.

Chapter 2: Theoretical Framework

Greeno and van de Sande's 2007 study is seminal for the framework of this paper by explicitly calling out students listening to each other. While the paper is primarily about bridging "situative" and "cognitive" lenses, during this work, the authors conceptualize discourse as a joint act where "a minimal unit of conversation… includes a presentation by one of the participants and acceptance of that by (an)other participant(s)" (p. 11) - similar to the smallest grain-size of two turns of talk used by Barron and Webb. Using this conceptualization of joint act discourse, Greeno and van de Sande (2007) name 'constructive listening' as "a property of activity that seems to be required for success in constructing perspectival understanding [or a group's knowing and understanding]" (p.17). They define "constructive listening" as

> *"attempting to understand the perspective of (an)other participant(s). That is, there were one or more inquirers and an informant. The effort on the part of the inquirer(s) was significant, involving active questioning of the informant, careful attention to the informant's statements including inferences of his or her meaning, and substantial work in finding relations between elements contributed by the informant to construct a coherent organization of ideas and information. The communicative interactions in these episodes were not symmetrical – the inquirers and the informants contributed different functions to the interaction. Even so, they were highly cooperative and mutually effortful, with the informants attending to the inquirers' questions and providing information and suggestions helpfully" (Greeno & van de Sande, 2007, p.17).*

However, the excerpt above represents the full development of the construct of 'constructive listening.' This conceptualization is not operationalizable in its current state. We find the work to connect these ideas in their 2012 paper where "constructive listening" is re-conceptualized as "positional framing" (introduced

fully in this chapter under 'Dimensions of Perspectival Framing') but many of these ideas remain. Most readily apparent, the two roles of inquirer (re-named "listener") and informant (re-named "source") still have distinct roles which contribute to constructing "a coherent organization of ideas."

Van de Sande and Greeno (2012) develop their theory of Perspectival Understanding into Perspectival Framing. This more recent work advances their ideas in two distinct ways. First, the authors connect their previous idea of "coherent organization of ideas and information" to framing literature. Additionally, they explicitly delineate two dimensions of framing (positional framing and cognitive framing) based on their previous two lenses (situative and cognitive).

Framing

Framing answers the question 'What is going on here?' (Goffman, 1974). Frames are constructed based upon situational cues. A person's framing shapes what they pay attention to and how they make sense of things. Because frames are context dependent, slight changes to a situation may change what students perceive or expect (McCormick & Hammer, 2016).

People communicate their framings to others. These communications of framings between people could be thought of as Bateson's idea of meta-messages. "In any normal relationship there is a constant interchange of meta-communicative messages such as 'What do you mean?' or 'Why did you do that?' or 'Are you kidding me?' and so on" (Bateson, 1987, p. 215).

This communication of framing happens through the same utterances of discourse. Tannen (1993) explains "notions of script, frame, and schema can be understood as structures of expectation based on past experience, and that these structures can be seen in the surface linguistic form of the sentences of a narrative" (p. 53). Tannen's work (1993) illustrates some ways framing can be seen in discourse. For example, "a negative statement is made only when its affirmative was expected" (Tannen, 1993, p. 44). So when you hear a driver exclaim 'he didn't even use his blinker!' it is evidence that he was expecting a turn signal before the other car maneuvered, which also indicates that the driver's framing of driving includes the use of turn signals.

Van de Sande and Greeno's 2012 connection to framing literature helps, particularly methodologically, since framing methodologies illuminate this meta-communication happening in student groups. This meta-communication or evidence of framing over time can show whether people are listening to each other. For example, if someone is asked to pick up 20 eggs from the store, they could respond with a clarification ('Two dozen?'), a curiosity ('What do you need exactly 20 eggs for?') or something similar. Regardless of the exact wording, this meta-message of 'I do not understand this request' shows evidence of trying to understand the other person (i.e., listening).

Framing methodologies allow us to incorporate many features of student discourse such as body language.

Scherr and Hammer (2009) illustrate how indications of framing are present in body language. Students who are framing the current activity as working on

worksheets indicate this by having their heads down, while actively writing or looking at their paper. In contrast, students who are framing the activity as a discussion indicate this by sitting up and looking between their peers and referencing shared materials on the table. Scherr and Hammer (2009) describe how a student in a group, in 'working on worksheets' body position, will sit up in a 'discuss' posture, looking to see if their peers are ready to discuss. This sitting up sends a meta-message to the group that the student is ready to discuss.

The student who sat up not only sends this 'ready to discuss' meta-message but also reads the meta-messages of their peers. Are the other students starting to sit up? Are the other students working on their worksheets without looking up? Where are they in completing the worksheet? If the student sees indications that no one else in the group is ready to discuss, the student's head returns back down, reverting to working on the worksheet.

Dimensions of Perspectival Framing

In addition to connecting "Perspectival Understanding" to the framing literature, Van de Sande and Greeno (2012) delineate two framing dimensions based on their 2007 work bridging the situative and cognitive lenses: cognitive framing and positional framing. They further break down cognitive framing into epistemological framing and conceptual framing. While in their analysis, Van de Sande and Greeno (2012) often refer back to this bigger construct of 'cognitive framing,' I discuss the three dimensions of framing without this 'cognitive framing' hierarchical category. As I later illustrate, these three framings as unique dimensions offer a lot of traction in messy interdisciplinary, collaborative data.

Epistemological framing refers to "participants' understanding of kinds of knowledge that are relevant for use in their activity and the kinds of knowledge, understanding, and information they need to construct to succeed in their activity" (Van de Sande & Greeno, 2012, p.2) (see also DiSessa, 1993). In deciding what knowledge is needed to succeed in the activity, students are also deciding what they perceive the activity to be. A student's epistemological framing answers the question "What is my goal for this activity?"

Conceptual framing refers to "the way or ways in which participants organize information in the situation they are discussing and the problem they are working on" (Van de Sande & Greeno, 2012, p.2). Depending on how they are framing a situation, a person adopts a set of expectations about a situation that causes them to foreground and background different knowledge resources. A student's conceptual framing answers the question "What do I already know that can help me accomplish my goal?"

Positional framing refers to the way participants understand everyone's role in a situation. Positional framing "includes a human participant who is inquiring, which we call a listener, and a source, which may be another human participant or a non-human system" (Van de Sande & Greeno, 2012, p.1). The role of the source is to act as the main authority on the disciplinary material. The role of the listener is fluid; the listener can be a simple recipient, a director of "the interaction, actively questioning the source," or a role was taken up "actively and jointly by more than one participant acting collaboratively" (Van de Sande &

Greeno, 2012, p.40). A student's positional framing answers the question "What is everyone's role in accomplishing the goal?"

All three of these types of framing are interrelated. The knowledge a student leverages for an activity (conceptual framing) depends on what knowledge that student thinks is relevant to accomplish their goals (epistemological framing). Knowledge (conceptual framing) changes for a listener as they receive information and restructure their understanding accordingly, and may change for a source as they adapt the information they are communicating to the listener's needs. The position of listener and source (positional framing), or the information that each seeks and provides, may change as participants recognize different goals or knowledge (epistemological framing) to be at play.

Each dimension of perspectival framing reveals a unique aspect of group work.

Previous work illustrates the methodological power of these different dimensions. While this work does not consider all of the dimensions of Perspectival Framing at once, the work below illustrates the ability of each dimension to reveal a unique aspect of group work. The next section presents an example analysis using all three dimensions of Perspectival Framing together.

As discussed previously, Scherr and Hammer (2009) present how an undergraduate physics lab group navigates *epistemological* framings. In Scherr and Hammer's work, they identified four different epistemological framings: joking, working on the worksheet, discussing, and talking to the TA. One could imagine how the group disagreeing on which of these epistemological framings

they are in could cause communication problems. Even if all of the students were framing the activity as a discussion, one student could be trying to understand the underlying physics concepts while another student was attempting to understand the mathematics. Epistemological framing can help illuminate these types of communication failures where students seem to be talking about the same thing but are not quite understanding one another.

Roschelle (1992) presents an example of *conceptual* convergence between a pair of high school girls. Through his conceptual analysis, Roschelle tracks the different conceptual understandings the girls navigate through. Assuming that the members of the group are in comparable epistemological framings, this type of analysis highlights the differences or trajectories of conceptual resources students are leveraging to solve problems. In group contexts, discussion often causes students to shift which conceptual resources they are using as their peers call out properties or facets of the problem they were not previously considering. In this way, the dimension of conceptual framing can help explain how peers are shaping one another's understanding or coming to a shared understanding.

Goffman (1979), as well as Van Lagenhove and Harré (1999), talk about how people negotiate *positioning*. More recent research, such as Esmonde (2009), have considered positioning in an educational context. "Positioning happens all the time and in all contexts, through markers such as the language we speak, the way we dress, whom we interact with and how, and so on" (Esmonde, 2009, p. 1012). Re-consider Webb's work on sex affecting achievement in groups where she found differences between male and female achievement due to different

interactions in the groups (Webb 1984a). A construct like positioning, that can take into account students have expectations of their peers and are pressured to act in certain ways, can help us explain why the female students, who are socialized or positioned by society to help, were more likely to offer help in groups, resulting in males having more explanations given to them and procedural questions answered.

Perspectival Framing Requires Further Modification to Focus More Attention on Listening

While the re-conceptualization of Perspectival Understanding to Perspectival Framing contributes relevant methodological traction, Van de Sande and Greeno's (2012) work de-emphasized constructive listening. To illustrate the conceptual gaps experienced when applying Perspectival Framing to look at student listening, I present Van de Sande and Greeno's (2012) re-analysis of Roschelle (1992). Below, I highlight three specific areas of Perspectival Framing to modify: (1) understanding how two individual framings relate to one another (e.g., framing alignment, shared framings, etc.), (2) refining Van de Sande and Greeno's conceptualization of positional framing to illuminate the negotiated nature of positioning more fully and (3) conceptualizing how exactly students are listening or attending to their peers' framings.

Van de Sande and Greeno's re-analysis of Roschelle (1992) using Perspectival Framing.

Below, I present the data context of the case as presented by Van de Sande and Greeno (2012), a summary of their analysis, and then an argument that the gaps

listed above exist when using the construct of Perspectival Framing to analyze student listening.

In the data below, "two students worked collaboratively on tasks that used an interactive computer program, the Envisioning Machine. The program displayed two windows, called the Newtonian World and the Observable World. The program displayed animations involving the motion of a dot (called a ball) in the Observable World and a circle (called a particle) with two arrows attached in the Newtonian World that left a dotted-line trace of each motion. Each problem, which Roschelle called a challenge, presented a motion of the ball, determined by the program. The program was written so that the motion of the particle was determined by the lengths and directions of the arrows. One arrow, called the thin arrow, extended from the center of the particle and represented the initial velocity of the particle's motion. The other arrow, called the thick arrow, extended from the head of the thin arrow and represented acceleration. The display is illustrated in Figure 1, where acceleration occurs throughout the motion event" (Van de Sande & Greeno, 2012, p. 29).

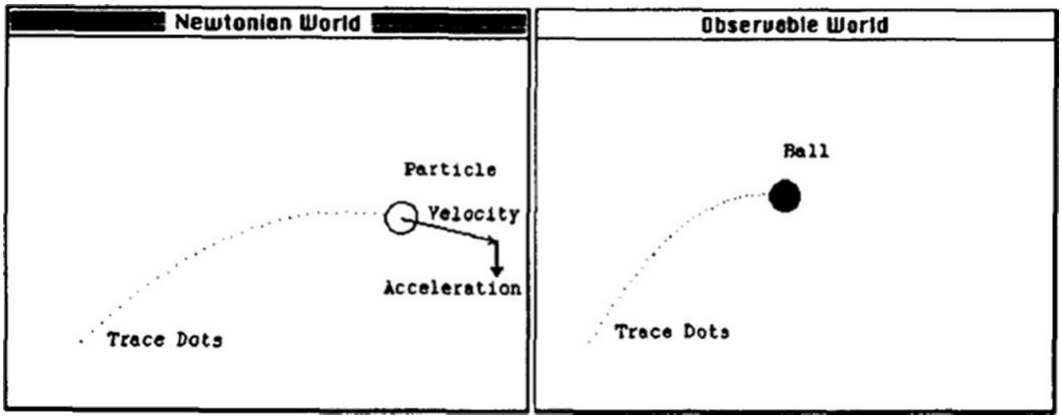


Figure 1: The Envisioning Machine. Adapted from Roschelle (1992, p.340)

In the episode below, the two students, Carol and Dana, were trying to set the thick arrow (representing acceleration) such that the ball followed the trajectory shown in Figure 2 (left). During their problem solving, Carol and Dana try multiple solutions (Figure 2 right). Over time, the two students change the bold arrow from the shape of the second segment of the trajectory to a longer and more downward position. Van de Sande and Greeno (2012) "interpret their learning as an example of conceptual reframing" (p. 30) summarized in Table 1.

Table 1:Hypothesized Framings of the Envisioning Machine (van de Sande & Greeno, 2012, p.31)

Framing	*Before Reframing*	*After Reframing*
Components in foreground	Thick arrow and direction of motion after change in direction	Thick arrow, thin arrow, and direction of motion after change in direction
Relations between components	Thick arrow's direction causes the direction of the second segment of motion	Thick arrow causes the change of direction of the thin arrow, and thin arrow causes the direction of motion

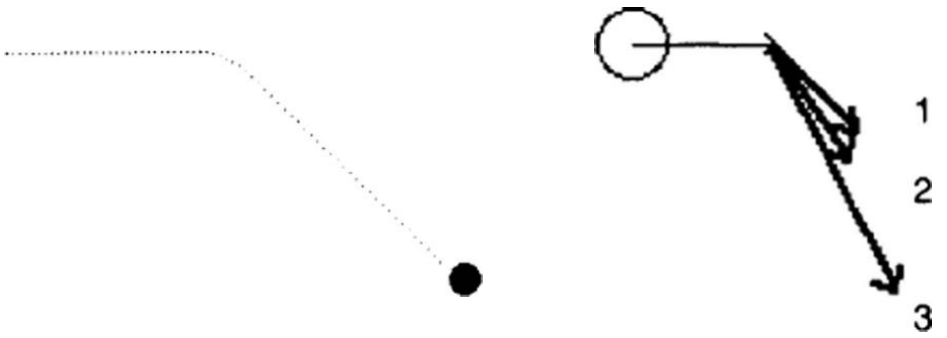


Figure 2 (left) The desired trajectory, a 45-degree bend

(right) Three solution attempts (Roschelle, 1992, p.245-246)

"Eventually Carol and Dana tried pointing the thick arrow vertically downward, which produced the correct solution. Dana said, 'But it doesn't go at a ninety degree angle. I don't understand.' Then they continued with the following dialogue:" (Van de Sande & Greeno, 2012, p. 32).

1. Dana (D): But what I don't understand is how the lengthening the positioning of arrow—
2. Carol (C): Ooh, you know what I think it is? It's like the line. Fat arrow is the line of where it pulls that down. Like see how that makes this dotted line. That was the black arrow. It pulls it.
3. D: You're saying this[dotted line] is the black arrow?
4. C: Yeah.
5. D: and it pulls it the other other arrow *(points to vel [thin arrow] with mouse cursor)* like—
6. C: Like on its hinge. It pulls the other arrow on the hinge down to the tip of the black arrow.
7. D: Making the line that you see here (gestures to the trajectory after the 45 degree bend).
8. C: Right. (Roschelle, 1992, p.247)

"We take Carol and Dana's unsuccessful settings of the thick arrow (in Figure 2) as evidence that their initial framing was misaligned with the program's intended framing. They jointly adopted a positioning as a listener, with the computer program as the source. Their shift in conceptual framing included a change in perspective in the sense that it included changing the properties and relations that were in the foreground of their understanding. Before the shift, as we summarize in Table 1, the foregrounded properties were the direction of the thick arrow and the direction of the particle's motion after the path turned; Carol and Dana believed that the direction of this motion should be the same as the direction of

the thick arrow. After they reframed their understanding the foregrounded properties included the thick arrow, the direction of the thin arrow, the change of the thin arrow during the turning event, and the correspondence between the thick arrow and the path of the thin arrowhead when the particle's path was turning" (Van de Sande & Greeno, 2012, p. 32-33).

Proposed Modifications to Perspectival Framing to Focus on Student Listening

While Van de Sande and Greeno's (2012) analysis highlights many aspects of the case, I argue there is still work to be done to use this framework to study student listening.

We need an understanding of how two individual framings relate to one another.

Since people use their current framing to interpret what they hear and see, as well as to help them express what they are thinking, it is important to know when framings are unaligned or shared by group members. I argue that the data above illustrates a lot of student effort to build a shared conceptual framing. In Roschelle's words, the "students responded to utterances with mutual concern for shared knowledge, exerting deliberate effort to create convergence and avoid divergence" (p. 264). Referring back to the transcript, in lines 3 and 5 Carol asks specific questions about her interpretation of Dana's idea – explicit effort towards understanding Dana. Likewise, Dana hears these questions and in an attempt to rectify Carol's apparent confusion, tries to re-explain her idea on line 6. Only

once Dana presents discursive evidence that she has a shared conceptual framing (line 7), does Carol confirm this understanding and they move on.

While Van de Sande and Greeno talk about the shifts in conceptual framing (summarized in Table 1), they seem to take for granted this work was done to create and maintain a shared framing (particularly this intentional work to stay together during frameshifts).

Van de Sande and Greeno (2012) talk about framing misalignment, but they describe the discrepancy between the computer and the shared student framing.

> *"Carol and Dana had a conceptual framing that was misaligned with a framing of their source that would support their understanding, and they detected that misalignment when information produced by the program was discrepant from their expectations. Their success in reaching a conceptual framing aligned with the program resulted from their interacting with the program in an exploratory way. We interpret their success as a reframing that was achieved when Carol noticed the correspondence between the thick arrow and the path of the head of the thin arrow, as shown in Figure 2" (Van de Sande & Greeno, 2012, p. 33).*

While their conceptualization of misaligned and aligned frame is the same as mine and that of previous literature (e.g., Scherr & Hammer, 2009), Van de Sande and Greeno (2012) assume the two students' framings are aligned. It is important not to assume or automatically characterize the whole group as having one framing, but instead, analyze the framings of the individuals and then consider how the individual framings relate to one another. I posit that in groups where there is a shared framing, like in the pair above, there are important dynamics of the group, specifically listening, that create and maintain them.

We need a refined conceptualization of Positional Framing.

In addition to understanding how individual framings relate to one another, there is also some work needed to understand how individual framings, particularly positional framings, are negotiated. Van de Sande and Greeno (2012) state that "Carol and Dana jointly were positioned as a listener, with the computer program positioned as the source" (p. 33).

In terms of positional framing in this episode, I argue there are two levels at play. The first level is that both girls are looking to, or positioning, the simulation as the disciplinary expert whose feedback they are trying to understand (similar to Van de Sande and Greeno's re-analysis). However, Dana's utterance on Line 1, "I don't understand," is a *bid* to position Carol as a source of understanding. Carol *accepts* this positioning in the following line ("you know what I think it is?"). The rest of the transcript, as established quickly in the first two lines, shows Dana (positioned as Listener) trying to make sense of Carol's understanding, and Carol (positioned as Source) trying to share her understanding with Dana. This positioning work the girls are doing takes place in a nested positional framing.

While the over-arching positional framing remains the same, at the start of the next episode presented by Van de Sande and Greeno (2012), you can see the two girls have actually switched positional framings.

35. C: So if we wanted to pull this (vel [head of thin arrow]) down
to there (a vertical line). We'd have to have this (acc [thick
arrow]) all the way around or something like that (begins to

set acceleration [thick arrow], but doesn't release mouse button).

36. D: No, 'cause that wouldn't that make this (*vel [thin arrow]*) tip swing around to that (*acc [thick arrow]*) tip and make that angle? *[ambiguous gesture]*.

37. C: What angle? (aborts setting acceleration [thick arrow])

Instead of accepting Carol's bid to be positioned as a source of understanding (line 35), Dana instead rejects the bid and makes a bid to be the source (line 36), which Carol accepts (line 37). This results in the opposite nested positional framing.

This refinement of positional framing which addresses nested framings and conceptualizes positional framing as a more negotiated, dynamic property, allows for us to see more student listening. Just like in the discussion around the fact that listening is required to create and maintain shared framings, students have to listen to do this positional framing negotiation work.

We need a conceptualization of how students are listening to their peer's framings.

Finally, if this refinement of Perspectival Framing discusses students doing listening work to create and maintain shared framings, and listening to one another while negotiating positional framings, we need a conceptualization of how students are listening to their peer's framings. There is some evidence above of how we (and one might infer the students) are able to see their peer's conceptual and positional framings. We see that there are surface level discursive

markers, as discussed above (Tannen 1993), that can help us, and the students in the moment, hear their peer's framing.

For example, in positional framing, we see the bids the students start their exchanges with as evidence that they hear each other's understanding of their roles in the group, especially since they either accept or counter-bid in the next turn of talk. Throughout the episode, the fact that Dana asks a question (line 3) and Carol answers (line 4) and later confirms Dana's explanation (line 8) are further indicators of the established positional framing.

In conceptual framing, we see hints of framing over various lines of the transcript (lines 2 and 6 for Carol and lines 5 and 7 for Dana). Van de Sande and Greeno (2012) use the runs of the simulation and student gestures to piece these hints together into a summary of the students shared conceptual framing (Table 1). The fact that the students are building off each other's sentences (lines 5-8) would indicate they both have an understanding of the other's conceptual framing though it is hard to point to specific evidence of them "hearing" one another's framing. This is possibly due to the fact they start this episode having already played with the simulation together and constructed a shared conceptual framing. This could indicate that when students are in shared framings, they are doing less visible work to hear each other's framing. Possibly, every peer utterance that makes sense in their current framing is evidence to them the group is still in a shared framing.

Before looking for evidence of student's hearing their peer's epistemological frame, we should pause and address epistemological framing in

this episode. In terms of epistemological framing, while Roschelle (1992) never directly addresses it, both girls seem to be making sense of the Envisioning Machine. The first line of the transcript ("I don't understand") hints at Dana's goal of the activity being understanding. Carol's response ("you know what I think it is?") which offers how she is making sense of the simulation indicates her buy-in to this epistemological framing. If either of the students decided the goal was to match the patterns presented as quickly as possible, the discussion would look much different – with one or both students proposing different configurations to run without much discussion dissecting the results of each simulation.

Similar to conceptual framing, because the pair so quickly establishes and stays in this epistemological framing, there does not seem to be evidence of the students attending to one another's epistemological framing. One might claim that in those first two lines of the transcript I cite as evidence of epistemological framing are evidence similar to positional framing where Dana makes a *bid* for the epistemological framing to be understanding, and Carol agrees to this framing in line 2. Additionally, the mechanistic word choice in the transcript ("pulls" [lines 2, 5 and 6], "makes"/"making" [lines 2 and 7], and "hinge" [line 6: "pulls the other arrow on the hinge"]) could indicate a goal of understanding the simulation. However, none of this illustrates a listening to peer epistemological framing with the same clarity as Scherr and Hammer's (2009) students' body positions described above.

Due to the concerns highlighted in discussing students hearing conceptual and epistemological framings, it is important to note that lack of evidence of

student listening to framings does not equate to lack of student listening to framings. Given the heavily contextualized nature of communication, there may be evidence that researchers, with only partial histories of students' relationships, cannot identify. This is particularly true in classroom data where students might have known each other for years and have vast shared experiences in school. Students, then, have a separate set of evidence than researchers. Even in situations where it is difficult for researchers to point to concrete evidence of student listening, there are probably small indications the students see in their interactions with their peers.

As illustrated above, work needs to be done to make Perspectival Framing illuminate student listening. The body of this dissertation will address this work through both theoretical and methodological advances. In the final chapter of the dissertation, I will show how the three studies below build on and modify this framework in order to contribute a way to understand student listening to the literature.

Chapter 3: Research Context and Methodology

This chapter presents an overarching research context and the underpinnings of my methodological approach. In the subsequent empirical chapters, I explain in more detail the group selection, data selection, project context, and analysis used.

Overarching Research Project: CodeR4Stats

All the data in this dissertation is from the CodeR4Stats project (funded by the National Science Foundation DRL grant 1418163). CodeR4Stats is a design-based research project to replace calculators in a non-AP urban high school statistics classroom with the statistical programming language R. By teaching the students R, they are able to work on larger, authentic data sets as part of open-ended projects. In the first year (2015-2016), students final project used simulated student data and students were asked to choose a college or university and model the admissions process. Students struggled to integrate computational structures such as loops and decisions structures into a functional program, partly due to R's implementation of for loops. In response to this, the following year (2016-2017) the final project was much more data-driven – allowing students to interact with R in a way that was more similar to how statisticians use the language. Students chose from five real-world data sets varying from survey data FiveThirtyEight released (see data.FiveThirtyEight.com) to energy usage statistics released by the U.S. government.

While the vast majority of the data presented is from these final projects, in Chapter 5, there is also data from days where students were working on smaller problems in order to learn and practice programming R commands. These

instructional days usually started with the classroom teacher reminding the students of a previously learned statistical concept, introducing the R command that corresponded to the concept, and then walking through a programming example. Students then spent the remainder of class time working on textbook problems or similarly closed-ended problems assigned via an online system. While working, students were allowed and encouraged to help one another and discuss problems. These moments of impromptu interaction varied in length and different students engaged with their peers in different ways (some becoming informal pairs and others not interacting with their peers at all), so I would not characterize this entire subset of data as collaborative. The data selected from this subset (in Chapter 5) were two students who wound up working closely as an informal pair throughout the year.

Data collection.

Over the course of both years of the project, I collected data any days that students were using RStudio to program in R or were working on a bigger project that had a programming component. Students who had consented sat on one side of the classroom with webcams mounted on their monitors. At the start of each data collection, I prompted students on the consenting side of the room to start screen recording software that captured all their screen interactions and video (with audio) from the webcams. Due to the poor quality of the webcam microphones, I placed audio recorders between computers, and pointed them towards the students. In addition to student data, I video recorded the front board so that any teacher instruction was captured.

I sorted collected data by date and then (on days where students were working together) by the group. Before analysis, I synchronized the screen recordings (including poor quality audio and webcam feed) from each student in the group and the higher-quality audio from the audio recorders so that researchers viewing the data saw all the group members and their screens along with the high-quality audio.

Affordance of novice computer programmers.

One feature of this project and the data collected from it is that the students were almost all new to programming. Unlike more experienced or fluent computer programmers, the frequent struggles the students ran into while programming helped make visible a lot of student thinking. It seemed that due to this lack of fluency in programming, students had a tendency to talk to their partner, look up how to program certain statistical concepts online, and audibly react to the computer's behaviors. This usage of outside resources and capturable behaviors gave us insights into how students were breaking down problems, understanding the computer commands, make sense of the computer output, and troubleshooting errors that would have otherwise been invisible.

Methodology

The analytical approach throughout this dissertation was based on the framing literature (discussed in the previous chapter) which illustrates how discursive markers communicate a speaker's framing. Tannen (1993) explains how our expectations and therefore our framings can be inferred from the content of our utterances. For example, by stating something in the negative (e.g., "He did not

complete the task"), the speaker is revealing that they expected the opposite to happen (e.g., Speaker expected him to finish the task). Other literature has illustrated how tone, gesture, and body position can also reveal a person's framing (e.g., Scherr & Hammer, 2009; Roschelle, 1992).

Due to the nuanced nature of these markers of framing, I primarily analyzed all the presented data as video. In order to allow readers access to the same richness of the data, the video for all presented transcript is included in **Appendix 5: Video of Data Presented in Empirical Chapters**.

In the empirical chapters below, I address slightly different research questions that highlight different aspects of the data. Therefore, within each empirical chapter below I have included a Methods section with a more focused description of the specific context and analytical tools.

Chapter 4: Group Members' Frame Switching to Understand Each Other

Abstract

Group work in educational settings is becoming more commonplace fueled by their recent inclusion in standards and promised benefits. However, oftentimes groups are unsuccessful, and education researchers do not necessarily know why due to our piece-meal understanding of how groups work. In this paper, I focus on *how* collaboration occurs in student groups. I argue that the construct of *framing* is useful for exploring this question across many different settings, giving it the potential to help build a unifying collaboration framework. Through a review of the literature and the presented case study, I answer the question of *what work do students do to understand each other?* In the literature, we see many actions that students take to maintain complimentary perspectives of activities, referred to as a shared group frame. The literature also reveals a lack of these actions in groups with conflicting understandings of the activity, referred to as groups without a shared frame. The case study presented below lies in the middle of this spectrum where one student frame-switches, or changes their perspective of the situation, to interact productively with his two group mates.

Introduction

Collaboration, cooperation, teamwork, working together, group work – whatever you call it, students are interacting with one another in education settings. Educators increasingly ask students to share knowledge or ideas with their peers during collaborative activities such as fishbowl, jigsaw, think-pair-share, learning

together, and student team learning (e.g., Azlina & Nik, 2010; Bossert, 1988). This growing use of student groups is motivated by a number of reasons such as curriculum standards, parallels to professional practices, and potential benefits for learning.

Standards at multiple levels call for students to work together. The Next Generation Science Standards (NGSS) call for K-12 students to "plan and carry out investigations in the field or laboratory, working collaboratively as well as individually" (NGSS, 2013, p. 7). In higher education, student outcomes for undergraduate engineering programs list "an ability to function on multidisciplinary teams" and "an ability to communicate effectively" (ABET, n.d.).

Even those not under the purview of these standards implement student groups given the plethora of promised benefits. These positive outcomes include increased test scores, developing higher order thinking (Johnson & Johnson, 1981), better problem-solving outcomes (Cockburn & Williams, 2000; Williams & Upchurch, 2001), and student career preparation (Lewis, Titterton, & Clancy, 2012).

Despite all of these potential benefits, placing students in groups does not necessarily lead to positive outcomes. "There [is an] important variation in effectiveness between studies. In some of the early studies, cooperative learning was associated with results that were merely as good as those with more traditional forms of instruction and not necessarily superior" (Cohen, 1994, p. 2). Others even report a possible negative impact of group work versus the traditional

approach; when "coordination costs outweigh the potential benefits of collaboration, there can be group failures" (e.g., Nokes-Malach, Richey, & Gadgil, 2015, p. 648). Even within the same classroom, it is hard to classify the use of groups as wholly positive (Barron, 2003).

These troubling results make sense – group work is hard. "By asking learners to make sense of a problem together, they are faced with challenges of establishing common frames of reference, resolving discrepancies in understanding, negotiating issues of individual and collective action, and coming to joint understanding" (Barron, 2000, p. 404). To address these complex social dynamics, in this paper I address the question *what work do students do to understand each other?*

Answering this question is difficult due to the lack of a comprehensive framework that can help explain how student groups function. Recent researchers

> *"have focused on collaborative process – on what goes on during a collaborative episode…[attempted] to structure collaborative instruction… [focused] on collaborator backgrounds – what collaborators bring into a collaborative situation….[and focused] on collaboration tasks – how the task demands vary…While the value of each of these perspectives for contributing to explanations of variability is evident, we argue that it is time to bring the perspectives into a single comprehensive framework" (Barron et al., 2009, p. 25).*

I argue that the construct of *framing* is useful for explaining how collaboration works across many different settings, giving it the potential to help build a unifying framework. To illustrate this, I start the review with studies that have used framing literature to study group contexts. These studies illustrate the productivity of the construct of framing in collaboration. I also review

collaboration studies which I re-analyze using the construct of framing. These re-analyses combined with the initially reviewed studies reveal a spectrum of ways groups can frame the task at hand. I argue that this spectrum of group framing could provide a unifying framework for collaboration studies. Additionally, through this re-analysis, I reveal frame-switching as a series of actions, which the case study I present following the literature review explores further.

Theoretical Framework: Framing

Framing helps answer the question '*What is going on here?*' (Goffman, 1974). Framing is one's "structured expectations formed from previous experiences" (McCormick & Hammer, 2016, p. 47). A frame shapes what an individual pays attention to and how they make sense of things. At the same time, the current situation slowly becomes past experience, thereby influencing the frame itself. This makes framing "a dynamic interaction between expectations and perceptions. Frames are not static, rigid structures, but are active and responsive, perpetually evolving as they are informed, shaped and tuned with new experiences" (McCormick & Hammer, 2016, p. 47).

Frames are not correct or incorrect, nor are they correctly or incorrectly applied. While different frames applied to the same situation forefront different aspects of the situation, it does not make one frame "better" than the other. Frames can be talked about as productive or useful. Typically, when people find a frame not to be useful, they will replace it with another frame. For example, when you walk into a food establishment, there are a number of framings you can call on like a fast food framing where you order at the counter and pick it up at the

counter, a café framing where you order at the counter and food is brought to you, or a restaurant framing where a waiter takes your order at the table and brings your food to the table. One might walk into a food establishment and sit down after noticing other people seated. However, after no one appears to take their order, they might start considering another framing and look for a counter.

Frames are not mutually exclusive. At any given moment, many frames may be invoked at once or nested within one another (Tannen, 1993). This layering of frames might be organized based on locality. For example, a student in math class might have both a framing for school activated and nested within a framing for math class. Alternatively, you might organize frames based on your priorities. For example, a student doing a math activity in class might have a framing for sense-making in math activities activated but also have a framing for school activated which implies that if she does not finish the activity quickly, it will become homework.

In the section below, I consider studies that apply the construct of framing and consider group contexts, as well as re-interpret collaboration studies that illustrate aspects of framing.

Literature Review

This literature review provides examples of studies that have documented three different group framing scenarios. I start with a few studies that present groups who are able to maintain a *shared frame* to illustrate some of the work done to make a group function. I then review a study that illustrates a group *without a shared framing*. As you will see, the lack of shared framing creates a roadblock in

the presented group's productivity – one that they do not manage to overcome. Finally, I re-analyze a collaboration study where one student takes the initiative to switch between the disparate frames of his two group mates. I term this newly revealed student's action '*frame-switching*.'

Groups maintaining shared frames.

I present an example of a series of actions groups use to maintain a shared framing. Scherr and Hammer (2009) conceptualize framing in a collaborative educational setting by describing behavioral clusters observed in physics lab groups. They noted that students fluctuated among frames of completing the worksheets, discussing, responding to the teaching assistant, and joking. The data reveal these students are making bids to transition the group from one frame to another through body position. If after a few moments, no member joined them in the proposed frame, the student would typically revert back to the group's prior shared frame. This study explores a series of actions through which groups maintain already created frames – switching to frames together. These students are doing work to wait for a consensus before shifting frames. This work of waiting for a consensus also involves reading their peers' frames; in order to wait for others to join your framing, you have to know what framing they are in. Scherr and Hammer (2009) make it sound easy for a group to come to a shared framing and then maintain it by shifting together. However, this data was chosen deliberately to illustrate shared framing in the later part of the semester when students have been working together for a while. This means that as students make bids to transition, they are already familiar with the four frames of the group

and can quickly tell from body language if their peers are joining them or not. The data that follows will show, sharing frames is no simple task.

Even in groups that are able to shift frames together, this work can be burdensome and be accomplished through a different series of actions. Oliveira and Sadler's (2008) study look across three groups of undergraduate students discussing how a candle works. By comparing how these groups elaborate on each other's contributions and approach conflict, they conclude "student emphases on tangible products rather than conceptual development, highly competitive group environments, and unwillingness on the part of students to explore conceptual conflicts are among the most significant impediments to productive group tasks" (p. 656). Even in this short quote, we see implications of different framings the students took up during this activity: describing the candle as it melts, identifying the physical and chemical changes happening when a candle melts, debating and reaching group consensus.

Through a re-interpretation of their study, we see one particular triad manages to maintain a shared framing through a different process. While Oliveira and Sadler (2008) do not hand pick their groups or talk about framing explicitly, we can see how their discussion of a 'highly competitive' group, which I have hand-picked from their data, tacitly describes shifting of group framing. The authors discuss two group members being constantly at odds: Dana wanting to conceptualize and elaborate while Bob is more interested in getting answers on the worksheet. "Whoever wins Carol's support is able to influence group actions and the third person is consequently given a subordinate status within the group,

thus being expected simply to comply" (p. 646). Unlike Scheer and Hammer's 2009 study, we see a much more active attempt between Bob and Dana to dictate the shared group frame. The series of actions this group used to create and maintain their shared frame was to convince their third groupmate, Carol, in order to establish majority – a sharp contrast from the easy-going consensus in the Scherr and Hammer (2009) study. This contrast could possibly be due to the difference in the amount of time the groups had been established and working together. While Scherr and Hammer's data was from the end of a semester-long lab course, Oliveira and Sadler (2008)'s groups were newly formed.

The work students do to create and maintain shared framing is not always as evident as the series of actions presented in the previous two studies. Turning to an example of how student resilience and investment can prevent context from influencing framing, McCormick and Hammer (2016) illustrate how pairs of elementary students during an engineering project can stabilize their group framing around a project. They describe how many of the student groups switched from viewing the task as an authentic engineering task with an actual client when they became interested in using specific craft materials or impressing the teacher with their vocabulary. McCormick and Hammer's case study, however, focuses on how one pair's emotional investment in the engineering challenge task, building a dog pen to protect the dog, stabilizes their framing as engineers, despite the contextual forces attempting to shift their attention. For example, the teacher came up to the focal pair and asked them how they were going to test their dog pen – testing that would be done in the classroom under classroom constraints.

Instead of shifting to this classroom framing, the girls continue treating the project as purely an engineering project for the dog – ignoring the teacher's bid. McCormick and Hammer illustrate a few student motivations for a group to switch or maintain their shared framing. First is the role of context shifting groups framing. The groups interested in adding aspects to their project in order to use specific craft materials are making a framing shift from engineering, to a more playful trying to incorporate certain materials. Additionally, when the teacher praises a student describing their design for using the vocabulary term ("Okay, using some really good vocabulary. I'm hearing reinforce, stabilize, secure." and "I like the geometric terms we're using!" p. 51) the students "framing of the activity, in that moment, shifted to classroom expectations, influencing their choice of design features to highlight recognized words" (p. 51). Finally, we see the role of emotional investment in helping the focal pair of students ignore these contextual facets which motivated frame shifts in their peers. I see this emotional investment as a student action which insulates this focal pair from contextual forces. If such minute parts of settings, such as a single utterance or a shiny object, can cause a group to frame switch, then there must be work being done to maintain a shared frame in the face of these temptations. While the students in the case study seemed to effortlessly ignore contextual forces due to their overwhelming concern for the client, there are probably examples of this insulating work looking more effortful.

By considering the above studies from a framing perspective, the reader can see groups successfully sharing and shifting frames. Each study illustrates a

different series of actions students take to maintain this shared framing – from waiting for consensus, to establishing a majority, to emotional investment. This set of work leaves us with some important questions: What happens if something in the context shifts the frame of only one member of a group – breaking the shared group framing? How are these shared frames repaired? How did these shared frames form initially? What happens if a group never creates a shared framing at all?

Differences between groups with and without shared frames.

While the next study does not refer to framing explicitly, framing can help explain their results, specifically differences in collaboration dynamics.

In 6th grade mathematics classrooms, Webb, Troper, and Fall (1995) show that collaboration leads to positive outcomes when students receive elaborated explanations from their peers (i.e., level 6 was "a verbally labeled explanation of how to solve part or all of the problem," and level 2 was "the answer only") and then subsequently carry out a *constructive activity* (such as solving a problem using concepts stated or implied in the received explanation). More specifically, they found that "the level of elaboration of the help received in itself was not a direct predictor of posttest achievement: receiving help, even explanations, was not consistently related to achievement. Instead, the level of help received was a significant predictor of subsequent constructive problem-solving activity, which in turn was a strong predictor of posttest achievement" (p. 416).

Turning to the construct of framing, one possible reason why student explanations are only indirectly related to achievement is that the student

receiving the explanation has to do work to make sense of it. If this possible explanation held true, it would mean that the *level* of elaboration of the explanation is not what's relevant, and instead, we should be attending to how well the explanation matches the type of help a student needs. For example, if a student has already broken down the problem and only made a calculation error, a fully elaborated explanation on breaking down the problem is unhelpful. Conversely, if a student needs help breaking down the problem but receives calculation help, the student has less of a chance of making sense of this help. The authors even recognize the potential mismatch of frames between help giver to help receiver by saying that "one reason for the lack of a positive relationship between receiving explanations and achievement in previous research may be that additional conditions must be satisfied for students to be able to learn from the explanations they receive…[For example,] the explanations must be.. relevant to the target student's need for help" (p. 407). That is, while Webb et al. do not use framing, framing could help explain their results.

In order to further explore their results, Webb et al. (1995) propose "one factor [in the variation in constructive activity] may be the goal that students perceived for group work: to understand how to solve the problems or to get the correct answers written on their papers. Although the instructions to all groups stressed learning and understanding, some students and groups seemed interested only in obtaining the correct answer" (p. 418). Webb et al. (1995) provide an example of where students in the same group of four seem to have different goals. In their example below, I propose that student D is trying to get the correct answer

written down, whereas student B (and possibly C) are trying to help the help seeker, student A, understand.

The problem these students are working on is: "[Find] the cost of a 11-min call: 1st min costs $0.22, each additional minute costs $0.13"

10 A: I don't understand [the problem].
11 B: Do the additional minutes times 10, because the 1lth one, the first minute, cost $0.22.
12 A: Right.
13 B: So each additional minute times 10. Multiply.
14 C: Here. 13 times 10.
15 A: That's $1.30, right?
16 D: Just copy it down.
17 B: He knows this.
18 A: I don't know this!

The authors explain the behavior above as due to the group "[assuming] that some students already understood how to solve the problem and so did not need practice" (p. 420). I would assume the authors' classification of this group is mostly due to B's utterance on line 8 "He knows this." Their interpretation takes this utterance at face value, possibly understanding it as an agreement with D that since A now has most of the correct answer (as seen when he does the correct multiplication to get to $1.30) for the problem, he should just copy it down. However, I propose B is actually *protesting* D's switch in group framing – that A should not just copy it down and get the correct answer written but that in fact, A is capable of understanding. B's utterance is then understood as "He knows [how to do] this" as in A is capable.

Student A's framing can be seen a couple different ways throughout this transcript. First, he can be seen as trying to make sense of the problem throughout the transcript, so his utterance on line 9 is a protest against "just [copying] it

down." Alternatively, A's framing could be seen as shifting from trying to understand to trying to write down an answer. When student D reveals a different answer in utterance 7 (having added the $.22 for the first minute to the calculated $1.30), we could then view A's utterance on line 9 as resignation that he is not going to understand and so should just focus on completing the worksheet.

From this group, we see that lacking a shared group frame can hinder progress, regardless of how it is defined (understanding or completing the task). Even if we take student A to be frame-switching to understand student D, this move does not create a consensus in framing. Reconsidering Webb et al.'s (1995) study, we see how framing, which illuminates the mismatch of student perspectives in the group, can help explain their findings of the level of peer explanation not predicting achievement. In this example, we see some actions similar to the studies of groups with shared framing (i.e., emotional investment – in this case, investment in a peer's learning). However, possibly because not all students were performing the same actions, the group did not create a shared framing.

In the middle of the spectrum: Groups with individual members shifting frames.

Group framing is a spectrum with a complete shared framing on one end and no shared framing on the other (Figure 3). I present the next study as an interesting middle ground. I propose that some of these partial and temporarily shared group framings in the middle of the spectrum are created by partial and temporary group work. In other words, I argue that one student can partially or temporarily shift

their own framing to facilitate group work with another member in the group or the rest of the group for a short period of time.

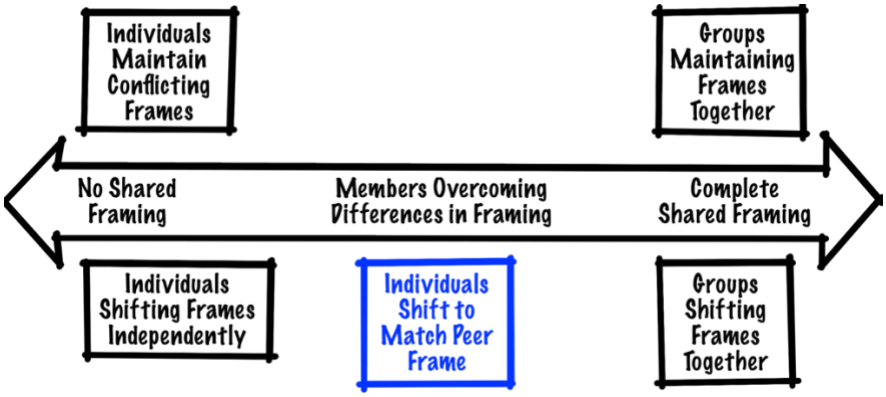


Figure 3: Setting previous studies along a spectrum to find space for frame-switching

Barron (2003) described how groups within the same 6th-grade classroom received different scores on a math workbook problem set. As she held other factors constant, Barron discovered that it was *not* past academic achievement, amount of talk, or the group ability to generate the right answer which dictated more successful groups, but instead the discursive engagement with other students' proposed ideas within the group. Barron coded the reaction of the two other members of the triad to a student's proposal as 'engaged' or 'unengaged.' Each of the peer's statements after the initial proposal fell into the category of discussing or accepting a proposal (resulting in an 'engaged' coded response) or the category of simply refusing or ignoring a proposal (resulting in an 'unengaged' coded response). Groups with mostly 'engaged' coded responses to proposals were much more successful than groups with mostly unengaged responses.

Barron also noticed that successful groups were not just listening to their peer's proposal, but in fact, listening *before* proposing ideas. Barron coded if

students in successful groups made proposals from the same problem space the group had just been discussing. She coded proposals as *directly related* "if a proposal matched the problem space the group had been working in just prior to the proposal" and coded proposals as *not-directly related* if the proposal did not match (p. 327). Successful groups had 98% of their proposals coded as directly related as opposed to less successful groups 40% – possibly indicating students in successful groups not just listening to one another, but also taking up their peer's implied problem space and building on each other's ideas.

While Barron does not talk about her findings in terms of framing, we can re-interpret and even explain her findings using framing. In terms of successful groups having mostly 'engaged' responses, this makes sense as students in the same framing as their peers are more ready to interact with their peers' ideas. Similarly, students who are proposing ideas directly related to the problem space indicated by their peer's previous utterances are probably doing so because they are in the same frame as their peer. These examples of students listening to one another before and after proposals might indicate that students in successful groups are more likely to attend to not just the content of their peer's utterance, but also the framing around it. This does not necessarily mean the creation or maintenance of shared group framing which involves all group members staying in the same framing, but instead implies that individual members can temporarily shift their framings to match their peers.

Turning to data from Barron's (2003) work, consider the work that Alex is doing to bridge Barry's mathematics framing (focused on numbers and

operations) and Charles's context-rich framing (focused on problem specifics). Barry focuses on bare numbers and operations (i.e., "eight divided by 24", "it's 3") while Charles is concerned about context (i.e. "this is the little boat") and always uses units when stating numbers (i.e., "3 hours", "24 miles", "8 miles per hour"). Alex, however, switches between the two framings, keeping the group together (i.e., line 148 to line 150). The problem is about one person trying to get two boats home without running out of fuel and before the sun goes down.

146. Barry: Put eight divided by 24.

147. Charles: No, but this is the little boat.

148. Alex: 24 divided by 8.

First, Alex addresses Barry's utterance by correcting his math. Just like Barry, Alex is using bare numbers. When Charles's utterance is not recognized, he repeats his concern.

149. Charles: This is the little boat ... no we be going back.

150. Alex: No this is the big boat because ... 8 miles, put eight miles.

Alex now turns his attention to Charles, discussing the context and adding units to his numbers.

151. Barry: Put eight divided by 24.

152. Alex: No, 24 divided by 8.

153. Barry: Oh yeah, no, it's 3. (shakes his head, as if to clear it)

154. Alex: It's 3 exactly.

155. Barry: Yeah, right.

156. Alex: Erase that point 0, on both of them, no leave it on the other one because ...

Once again, Alex responds to Barry in his mathematics frame using numbers with no units. They discuss the accuracy of their numeric answer to the math problem and discuss the number of significant figures to represent. When Charles re-states the answer, he is still using units and paying attention to context.

157. Charles: Okay 3 hours.

158. Alex: Yeah. put "to home" (instructing Charles to write this) ... to, home, yeah.

159. Charles: Eight miles per hour, 24 miles. (as he writes)

160. Alex: Home ... now you can put, he can.

161. Charles: And it only takes 3 hours. (as he writes)

Alex, in response to Charles's utterance with units, turns his framing back to context and adds that this number represents hours "to home."

Without Alex there to act as a bridge, we could easily imagine how Barry and Charles might have talked past one another – their communication completely failing. Barron (2003) presents this as a case of co-construction, illustrating that no one student is presenting whole ideas, but instead the whole idea is present across the group. I argue that this brief analysis reveals Alex as doing pivotal work to understand his peers and that without his frame switching, this productive co-construction would not exist.

Tying this work back to work we have seen students do in the other studies, I propose what we see here is a unique middle ground not illustrated in

the other studies. Instead of the whole group shifting the group framing or an individual shifting their framing without specifically attending to their peers, we see a group member very purposefully shifting his framing in order to create temporary, localized sub-group framings. This is different from shared group framing where all students in the group are in the same shared framing and switch framings together because it is one single student doing the work of identifying their peer's frame and switching to it. It is also different from no shared group framing in that there is at least one student attending to their peers and their framing.

Contribution: Overcoming differences in framing

In the literature reviewed above, we saw whole groups within the same shared framing (Scherr & Hammer, 2005; McCormick & Hammer, 2016; Webb et al., 1995) but also saw that this is not always the case; in many groups, students frame problems differently than their group mates. This difference in student framing can lead to communication concerns within the group. By tracking each individual student's framing, as opposed to the collective framing of the group, we can gain insight into the messiness that occurs in the middle of the spectrum. Despite the messiness of different individual frames, student groups still manage to make progress.

The data I present below is an example of a series of actions students use to get over this hurdle, similar to the one seen in Barron's data: frame switching. When a peer makes an utterance, that student not only interprets the content but also information about their peer's perspective. When responding to their peer,

they might, temporarily, shift their own framing to match that of their peers. By frame switching into a complementary frame to communicate with a peer, these students are doing work critical to understanding one another.

In the case below, I address the same question answered throughout the literature review: *what work do members of a group do to understand other members of the group*? My case directly builds on previous work in a couple of ways. First, there is an example of group divergence. Two students who are initially sharing a group frame, over about a day, start framing the task differently. Second, there is an example of not just one, but two members of a triad using frame-switching to understand their peers.

Methods

Data context.

The CodeR4Stats project explores the integration of data analysis and computational thinking into the high school Statistics curriculum through the design of rich, collaborative activities grounded in real data that is relevant to students' lives. Data for this paper are drawn from a 10-day CodeR4Stats unit in an urban New England public school where 12th graders in a non-AP Statistics course were asked to model the college admissions process of a school of their choosing. The student groups each developed a selection model, which they were then asked to code in the R programming language. Applicant data was generated based on the school they picked, and the groups ran the data through their programmed models to see who got "accepted" to their chosen school.

Data collection.

Each group with full IRB approval was recorded via webcams and supplemental audio recording devices. Additionally, we recorded the computer screens of each individual student within the group. These different pieces of data (video, audio, and screen recordings) were later synchronized for a complete view of data. Student work from these groups turned into the teacher was also collected. The full data corpus from this academic year consists of a month-long series of statistics problems and activities using R from the fall semester, as well as the 10-day project described above which was completed in the Spring semester with the same students.

Participants.

The triad presented in this paper consisted of two white females, Grace and Sara, and one male of color, Victor. As we did not collect self-identifying demographics from the students, these descriptions are the researcher's approximations based on their identity presentation.

Sara was described as a high-achieving student by the classroom teacher. Grace seemed less interested in math and more interested in English, at one point in the year explaining to the researcher of her attempt to get published work in every student publication in the school. Victor was quiet throughout the R units, but during times where the students were working on their computers, he seemed engaged in the task. This is in contrast to many of his peers, who in the throes of spring semester senioritis, browsed the internet and played online flash games in lieu of on-task behaviors.

Data selection.

The data analyzed here are from a single group (described above) on days 4 through 6 of the 10-day unit, where the bulk of the coding took place. This group was selected because in the moment it was clear they made attempts to make sure everyone could contribute to the project by sharing the code on GoogleDocs. Additionally, when reviewing the data afterward, the group was surprisingly functional and talkative despite all the members working on different aspects of the project. The analyzed transcript was chosen from the days where programming was the group's primary activity. The transcript sections presented below were selected due to their representativeness of the group's frame switching behaviors.

Analysis.

During this part of the project, the code plays a central role, so my analysis is focused on how students are framing the code. Due to the project task of modeling a college admissions process, the code itself could potentially take on many different representational meanings. To identify these meanings, I read through the transcript multiple times to refine framings of the code which emerged from the data. I found the following set of framings (see Table 2) presented by the students on multiple occasions. It is important to note that I did not create these framings prior to coding – these emerged during the analysis of the data.

Table 2: Summary of Common Framings throughout Analyzed Data

Framing	Description	Examples
Code as a model of the real world	Code treated as representing the actual university, the	"So here it says [the University] admitted 2142."

	university's desires and referring to 'they'	
Code as functional program	Code talked about as something the computer is going to run, talked about as 'working' or not and discussion of code errors	"Let's see if this [program] works. *runs code* It's not doing anything. It's still not working."
Code as representation of group's admission model	Code talked about as representing the group's model, referring to previous discussions and referring to 'us' / 'we'	"We said at least 2 [extracurricular activities in our model], right?"
Code as backup	Code talked about has been saved or updating code to keep an accurate backup	"Okay, now this is the old code. This this down here is the new code."
Code as program that takes in data	Code talked about as matching data formatting or talk around understanding data	"So [the column on the data set is called] Letters. Oh, hold on. Letters [of recommendation]"

To identify these framings of the code for each line of the transcript was a multi-step process. First, I looked at each individual line of the transcript within the larger context for indications of discussion around 1) the code, 2) programming, or 3) the project. Second, I considered the topic of the utterance, the exact line of the transcript, and the visible code to look for evidence of the student's framing. Using line 4.13 in the transcript presented below as an example, Sara says "How many students are we admitting?". Her screen indicates she is talking about the group's code, specifically a number from the teacher's example that she is trying to change. That particular piece of the code dictates the number of times the for loop runs – and in this project, the number of times the for loop runs is dependent on which university is being modeled. From the word 'we' it is clear she is referencing the group, and therefore this is a question about the group's admission

model. These clues indicate Sara is framing that piece of the code as a representation of the group's admission model.

Finally, I looked at the analysis of the transcript lines to investigate trends over time, the difference between student framings within the group and the influence of students' framings on their group members.

Qualitative Results

Over the three days presented in the transcript below, the group's framing diverges; we see students go from being in the same frame to students being in different frames from their group mates. Once students are in different frames there could be issues with communication, but we see that to navigate their different frames, students switch into their peer's frame.

By the beginning of Day 4, the group had already written an application for the college they are modeling and decided on what factors they are going to consider for their admissions model. Day 4 started with a brief refresher on useful R methods before the students began turning their admissions model into code. The group of three students we are following, Grace, Sara, and Victor, are each sitting at their own computer with Grace in the middle. The two girls, Grace and Sara, start discussing and decide on 2080 as the cut off for SAT scores.

Presented below are eight segments of discourse from longer clips representing each of the three days discussed. Line numbers denote the day and the line from the complete clip transcript. Jumps in line numbers between transcript signal un-presented discourse. For the complete transcript of the clips, see Appendix 1.

Day 4 transcript.

After deciding on the SAT score cut off for their college (completing code lines 1 and 2 in Figure 4), the girls then shift their attention to the other programming notes that had just been discussed and are on the whiteboard at the front of the room. They copy the notes into their RStudio (lines 3-5 in Figure 4).

Transcript	**Framing of Code**
4.09 Grace: i Coding Line 3: {print i}	Functional program
4.10 Sara+Grace: else Coding Line 4: else	Functional program
4.11 Sara: I don't know what's- I forget what's supposed to be over here [referring to ellipses] Coding line 5: {…}	Functional program

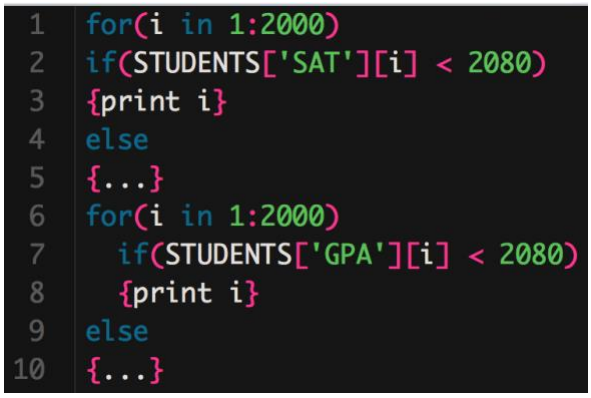


Figure 4: Student code generation

The girls' framing of the situation is trying to create a functioning R program [4.09-4.11]. In this framing, the girls talk about syntax and as we will see later, error messages when attempting to run the code. As they finish copying the if/else decision structure into their loop they try to figure out what goes inside the else block [4.11] and what comes after the completed loop [4.12] (Figure 4: lines 1-5).

With the first part of the program that filters out students with low SAT scores done for now, the students start working on their next criterion: GPA.

Transcript	**Framing of Code**
4.12 Sara: Umm... so we need to repeat that [referring to for loop on lines 1-5] Coding lines 6-10: Pasting from lines 1-5	Representation of group's admission model
4.13 Sara: How many students are we admitting? Looking at code line 6: for (i in 1:2000)	Representation of group's admission model
4.14 Grace: Umm... I don't know Coding line 7: Changing 'SAT' to 'GPA'	
4.15 Grace: What did we say for GPA? *mumbling while typing into Google* Coding line 7: Deleting 2080	Representation of group's admission model

The girls' framing shifts towards trying to represent the group's admission model – proposing that "we need to repeat that" [4.12] because they are basing their decision on more than just SAT scores. This utterance by Sara illustrates her shifting framing from code as functional to code as representing the group model. Sara continues by trying to figure out what number replaces the 2000 on lines 1 and 6 (Figure 4) while Grace sets the cut off for GPA. In line 4.15 we see that Grace has joined in Sara's framing of code as a representation of the group's admission model, as she starts to figure out what GPA cutoff to put on line 7 of the code (Figure 4).

The girls continue trying to answer the questions they propose about the code, by turning to the real data of the school they are modeling.

Transcript	**Framing of Code**
4.16 Sara: I wanna say 4.18 is the average	Model of the real world
4.17 Grace: Let's see what the internet says	Model of the real world
4.18 Sara: So here it says they admitted 2142. [Looking at Grace's search results] Yeah 4.18	Model of the real world
4.19 Grace: Yeah, I just wanna know like the bottom like...	Model of the real world

4.20 Sara: I don't think they put (inaudible) up	Model of the real world

This new framing starts off when Sara recalls the average GPA which the students were required to look up the previous week ("I wanna say 4.18 is the average [GPA]"). The students then sense-make about the collective applicant data set they are looking at, rationalizing that if 4.18 is the average GPA of admitted students [line 4.16], they need a value lower cutoff since average means there are some below that number [4.19 and 4.22]. Grace reverts back to her idea of looking at the bottom 25th percentile number [4.19], which is how they decided the SAT cutoff, but when they cannot find this data [4.20], they call on their own expertise [4.22].

First Sara, and then Grace, shift from their previous framing of functional code [4.09-4.11] to framing the code as a representation of the group's admission model [4.12-4.15]. While framing the code as a representation of their model, the girls often use the pronoun 'we' referring to their past selves. The girls start to think about the code as more of a model of real-world college admissions [4.16-4.20]. In this framing, they leverage data they have found about the real university's students body (4.18 average, 2142 admitted students, 42497 applicants) as well as calling on their knowledge of the school system in general ("We could do like 3.8 or something… Cause that's still like an A"). Below, on line 4.22, Sara switches back to the 'we' pronoun, creating another framing shift back to the group's admission model. Because the girl's framing of the code as a representation of the real world is bookended by framing the code as the group's admissions model and the topic of GPA and number admitted holds through the

framing changes, it is likely that instead of completely switching frames, like we see in the shift from viewing the code as functional code, that the girls are nesting the framing of real-world college admissions inside the framing of the code as their group's model. This nesting comes about as they need information to complete the group's frame, so they temporarily go to look at the school's facts and figures, before using those to answer their initial question.

Transcript	**Framing of Code**
4.21 Grace: It's true	
4.22 Sara: We could do like 3.8 or something	Representation of group's admission model
4.23 Grace: okay Coding line 7: Typing 3.8	
4.30 Sara: Oh, it says here that 1% were admitted with a GPA below 3.7 so Coding lines 11-20: Pasting lines 1-10	
4.31 Grace: Okay, I'll change this to 3.7 - for now. Coding line 7: Changing 3.8 to 3.7 Extracurriculars? We gave the value of- Coding line 12: Changing 'SAT' to 'Extracurriculars'	Representation of group's admission model
4.32 Sara: We said at least 2, right?	Representation of group's admission model
4.33 Grace: Greater than 2	
4.34 Sara: So greater than 1 Coding line 12: Changing 2080 to 1	

Their framing of the code as a representation of the group's admission model persists in the final snippet of the transcript. Interpreting their model and representing it with code is going well despite a few hindrances such as translating the criteria ("at least 2" extracurriculars gets translated to "greater than 2," but the mistake is easily caught "So greater than 1").

Throughout this day's transcript, we see some group shifts in framing of the code as a functional program, to the code as a representation of the group's

admission model, to the nested framing of code as a model of the real world, back to the code as a representation of the group's admission model.

Day 5 transcript.

Below, unlike the day before, the girls are in different framings and talk past one another. While Sara is trying to think about how to represent what state students come from numerically (which they call Geography), Grace tries to get the code to work. There is no evidence that either girl hears what the other is saying.

Transcript	**Framing of Code**
5.23 Grace: Let's see if [the code] works. *runs code* It's not doing anything. It's still not working	Functional program
5.24 Sara: Let me ask [the researcher about] Geography(inaudible)	Representation of group's admission model
5.25 Grace: Okay, I'm going to delete this [referring to for loop looking at letters of recommendation where the error is being thrown].	
5.26 Sara: So like geography wise we want like...	Representation of group's admission model
5.27 Grace: I'm deleting some of [the code] temporarily just so I can see if what we have right now works	Functional program Backup
5.28 Sara: Or do we want it [the student geography data] numbered by region? No, I don't like that.	Representation of group's admission model

The girls start this snippet in different frames: Grace framing the code as a functional program and Sara framing the code as a representation of the group's admission model. We see Grace's frame shift [5.23 to 5.27] from solely the code as a working R program to also include elements of the framing of the GoogleDoc code as a record. By leveraging this nested framing of having a backup, she is comfortable "deleting some of this temporarily just so [she] can see if what [they] have right now works" [5.27].

While the day before and earlier this day both girls were in the same frame, because Sara now has access to the group's code she starts to diverge from Grace's attempt to get the code to work and instead continues trying to represent their admission model (the part that considers where an applicant is from) in a quantified way that the code will be able to interpret. We see that access to the external representation affords Sara the ability to do some work on her own – in a productive way but on a separate part of the project.

While Day 4 illustrated one end of the group framing spectrum, shared group framing, Day 5 illustrates the pair on the other end, no shared framing. This day's transcript illuminates the fact that the girls did not instantly start frame-switching in lieu of their shared framing and that they, temporarily, looked like a rather dysfunctional group. However, groups are dynamic, and in Day 6 we see an example of this same group in the middle of the spectrum, a group with lots of frame-switching.

Day 6 transcript.

The next school day, the students receive their custom-generated applicant data to run through their model. Grace tries to upload the data into RStudio, which blocks any work on the code in the environment while it uploads. Unable to make progress in the coding environment, Grace is forced to code inside GoogleDocs. For additional context, I have provided code changes on GoogleDocs in boxes where new code is bolded and colored and deleted code is crossed out.

Transcript	**Framing of Code**
6.01 Grace: Okay, now this is the old code. This this down here is the new code	Backup
6.02 Sara: New code	Backup

6.03 Grace: Let's see. List umm... Grace Coding on Line 1: list	Functional program
6.04 Grace: array students. Geography. Okay, but where do I go from here? Grace Coding on Line 1: list(arraySTUDENTS[[‘Geography]]	Functional program
Victor coding on Line 1: list(arraySTUDENTS[[‘Geography’]]	Functional program
6.05 Victor: Wait, why do we have geography?	

Grace starts this snippet by calling attention to the logging aspect of the GoogleDoc representation before trying to code the part of the model that considers where the applicant is from. Unlike before with SAT and GPA, and possibly foreshadowed by Sara’s comments about how to represent geography quantitatively in the last snippet, Grace seems stuck, asking “where do I go from here?” [6.04]. Victor makes a small syntactical correction on the code Grace just typed into GoogleDocs [6.05a] – providing the support she has lost due to moving away from RStudio, which would have marked the code as wrong – before asking about what the code has to do with their model [6.05b].

Grace is not the only one here doing work to attend to their peer’s framings. Sara’s utterance [6.02] is the first example of her frame-shifting to match Grace’s frame – up until this point Grace had been shifting in response to Sara’s framing. We also see that Victor is attending to Grace’s framing [6.05a] before posing a question [6.05b].

The transcript continues as Grace continues trying to answer Victor’s question.

Transcript	**Framing of Code**
6.06 Grace: Umm, because they do consider where you're from	Model of the real world

6.07 Victor: So you-	
6.08 Grace: Cause they want like a diverse class so like, they don't want like everyone to be from like California and New York, - from like North Dakota and stuff. It also makes them look better - like we have people from every state in the country. Even like Wyoming	Model of the real world

Up to this point Grace move frames from the GoogleDoc as a way of recording versions of code [6.01], to coding in it to create a working R program [6.03], and then with Victor's prompting, to code as a representation of the real world [6.06]. Victor asks a follow-up question, causing Grace to frame-switch yet again.

Transcript	**Framing of Code**
6.09 Victor: Yeah, but would you say like geography has to be from - like how would you write that in code?	Functional program
6.10 Grace: Well umm we're listing them 1 through 52, 51 being Washington DC, 52 being other countries. I don't know where to go from here. *mumbling* List array students geography	Functional program
6.11 Grace: *typing into Google* ascending	
6.12 Sara: *looking at generated data* So we need to talk about some stats. I assume a 1 means 1 generation. I don't see any twos. Unless a 1 just means they have (inaudible)	Program that takes in data
6.13 Grace: Umm... *typing*order Grace coding on Line 1: ~~list~~order(arraySTUDENTS[[‘Geography’]]	Functional program
6.14 Grace: Okay... umm. I still don't know how to do this	Functional program
6.15 Sara: Did you go to <WEBSITE>?	Functional program
6.16 Sara: So Letters. Oh, hold on. Letters Sara coding on different line: if(arraySTUDENTS[[‘LETTER~~S_best~~’][i]<6)	Program that takes in data
Grace coding on Line 1: ~~newdata(~~arraySTUDENTS[~~[‘Geography’]]~~order(Geography),] 6.17 Grace: I still think it's wrong.	Functional program

We see as Grace continues to address Victor's question, she frame-shifts [6.10] when she sees evidence he is in a different frame [6.09]. Grace then turns back to

trying to write functional code. Sara comes into the discussion, focusing on the newly received data [6.12], making sure that the code they have will be able to interface with the data set [6.16]. Sara is temporarily pulled into thinking about troubleshooting non-functioning code by Grace, suggesting the teacher's website as a resource [6.15] before turning back to ensuring that the column headers on the data set to match the categories in the code – correcting a discrepancy in naming for letters of recommendation [6.16]. This is the second example we see of Sara frame-switching to communicate with Grace.

Discussion

In the results above, I illustrated an example of one action, frame-switching, which students use to continue to understand one another after diverging their frames. This example suggests that when a student in this group hears an utterance, that student not only interprets the content but also information about their peer's perspective. When responding to their peer, the students above temporarily switch their own framing to match that of their peers. By frame switching into a complementary frame to communicate with a group member, these students are doing work that is critical to understanding one another.

The Grace, Sarah, and Victor case is particularly useful because we do not have the same scope of data from the re-interpreted studies. For example, in Webb et al. 's case (1995) we cannot make a clear conclusion on interpreting D's utterances due to lack of transcript and tone of voice represented in the original paper. Similarly, in Barron's work (2003), while we have more transcript, the presented data represents only a few minutes from one point in time. By

establishing this series of actions over a number of days, we see that this is not an accidental occurrence but work, effortful or not, that students are doing to understand one another.

Understanding the work of frame-switching as a 2-part process.

As I have discussed frame-switching as a series of actions, I want us to consider how frame-switching occurs. I propose frame-switching is a 2-part process. First, students have to recognize their peer's words as not making sense in their current frame. This recognition of their peer being in a conflicting frame triggers the next part of the process: students *trying* to make sense of their peer's utterance. This second step could occur in a number of ways. As we saw earlier, there can be different amounts of work to group frame-switch (as seen between the lab group seamlessly switching shared frames in Scherr and Hammer (2009) and the two members of the triad vying for the third's vote to enforce majority rules in Oliveira and Sadler (2008)). It makes sense that individual frame-shifting can also take different amounts of work.

The "easiest" way for the second step, students making sense of their peer's words, to occur is for students to re-interpret the utterance in different readily available framings until it makes sense. This is what we see in the data above. While in a shared frame at the beginning of the case, the girls activate the four main framings of the project (see first four rows of Table 2), they later use these same four framings after diverging. Switching is then a matter of recall.

Another example of this is Barron's data (2003) of one boy alternating frames to match the group mate that was speaking. While it is hard to make

claims without more transcript in the above cases, the seemingly easy transitions in Barron's data above might hint that it falls into this category. As one boy transitions between the two frames of math and context, it is clear that, especially after a couple of frame-shifts, he is simply activating a recently activated frame.

Another "harder" way for the students to make sense of their peer's words is for them to create a new framing. A new frame would need to be built if none of a student's easily called upon framings would help decipher their peer's utterance. In the literature, Roschelle (1992) illustrates an example of framing convergence.

Finally, students might choose not to make sense of their peer's utterance. One possible reason groups stay in conflicting states is they reach the point where they recognize the need for a new or different frame and then do not or fail to do the work. Turning to the example of students in conflicting states in Webb et al. (1995), it seems like one student, student B who is framing the assignment as a chance to understand the content, recognizes student D's different framing of trying to get the assignment done quickly. Student B protests this framing of speed, imploring student D to give their group mate a chance to *understand* the problem instead of copy the answer. It is possible that student D continues in his speed framing after the transcript ends. While student B recognizes the difference in framing, either the lack of recognition by others, such as student D, or their failure to shift frames, leaves the group in conflicting frames.

Implications

Whether it is making sure everyone speaks or has a turn on the computer, we should consider what work is being done in the group before creating a contextual force that might disrupt a productive group framing (as we saw the teacher do by praising vocabulary in McCormick & Hammer, 2016). Teachers should consider not only *who* is talking in the group or doing what task, but also *how* students are talking to and possibly, more importantly, listening to one another. We need to spend the time and effort to pay attention to work already being done in groups before we intervene. Along those same lines, researchers who study group work need to consider all of the work students are doing to understand one another before dismissing it. While many studies call attention to inequities in participation (Lewis & Shah, 2015; Shah, Lewis, & Caires, 2014) or describe group marginalization of members (Dookie, 2014; Dookie, 2015), it is important not to be so focused on dysfunction as to ignore the work students are doing.

Limitations and Future Work

An important argument I made at the beginning was that framing, as a construct, can help create a theoretical underpinning for what on the surface appear to be many disjoint collaboration studies. However, the portrayal of the rich framing literature in this paper has been simplified in order to focus on comparing frames across individuals. Throughout much of this paper, a reader might infer that frames are static, often pre-constructed, objects students can switch in the literal sense (much like switching a frame on a painting). Future work would need to

address the many pieces of framing literature touched upon here, such as the fact framing is a dynamic process involving resources assembled in the moment.

This work would help uncover even more dynamics. For example, because frames "are active and responsive, perpetually evolving as they are informed, shaped and tuned with new experiences" (McCormick & Hammer, 2016, p. 47) the experiences of past utterances with a partner can help shape a student's framing in a way that is increasingly aligned over time. This could be another form of frame maintenance only seen with a more traditional framing analysis.

Another way framing literature might help in future work is explaining the type of divergence seen in this data. While it might be tempting to look at divergence as a failure to frame-switch into their peer's framing, as we see in the case above, the two girls continue to switch frames readily. One possible explanation for why the girls are able to switch around to different framings while staying on the same page is they might share an over-arching framing of 'what kinds of things are we doing for this project?' while switching around the local frames which answer the question of 'what am I doing now?'

Conclusions

There is a lot of work happening in student groups so that students can understand one another. Framing is a useful construct for tying together a wide variety of the literature's ideas about collaboration and illuminating the work happening in groups. Through framing, we see one such dynamic, frame-switching, where students are both recognizing a difference in framing and then shifting into a complimentary frame. While students are doing all this work, teachers should be

wary of disrupting group dynamics through intervention. On a similar note, researchers should be wary of dismissing the work done in group dynamics – even when groups are unsuccessful.

Chapter 5: Unpacking How Students Listen to Group Mates: Secondary Listening, Secondary Sourcing, and Attending to Framing

Abstract

Previous research has illustrated that student discourse affects the output and learning outcomes of student groups. I build on this literature by presenting a different focus; while many studies have made progress looking at the literal meaning of a student's words to another student (e.g., type of response to peer's proposed idea), I look for evidence of student listening. I propose that listening happens along multiple dimensions and that collaborative groups are doing a lot of work to understand not only the explicit content of utterances but also the implicit messages from their peers.

This paper presents data from a project to infuse computing into a high school statistics course. I analyze three episodes of video data to illuminate the different types of listening students are doing and to refine methods for identifying them. Using these methods, future work can identify the work students are doing to listen to their peers, even in situations where groups do not seem to be communicating effectively. Once developed, this body of literature on how students are working together in groups will help inform how to support students' development of effective group work practices.

Introduction

Previous work points to student discourse as a major factor for whether groups are successful or not in producing output or on subsequent tests (Webb, 1984; Chizhik, 2001; Barron, 2003). For example, Chizhik (2001) looked at which

students got opportunities to give explanations to peers during group work – concluding that giving explanations led to better achievement scores after group work. Barron (2003) coded how students responded to peer's proposals, noting that engaging responses such as acceptance and discussions (i.e., questions or presenting reasoning) led to more correct answers than rejecting or ignoring proposals. However, Webb's work looking at the discourse between peers giving and receiving help in math indicated that "the level of help that students received…did not predict achievement" on the post-test (Webb, Troper & Fall, 1995).

One possible reason Webb et al.'s (1995) study did not find a direct relationship between the level of help students were providing to their peers and achievement is that it did not account for the action happening between two turns of talk: listening. Whether it was between a request for help and an explanation or between a proposal and a response, the students in the group were presumably listening to their groupmates. However, there are currently no frameworks in the literature to study listening in student group discourse. To create one, I build on van de Sande and Greeno's re-conceptualization of "constructive listening" by introducing 'attending to student framing,' 'secondary listening,' and 'secondary sourcing.' I use this augmented framework to explore the data.

Theoretical Framework: Perspectival Framing

Greeno and van de Sande's (2007) work on *perspectival understanding* is one of the few research studies that explicitly calls out students listening to each other. While the paper is primarily about bridging a "situative" and "cognitive" lenses,

during this work, the authors conceptualize discourse as a joint act where "a minimal unit of conversation… includes a presentation by one of the participants and acceptance of that by (an)other participant(s)" (p. 11). Using this conceptualization of joint act discourse on data, Greeno and van de Sande (2007) name 'constructive listening' as "a property of activity that seems to be required for success in constructing perspectival understanding" which is a group's knowing and understanding (p.17). They define "constructive listening" as

> *"attempting to understand the perspective of (an)other participant(s). That is, there were one or more inquirers and an informant. The effort on the part of the inquirer(s) was significant, involving active questioning of the informant, careful attention to the informant's statements including inferences of his or her meaning, and substantial work in finding relations between elements contributed by the informant to construct a coherent organization of ideas and information. The communicative interactions in these episodes were not symmetrical – the inquirers and the informants contributed different functions to the interaction. Even so, they were highly cooperative and mutually effortful, with the informants attending to the inquirers' questions and providing information and suggestions helpfully" (Greeno & van de Sande, 2007, p.17).*

In this 2007 work, Greeno and van de Sande do not offer explicit markers of listening. For that, I turn to their more recent work.

Van de Sande and Greeno (2012) develop their theory of perspectival understanding into perspectival framing, in two distinct ways. First, the authors connect their previous idea of "coherent organization of ideas and information" to framing literature. Additionally, they explicitly delineate three dimensions of framing (positional framing, epistemological framing, and conceptual framing) based on their previous two lenses (situative and cognitive).

Their previous idea of "constructive listening" has been re-conceptualized as "positional framing" but many of the ideas behind constructive listening remain. Most readily apparent, the two roles of inquirer (re-named "listener") and informant (re-named "source") have distinct functions which contribute to constructing "a coherent organization of ideas." This re-conceptualization grounds their idea in framing literature, which offers a methodology for identifying constructive listening, and illustrates how the idea of positional framing is influenced by and influences students' conceptual and epistemological framings. We start the discussion of each of these connections to the literature by reviewing the construct of *framing*.

Framing.

Framing explores how people answer the question 'What is going on here?' as they participate in a social activity (Goffman, 1974). Frames are constructed based upon situational cues and shape what a person pays attention to and how they make sense of things. If a student is told to "think of variables" in a mathematics class, they may think of a letter used to represent a set of numbers that satisfy certain constraints ($x > 3$). If they are in a computing class, they may think about a way to label and store data (myData = **[]**).

Frames are context dependent, and small changes to a situation may change what students perceive or expect (McCormick & Hammer, 2016). For example, if a student in a computing class is told to "think of variables" while struggling with a programming task, they may interpret this to mean that there is an error in how they are declaring and setting variables in their program. But if

they are told to "think of variables" at the beginning of a new unit, they may expect to be introduced to a new data type. In this way, frames are "structured expectations formed from previous experiences…active and responsive, perpetually evolving as they are informed, shaped and tuned with new experiences" (McCormick & Hammer, 2016, p.47).

People communicate their framings to others. These communications of framings between people could be thought of as Bateson's idea of meta-messages. "In any normal relationship there is a constant interchange of metacommunicative messages such as 'What do you mean?' or 'Why did you do that?' or 'Are you kidding me?' and so on" (Bateson, 1987, p. 215). This communication happens through the same utterances of discourse. Tannen (1993) explains "notions of script, frame, and schema can be understood as structures of expectation based on past experience, and that these structures can be seen in the surface linguistic form of the sentences of a narrative" (p. 53). Tannen's work (1993) illustrates a number of ways framing can be seen in discourse. For example, "a negative statement is made only when its affirmative was expected" (Tannen, 1993, p. 44).

The methodology I use is based on Tannen's work illustrating that these meta-messages or framings can be seen through surface-level indicators. The discourse-centered methodology is introduced in the Methods section. In the section below, I return to Van de Sande and Greeno's (2012) study by describing their three dimensions of Perspectival Framing, which they conceptualized using framing literature.

Perspectival framing.

Van de Sande and Greeno's (2012) notion of *perspectival framing* emphasizes that frames are likely to differ across people as a result of the different sets of knowledge and schemata they hold based on their individual experiences and perspectives. Perspectival framing contributes analytic tools to highlight how an individual's framing of a situation influences what knowledge they bring to bear, and how they perceive themselves and others. Van de Sande and Greeno identify three dimensions of perspectival framing: epistemological, conceptual, and positional.

Epistemological framing is "participants' understanding of kinds of knowledge that are relevant for use in their activity and the kinds of knowledge, understanding, and information they need to construct to succeed in their activity" (Van de Sande & Greeno, 2012, p.2; see also DiSessa, 1993). In deciding what knowledge is needed to succeed in an activity, students are also deciding what they perceive the activity to be. A student's epistemological framing answers the question 'What is my goal for this activity?' In a group setting, productive groups would share an understanding of the activity goal. Scherr and Hammer (2009) present how a physics lab group navigates between four different epistemological framings while staying within a shared framing (discussed below). This requires the students to 'hear' or identify proposed epistemological framings.

Conceptual framing is "the way or ways in which participants organize information in the situation they are discussing and the problem they are working on" (Van de Sande & Greeno, 2012, p.2). Given how they frame a

situation, a person will have a set of expectations about a situation that will cause them to foreground and background different knowledge resources. A student's conceptual framing answers the question 'What do I already know that can help me accomplish my goal?' In a group setting, productive groups would share similar conceptual resources. Roschelle (1992) presents an example of conceptual convergence among a pair of girls exploring a physics simulation. This required each girl to 'hear' or understand the other's proposed conceptual understandings.

Positional framing refers to the way participants understand everyone's role in a situation. Positional framing "includes a human participant who is inquiring, which we call a listener, and a source, which may be another human participant or a non-human system" (Van de Sande & Greeno, 2012, p.1). The role of the source is to act as the main authority on the disciplinary material. The role of the listener is fluid; the listener can be a simple recipient, a director of "the interaction, actively questioning the source," or a role was taken up "actively and jointly by more than one participant acting collaboratively" (Van de Sande & Greeno, 2012, p.40). A student's positional framing answers the question 'What is everyone's role in accomplishing the goal?' In a group setting, productive groups would have a shared understanding of everyone's role. Goffman (1979), as well as Van Langenhove and Harré (1999), talk about how people negotiate positioning. This negotiation not only consists of bids but also requires people to 'hear' or recognize the proposed positioning in order to respond.

Van de Sande and Greeno (2012) argue that all three of these types of framing are interrelated. The knowledge a student leverages for an activity (conceptual framing) depends on what knowledge that student thinks is relevant to accomplish their goals (epistemological framing). Knowledge (conceptual framing) changes for a listener as they receive information and restructure their understanding accordingly, and may change for a source as they adapt the information they are communicating to the listener's needs. The position of listener and source (positional framing), or the information that each seeks and provides, may change as participants recognize different goals or knowledge (epistemological framing) to be at play.

Van de Sande and Greeno (2012) present data illustrating not only the interplay between these dimensions but also noting whether groups of students were within the same framings or not. While their work illustrates the use of Perspectival Framing on a small selection of data, there is some work to be done to use this framework to illuminate listening in group settings.

Using Perspectival Framing To Identify Listening

In order for perspectival framing to be applied to identify student listening, we need to address the questions which arise from this shift in focus. First, how do we refine positional framing so that it embraces students not only as sources for disciplinary knowledge but also as sources for understanding and interpreting what is known? Second, if perspectival framing is based on the idea that every person's perspective and framing is different since they have unique experiences, how do we conceptualize two students understanding each other? Finally, how do

we anticipate seeing evidence of students listening to or receiving these meta-messages of their peer's framings? Below, I address each of these questions.

Secondary listening.

We first consider the type of listening done along the positional dimension and build on it to include students as sources of their own understanding. It is important to take a moment to reflect on the difference between the use of 'listener' and 'listening' in this paper. 'Listener' is a role or position while 'listening' is an action. Similarly, 'source' is a role or position while 'providing information' is an action. As we continue, please note that just because an individual is described as 'listening,' it does not necessarily mean that the individual is positioned as the 'listener.'

Going back to the construct of framing, frames can be nested within one another. For example, in Tannen's study (1993) where participants were asked to recount a short film she showed them, she "[considers] these various levels of expectation structures in turn, in order of scope (that is, from the overriding context, subject of experiment, to the relatively narrow object level)" (p. 22).

Similarly, I propose the role of the source is a nested one; the source must act as the main authority on disciplinary material while taking up a temporary, *secondary listener* role to understand the primary listener's conceptualization of the material. This nested secondary listener role can be thought of as the listening a lecturer might do as they lecture. While the lecturer's source role is to provide information to the student listener, some sources will take this a step further to engage in secondary listening to ensure that their information is actually being

received by the listener. A lecturer taking up the secondary listener role might ask questions during lectures or read students' work while asking themselves: Are the students (as listeners) understanding what I am saying? How does a given student listener think about this disciplinary concept?

Evidence of secondary listening might look like re-stating an explanation in a different way after hearing the listener ask questions or try to re-state it. The source might take cues from the listener's facial expressions, the tone of voice, and body language to figure out if the listener is confused or stuck. The source might see evidence of the listener's understanding of answers on a worksheet or code on a computer screen.

Secondary Listening might also look like students discussing a data science project (Figure 5).

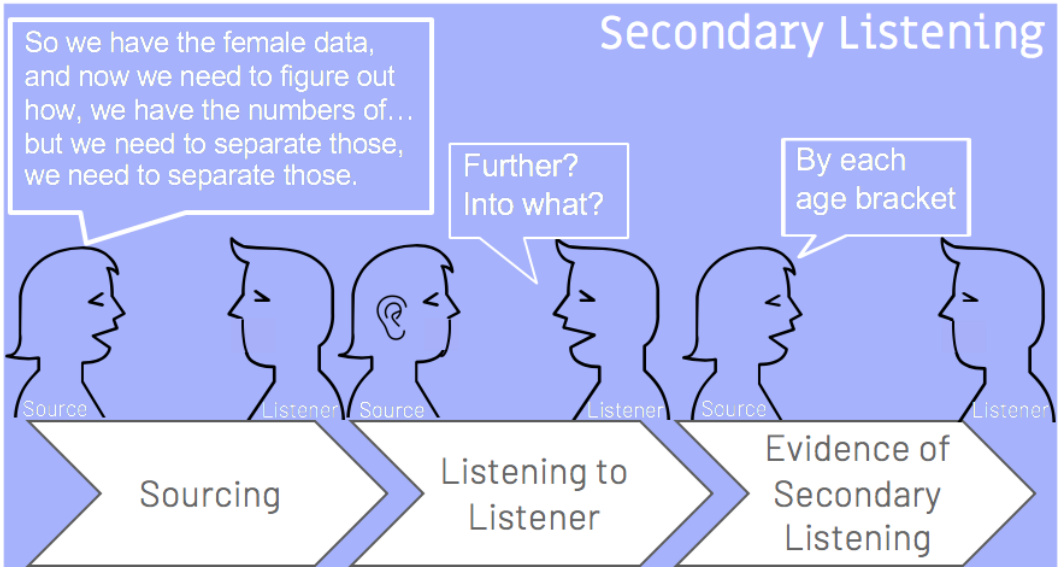


Figure 5: Example of Secondary Listening from data

One student, the source, provides a status report on where she is with filtering the data. Her partner asks a clarifying question, unsure how she wants to separate the

data further. You will notice that in the first explanation, there was no mention of age – it was only after the question asking about the next filter that the source provided this new information to the listener. This introduction of new information due to the listener's question provides evidence that the source was secondary listening.

Secondary sourcing.

In addition to this nested secondary listener role, I also propose a *secondary source* role. A listener who is actively asking questions, trying to re-state explanations or give other kinds of feedback to the primary source would serve as a source of their own understanding. While the primary source is the source of information for the discipline, the listener taking up the role of the secondary source is the source of information of the listener's understanding of that content. I consider the attempts to incorporate what the primary source is saying and giving feedback, particularly asking questions, to be active work.

An example of secondary sourcing might be those same students having a discussion about what to name the data now that it is filtered by age bracket (Figure 6).

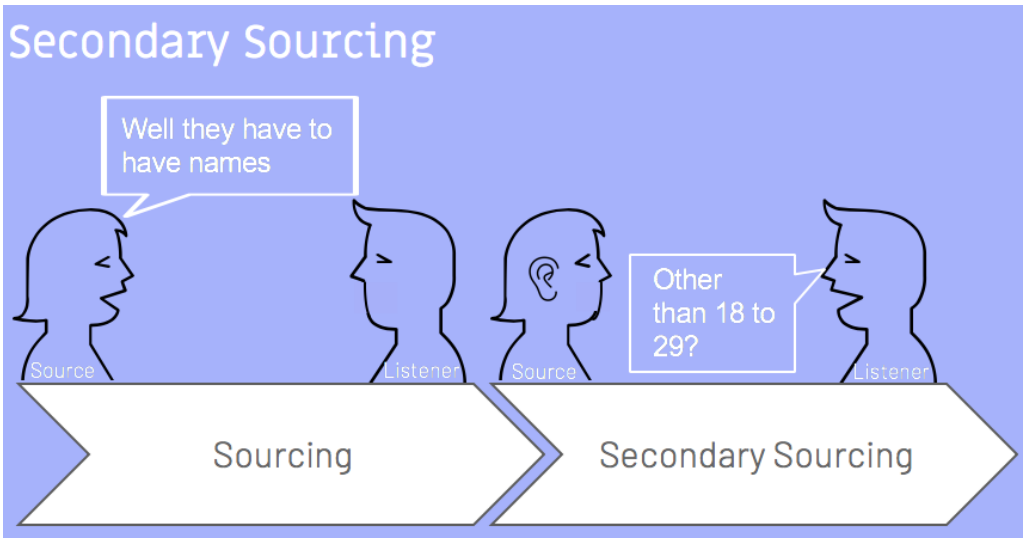


Figure 6: Example of Secondary Sourcing

The source is trying to put the data into variables and asks her partner what to name them. When her partner seems confused, she insists that "they have to have names." The listener, still puzzled, clarifies "other than 18 to 29?" This move is the source attempting to understand why the age brackets are insufficient names.

This active work to source understanding goes beyond understanding the information the source presented; it can also include sourcing their understanding of the problem at hand. Phillips, Watkins, and Hammer (2017) call the work students do to identify gaps in one's understanding required to ask questions "problematizing." Student problematizing includes "moments of students trying to determine what the gap or inconsistency was in their understanding, as well as moments of students, convinced themselves, trying to convince their classmates that something was missing or amiss" (Phillips, Watkins, & Hammer, 2017, p. 9). This means that listeners who actively ask questions and give feedback about their understanding are doing work to identify gaps in their understanding and convince the primary source that there is a gap. This work is not described in Van

de Sande and Greeno's conception of the listener role, so I propose this is the work done in the nested role of secondary source.

Listening to framing in group contexts.

As introduced above, in productive group settings, students might share framings. This idea of complementary or conflicting frames is referred to as "Framing Alignment." While framing alignment (discussed in the next subsection) is a part of Van de Sande and Greeno's framework, I propose adding the construct of "attention to framing" (introduced in the subsequent subsection) to Perspectival Framing in in order to address the question of *how* students are doing the work of identifying their peer's framings through listening.

Framing alignment.

Van de Sande and Greeno (2012) emphasize that perspectival framing is rooted in individual perspectives. People may have different expectations for what is going on, different sets of knowledge that they may or may not leverage, and different understandings about who should be the source or listener during an activity. Thus it is unlikely groups will automatically agree in their framing of a task.

Framing alignment is defined as a way for participants to co-construct framings of a situation (Van de Sande & Greeno, 2012). If two students are employing contradicting frames, they will reach a moment of conflict. For example, if one student frames an assignment as an occasion to demonstrate knowledge and another student frames the task as a chance to check for understanding of previously learned concepts, one student might want to work

quickly while the other may wish to take time and review why they got a particular answer. In order for this group to make progress, one or both of the students will need to shift their framing to align with the other student. When their frames align, the conflict resolves, signaling mutual understanding of the task at hand.

Framing alignment has been explored in other work. Scherr and Hammer (2009) explored framing in a collaborative educational setting through an analysis of student behaviors including vocal register, gestures, and body language. They identified four clusters of behavior they argued indicated different shared framings of educational activities: (1) completing worksheets, (2) discussion, (3) responding to the Teaching Assistant, and (4) joking. For example, completing worksheets was characterized by students with their heads down, writing. Discussion was characterized by students' heads up, shifting gaze to one another and activity materials.

Scherr and Hammer's analysis revealed that individual students would often make bids to move the group from one *epistemological frame* to another through body position. For example, when a student was done working on a worksheet problem, they might sit up, ready to discuss. If after a few moments no member joined them in the new proposed frame, the student would typically revert back to completing worksheets. This demonstrates that students often work to negotiate shared frames during collaborative activities and that such negotiation is not always straightforward.

Van de Sande and Greeno (2012) tracked framing over time to explore how students in a group reached *conceptual framing alignment* through talk. They presented three ways that participants' conceptual framings can be aligned: (1) participants possess and activate knowledge structures that are well-aligned, (2) the listener lacks pre-existing knowledge consistent with the source and therefore uses information from the source to construct a new knowledge structure, or (3) both participants lack pre-existing schemata, and switch roles as listener and the source to jointly construct new knowledge structures. These processes for reaching alignment have different levels of complexity in terms of the work that is required and the learning that is achieved. For example, an activity that requires students to activate the same pre-existing schema, like something previously learned in class, is likely to be less complex and produce less new knowledge than one where students need to construct a new conceptual frame jointly.

Positional framing, which is built on the construct of positioning (Van Langenhove & Harré, 1999), is likely also negotiated in interaction. For example, a student might take up the role of source by stating an answer. Their peer may respond in a way that accepts the role of listener (for instance, by asking for clarification about the answer provided), or by making a bid for the source position (by critiquing the answer provided). The latter represents a misalignment of positional framings; this misalignment could be renegotiated or resolved by future interactions between the students and other materials or people involved in the activity. For example, students may achieve realignment of positional framing

by agreeing to consult a textbook, positioning both of themselves as listeners relative to a material informational source.

When discussing framing alignment along these three dimensions of Perspectival Framing (conceptual, epistemological, and positional), the most noticeable features within discourse are the mismatch of framings or shift in framings. While it might be possible to show through features like body position that groups are within aligned framings, the contrast during moments of unaligned framing will probably be more noticeable. As I conceptualize and operationalize the ways students are listening to one another, I note that discursive evidence might be most prominent in situations where framings are unaligned and do not take lack of evidence to mean lack of listening.

Attention to framing.

In addition to secondary listening and secondary sourcing, I also add *attention to framing* as a marker of listening to perspectival framing to conceptualize how students are receiving meta-messages from their peers.

Attention to framing could be thought of as the receiving part of Bateson's idea of meta-messaging. Bateson discusses signs that these metacommunicative messages are transferring between two monkeys playing in a zoo: "this phenomenon, play, could only occur if the participant organisms were capable of some degree of metacommunication, i.e., of exchanging signals which would carry the message 'this is play'" (Bateson 1987, p. 179). Translating this back to humans in an educational context, I explicitly call out the type of *attention to framing* that a student might do, such as reading facial expressions, listening to

voice pitch or attempting to identify the underlying conceptual conflict behind a question (as opposed to just answering it).

These pre-requisite efforts of attending to framings do not always lead to successful framing alignments – but they should be recognized as the beginnings of important group work skills. Even when student framings do not align, attending to framings can reveal opportunities to negotiate framings along certain dimensions. As an example of unaligned framing, I present data from Tannen and Wallat (1987)'s framing analysis and re-interpret it through the construct of attending to framing. While the authors discussed this data as mismatched schemata, I argue that there is still important work being done by the Doctor to recognize the Mother's conception of 'health' and even attempts to shift the Mother's framing of what 'healthy' means for a child with cystic fibrosis.

1. Doctor: Jody? . . . I want to look in your ears. . . . Jody?
2. Mother: This problem that that she has, . . . is not . . . interfering with her breathing, is it?
3. Child: /Hello/ [spoken into ophthalmoscope]
4. Doctor: No.
5. Mother: It just appears that way?
6. Doctor: Yes. It's very . . . it's . . . really . . . it's like floppy you know and that's why it sounds the way it is.
7. Mother: She worries me at night.
8. Doctor: Yes

9. Mother: Because uh . . . when she's asleep I keep checking on her so she doesn't~
10. Doctor: As you know the important
11. Mother: I keep thinking she's not breathing properly. [spoken while chuckling]
12. Doctor: As you know, the important thing is that she does have difficulty with the use of her muscles.
13. Mother: mhm
14. Doctor: So she has difficulty with the use of her muscles, . . as far as the muscles of her chest, that are used with breathing. Y'know as well as the drooling, the muscles with swallowing, and all that so all her muscles
15. Mother: Is there some exercise /to strengthen or help that/.

The Mother presents a concern about interference with her daughter's breathing (line 2), but the Doctor quickly informs her that there is no interference (line 4). When the Mother is still concerned (line 5), the Doctor reassures the Mother (line 6) by trying to explain the perceived symptom of noisy breathing. When the Mother continues to insist that her child's breathing is not normal or healthy (lines 7, 9, 11) the Doctor hears that her attempts to connect the Mother's existing knowledge of cystic fibrosis to the breathing sounds are failing. The Doctor takes this failure as a sign that the Mother does not have her knowledge of cystic fibrosis in her current conceptual framing – which could be why the Mother did not pick up on the word 'floppy' – the Doctor's alluding to Judy's muscle

weakness caused by her cystic fibrosis. The Doctor instead attempts to align their conceptual frames by explicitly calling out what knowledge she views as missing from the Mother's conceptual framing (line 14). In line 15, we see that despite the Doctor's recognition of framing misalignment through attending to framing and even an attempt to align their frames, the Mother is still not connecting this weakness back to her understanding of her daughter's cystic fibrosis.

Later in the examination, the Doctor is listening to the daughter's breathing, and the Mother once again comments about how noisy her daughter's breathing is.

16. Doctor: Now I want you to listen, Jody. We're going to listen to you breathe. Can you? Look at me. Can you go like this? [inhales] Good. Oh you know how to do all this. You've been to a lot of doctors. [Jody inhales] Good. Good. Once . . . good. Okay. Once more. Oh you have a lot of extra noise on this side. Go ahead. Do it once more. Once more. –
17. Mother: That's the particular noise she makes when she sleeps. [chuckle]
18. Doctor: Once more. Yeah I hear all that. One more. One more. [laughs] Once more. Okay. That's good. She has very coarse breath sounds um . . . and you can hear a lot of the noises you hear when she breathes you can hear when you listen. But there's nothing that's

19. Mother: That's the kind of noise I hear when she's sleeping at night.
20. Doctor: Yes. There's nothing really as far as a pneumonia is concerned or as far as any um anything here. There's no wheezing um which would suggest a tightness or a constriction of the thing. There's no wheezing at all. What it is is mainly very coarse due to the . . . the wide open kind of flopping.

The Doctor confirms the symptoms the Mother is concerned about (lines 16, and 18) but once again tries to explain that for a child with cystic fibrosis this noisy breathing is not a concern. To illustrate this point the Doctor lists off things the Mother might think the noisy breathing is associated with such as pneumonia or constriction, assuring her that these are not actually present (line 20). The Doctor ends this utterance by once again alluding to the muscle weakness caused by cystic fibrosis, stating the muscles are "flopping." I propose that the fact the Mother did not seem to connect this noise with cystic fibrosis despite the Doctor's efforts to make these connections was noticed by the Doctor. In response, the Doctor tried yet another approach of eliminating other concerns to attempt to align the Mother's framing to hers.

While this is the end of the presented data and we do not see if this approach worked, we do see the 'attending to framing' the Doctor is doing as she attempts to help the Mother understand. Instead of constantly trying one approach to explain the cause of symptoms, the Doctor tries to address the continued misalignment of framings she hears through both trying to activate the

Mother's cystic fibrosis schemata into her conceptual framing and de-activate other causes of the noisy breathing.

While the work I propose is between students, I acknowledge work done in the "responsive teaching" literature where teachers attend to student framings. Radoff and Hammer (2015) state "responsive teaching should include attention to framing—to how students are approaching and understanding the activity—which is a wider scope of attention than to their particular ideas and questions within the activity" (p. 190). While this sounds a lot like my 'attention to framing', the teacher from this study had an agenda around shaping student framing, whereas most students probably go into group work without an intentional plan to coerce their peers into a specific framing. Despite this difference, I find it helpful to refer back to the responsive teaching research methodology in the methods section below.

By combining the construct of 'attending to framing' to perspectival framing we are able to not only see the multiple dimensions that students are negotiating and if they have managed to align frames, but also illuminate the work the students are doing to hear meta-messages from their peers. In addition, by calling out the 'secondary listener' and 'secondary source' roles, I equip the reader with tools to productively analyze students listening to one another. Following the methods section are three cases where students appear to be listening to one another. Through the application of Perspectival Framing with Secondary Listening, Secondary Sourcing and Attending to Framing, different student discursive actions emerge.

Methods

Below, I introduce the context of the data before describing the analytical approach. In order to help the reader through the transcript presented in the next section, I provide examples of evidence for each of the three conceptualizations described above: Secondary Listening, Secondary Sourcing and Attending to Framing.

Coder4stats and computing in statistics.

We explore student listening in the context of an NSF-funded research project called CodeR4STATS (IIS-1418163), which seeks to transform high school statistics through activities that employ the R statistical programming language to work with large and authentic datasets. Students learned the statistics concepts before being introduced to R via a series of activities ranging from textbook problems to larger projects. For example, one activity involves measuring and documenting the lengths and widths of leaves from two different trees and then constructing fit models to examine patterns within and across samples. Another involves investigating university admissions reports and developing an algorithm to help make college admissions decisions for a large, hypothetical set of applicant records. Students worked independently on small problem sets but on these bigger projects they were in pairs or triads assigned by the classroom teacher.

Study context.

Our data are drawn from a non-AP statistics class participating in the CodeR4STATS project at a selective public high school in New England. The

teacher of this class is a designer of the CodeR4STATS materials and was accustomed to teaching with R. Over the course of the school year, we captured classroom data daily during periods of time when students were working intensively with R. The first author of this paper was present during data collection. We captured video and audio of consented students using small video cameras mounted on computer monitors, as well as synchronized video recordings of those student's on-screen activity.

Group and case selection.

The cases presented below are of two different groups. Each case shows a pair of students working on a different problem and so some of the cases presented below will illustrate more than one concept. The first case is of two students, Grace and Victor, who are from a triad that was previously studied (Chapter 4). This group was working on a larger project of modeling college admissions using R, and this data was taken towards the end of the school year. The data of this group was selected to provide a case where students seemed to be listening to one another well and are presented below as an example of 'attending to framing.' While brief, this example of 'attending to framing' looks quite different from the second case and allows us to illustrate some of the nuances of this construct.

The following two cases are of a pair of students, Dan and Mary, who are working on smaller assignments in the earlier part of the school year. Dan and Mary were selected because they seem to work together well – engaging with one another's ideas and helping each other with the assignments. The second case is broken into two parts due to its density; the first part illustrates an example of

attending to framing, while the second part illustrates both Secondary Listening and Secondary Sourcing. The third case presented below illustrates 'secondary listening'.

Analytical approach

After the school year was over, I organized and tagged the video data. To further unpack the student listening in these cases, I leverage methodology from Radoff and Hammer's (2015) responsive teaching study. Radoff and Hammer (2015) use an open-ended methodology for identifying teachers attending to student framing. Radoff and Hammer presume that a teacher, in the moment, notices at least some discursive evidence of framing that analysts are able to find in post-hoc analyses. The authors' analysis looks for discursive evidence of students framing, and indications of the teacher's attention to student framing in subsequent speech and actions.

In the analysis below, I adapt Radoff and Hammer's (2015) analytical approach to look for evidence of student attention to framing. I started by looking for discursive evidence of student framing (e.g., Tannen, 1993). I then looked for any kind of evidence that the student had "heard" or reacted to their peer's framings I already identified. While I do my best to represent the evidence in the transcript and descriptions below, I often cite non-verbal evidence more readily seen in the actual video. To access the video data presented in the transcript below, please see Appendix 5.

Overview of evidence.

To help the reader identify listening in the cases below, I start by presenting examples of the different types of listening conceptualized at the beginning of the paper: secondary listening, secondary sourcing and attending to framing.

Evidence of secondary listening and secondary sourcing.

Evidence of *secondary listening* appears in a discursive triplet. The pattern distilled from the video data presented as the transcript below is (1) statement from source, (2) reaction from the listener (not necessarily verbal), (3) modified re-statement or clarification from source. An example of this pattern would be:

> **Source:** Then you turn left off of Main Street onto College Avenue
> **Listener:** Left on College?
> **Source:** There will be a public library, and then you will turn left

In this example, we see that the source is trying to give directions to the listener. While doing so, the listener asks a clarification question, prompting the source to modify their explanation. This modification is evidence that the source is listening or attending to whether the listener understands the information being communicated. One way to confirm a source is reacting to the listener is to read the source's turns of talk without the listener's utterance. If the two statements do not flow, it indicates that the source is not simply continuing an explanation and that they are reacting to the listener.

Evidence of *secondary sourcing* in the data presented below appears in the form of questions. Some of the questions stand on their own, illustrating the gap in understanding the listener has identified. For example, "We are leaving at 6:30? When does the show start?" The listener is asking for more information from the source, providing the feedback of what pieces of knowledge are missing.

Some questions try to convince the primary source of a gap in their understanding. For example, **"**Are you sure the show starts at 7? The paper says 6:30." Unlike the previous example, the listener is trying to highlight what they see as a gap in the source's understanding.

Evidence of attending to framing

Evidence of *attending to framing* in the data presented below is more varied than the evidence discussed above. In lieu of trying to distill a single pattern across cases, I am going to illustrate how frame-switching and question-asking are both evidence of attending to framing.

First, and less subtly, one person can ask another person what they are doing. In this action the first person has implicitly recognized that their current framing of what is going on cannot make sense of the other person's actions. Unlike secondary sourcing where the listener is concerned about a missing piece of information, this attention to framing takes place along the epistemological dimension. For example, "Why are you just copying that? Do you understand it?" indicates an attempt to understand the person's framing of the situation (e.g., what is going on here).

Second, we look at a short piece of transcript of undergraduate physics students working together during a lab section from Scherr and Hammer's study (2009, p. 9-10) to illustrate frame-switching as evidence of attending to framing. Note that the italicized text indicates students are reading from a handout (shown in Figure 7) on Newton's third law which asks them to consider a heavy truck hitting an unoccupied parked car.

1 A: *Is your group's explanation in Part A similar or different?*

It's similar.

2 J: *Intuitively, the car reacts more, you'd rather be riding in the truck, so the car feels... is your group's explanation* similar or *different?*

3 A: It's the same. Right. OK, so, *according to Newton's Third Law, which of the...which of those forces...*

4 K: It says they're equal, right?

5 A: Yeah. Should be equal.

The main point of this tutorial is helping you learn more strategies for learning physics concepts that seem to defy common sense.

I. Newton's third law and common sense

According to Newton's third law, when two objects interact,

The force exerted by object A on object B is equal in strength (but opposite in direction) to the force exerted by object B on object A.

Often, this law makes perfect sense. But in some cases, it seems not to.

Consider a heavy truck ramming into a parked, unoccupied car.

A. According to common sense, which force (if either) is larger during the collision: the force exerted by the truck on the car, or the force exerted by the car on the truck? Explain the intuitive reasoning.

B. We've asked this question of many students, and a typical response goes like this:

"Intuitively, the car reacts more during the collision. (You'd rather be riding in the truck!) So the car feels the bigger force."

Is your group's explanation in part A similar to or different from this? Explain.

C. According to Newton's third law, which of those forces (if either) is bigger?

D. Experiment. Is this a case where Newton's third law doesn't apply? At the front of the room, the TA has set up an experiment that simulates a truck ramming a car. Go do the experiment and record the results here. You can also test whether Newton's third law holds for other collisions.

Figure 7: Worksheet from Scherr & Hammer (2009)

In the above transcript, we see that A is framing the task as getting the worksheet completed. There is evidence of this in line 1 where he immediately tried to

answer the question. When J reads off the next worksheet question, A immediately answers again and starts reading the next question aloud (line 3). At this point, K confirms what Newton's third law is even though A has moved on to the second part of the question (line 4). A confirms K's recollection of Newton's third law, while rephrasing it as the answer to the question (line 5).

Below, K makes a bid to *understand* this answer (line 6) and A switches his epistemological framing to match hers (line 7).

6 K: I kinda, I could never understand that, but. Does this go against the law then, or is it that they are equal but we just think it's the truck? You understand what my question...

7 A: We think it's the truck because the truck doesn't move backwards, I think. Right? Cause if there's equal and opposite forces, the truck... we would, if we actually saw it, we'd think the truck would hit the car and go backwards because of the force, but since...

This frame-switching we see A doing from completing the worksheet (line 1,3,5) to emphasizing understanding (line 7) seems to be in response to K's bid (line 6) to understand the problem. This evidence would then indicate that A was attending to K's framing.

Illustrations of Constructs

We present three analyses of students listening to one another, illustrating the different underlying types of listening. In the first case, Grace attends to Victor's framing of the project and switches into his framing to answer his questions. In

the second case, Mary attends to Dan's framing by explicitly asking him what he is trying to do. In the third case, Dan and Mary both work to understand each other but do not recognize that they are framing the problem differently.

Case 1: Grace and Victor – Attending to Framing (Illustrated by Frame Switching)

Our first case is of Victor and Grace working on creating a computational model in R to determine college admissions based on a number of application parameters. At this point in the project, the group has already envisioned an admissions model that would take into account specific student record inputs such as a GPA and SAT scores and determine admission based on various cutoff values. They are working on turning this model into R code that will be run on a sample data set to admit students. We start by establishing the students' conceptual and positional framing so the reader can focus on the epistemological framing while reading the transcript (Table 3).

Conceptually the two students have similar understandings of the group's envisioned model which includes the order different score filters are applied, as well as larger goals such as a diverse incoming class. This is unsurprising as the group, prior to starting to code, explicitly identified their school's admissions model in an assignment. Their admissions model included GPA, SAT score, extracurricular activities, and diversity, and there was no confusion about each aspects' inclusion in their envisioned model. However, Victor seems unaware of the role of the 'Geography' aspect Grace is currently programming, possibly because it falls under the broader category of diversity.

Additionally, while aspects like GPA and SAT are easily incorporated into the code by setting quantitative cutoffs, or rejecting everyone below a certain point, aspects like extracurricular activities and geography are less straightforward to translate into code because of their categorical nature. To handle the ambiguity previously, the group set a cut off for the number of extracurricular activities a student reported to simplify the translation of extracurriculars into code.

In the case of geography, however, neither student seems to have the conceptual resources activated that would enable them to make progress on coding the next step of the model. While it is clear they understand that schools take where students come from into account and try to accept students from as many states as possible, they have not worked out how to treat each individual student to create a diverse class.

The interesting facet of this excerpt, the students' epistemological framing, is tracked next to the transcript to help the reader follow along. For additional context, I have provided R code changes where new R code is bolded and colored. Throughout this excerpt, Grace is positioned as the 'source' with Victor positioned as 'listener'.

The excerpt starts with Grace talking to herself as she types the code. Victor makes a small syntax correction before engaging with Grace.

Table 3: Epistemological Frame-Switching in Case 1

Transcript	**Framing**
1 Grace: array students. Geography. Okay, but where do I go from here?	Coding model
Grace types code: list(arraySTUDENTS[['Geography]]	
Victor modifies code: list(arraySTUDENTS[['Geography**'**]]	
2 Victor: Wait, why do we have geography?	

3 Grace: Umm, because they do consider where you're from	Representing real world admissions in model
4 Victor: So you-	
5 Grace: Cause they want like a diverse class so like, they don't want like everyone to be from like California and New York, - from like North Dakota and stuff. It also makes them look better - like we have people from every state in the country. Even like Wyoming	
6 Victor: Yeah, but would you say like geography has to be from - like how would you write that in code?	Coding model
7 Grace: Well umm we're listing them 1 through 52, 51 being Washington DC, 52 being other countries. I don't know where to go from here. *mumbling* List array students geography	
8 Grace: *typing into Google* ascending	

Throughout the short excerpt, we see Grace and Victor navigate through different *epistemological framings* together. In the beginning, Grace mutters R code to herself as she types it in (line 1). Victor makes a small syntactical correction on the code Grace just typed into GoogleDocs. They are both framing the task as creating a functional code representation of their model.

When Victor asks "Wait, why do we have geography" (line 2), we see evidence that he is no longer merely focused on implementing the model in code but instead talking about their collectively established model. Grace, hearing this shift of framing in Victor's discourse, switches frames from coding their model to their model accurately representing admissions in the real world (line 3 and 5). This switch is evident in her discussion of "they" – referring to the real college admissions office the students are attempting to model as well as the fact she is explaining the connection between geography and the admissions process.

Victor then asks "how would you write that in code?" (line 6) reverting back to the coding the model framing. Once again, Grace hears this change in

framing and attempts to lay out what she knows but admits that she doesn't 'know where to go from here' (line 7).

While it appears that Victor is shifting framings, the interesting facet of this data is how Grace switches framings to match Victor's new framing immediately after he has spoken – providing evidence that she is listening. This shifting of epistemological framing would not be possible if Grace was not attending to Victor's framing.

Case 2: Dan and Mary

The second case is a different pair, Dan and Mary, who are working on plotting data they collected in a lab during the last class period. They were expected to create graphs similar to what they had previously done by hand – with titles, labels, and a trendline.

I split the second case into two sections – in the first we see a different kind of evidence of Attending to Framing. However, by the end of the first section, the pair has established a shared epistemological framing, and we start to see evidence of Secondary Listening and Secondary Sourcing. To clarify this shift, I give each section its own heading naming the type of illustrated listening.

Throughout this entire case, it is evident that the pair has a shared *positional* framing where Mary is the source and Dan is the listener. This is quickly established when Dan starts the episode by asking for help ("Wait, how do you do it? ") and Mary turns away from her work to help.

The second case begins as Dan is trying to move the graph he just created in R to a GoogleDoc he will submit for a grade. He asks Mary for help

without clarifying what he needs help with, and she has to work to understand what Dan is trying to do.

Case 2.1: Dan and Mary – Attending to Framing (Illustrated by Explicit Questions)

The focus of this excerpt is to illustrate how Mary is doing intentional work to understand Dan's actions. The way she goes about this, asking what he is trying to do, shows her attention to his epistemological framing. Some details from the video are added in italics to help the reader better understand the context of the utterance.

1 Dan Wait, how do you do it? Can I just drag the photo?
[*attempts to drag graph*]

2 Mary What?

3 Dan What is it doing? [drags transparent duplicate screen]

4 Mary What are you doing? Let go

5 Dan That's cool [lets go of the mouse button]

6 Mary What are you trying to do? Label it?

7 Dan No, I'm –

8 Mary No, you have to label it first anyways. You have to put the main title, and the ylab and xlab. The teacher literally just said that.

The lack of clarity in the first line forces Mary, who does not know what "it" is, to ask "What?". As Dan temporarily gets sidetracked by his computer's strange behavior (line 3), Mary still cannot make sense of Dan's request and so

reiterates her need for clarity ("What are you doing?") and tries to get him to focus enough to answer by requesting he "let go" of the mouse which is causing the confusing computer behavior. When Dan once again does not respond with his goal, Mary (line 6) further elaborates her question "What are you trying to do?" and even guesses as to what his goal is ("Label it?").

We see explicit efforts on Mary's part to understand and align herself with Dan's epistemological framing; that is, what his goal is in that moment. These repeated prompts to tell her what problem he is trying to solve (lines 2, 4, 6) illustrates Mary is putting in an effort to listen and understand what her group mate is doing.

There is a shift in line 8 that looks like a teacher move –Mary goes from spending effort figuring out what Dan is doing, then checks with her idea of what he should do next (adding labels), and upon realizing that is not what he is doing, she switches to correct him. This brings us to the second section where Dan's first utterance shows evidence of him taking up this goal of labeling the graph – establishing a shared epistemological framing.

Case 2.2: Dan and Mary – Secondary Listening and Secondary Sourcing

The second part of this case where they are in the same epistemological framing and in the same positional framing has examples of Mary secondary listening (summarized in Table 4).

9 Dan How?

10 [Student next to Dan] It doesn't do it when you-

11 Mary Yeah it does. You put it under plot x y. Right here. Plot x y. Your main is your title, xlab is the name for your x, ylab is the label for your y, then the color of the points, and then you do the abline.

12 Dan Calm down *[not typing yet – still looking at Mary's screen]*

13 Mary It's the exact same way if you were going to plot anything and then you just tell it all the stuff that you want.

14 Dan It never worked, but okay.

Responding to Dan's question of how to add the labels (line 9), Mary provides an explanation by describing the optional parameters available for the plotting method they are using, which take strings for the x and y-axis (xlab, ylab). This is the first instance of Mary re-explaining how to add labels as she had alluded to these commands in line 8 by saying 'xlab' and 'ylab' (see Table 4). Line 11 is in direct response to Dan's "how?" as evidenced by the procedural nature of her re-explanation. These three utterances together- Mary providing information, Dan reacting, and Mary reacting to Dan's reaction – illustrate secondary listening.

While this might seem similar to the work that Grace was doing in Case 1 when she was answering Victor's questions, the main difference here is that the work is clearly Secondary Listening. In the previous Case, Grace and Victor's frame shifting accounted for some of the changes to Grace's

explanation. In this case, because Mary and Dan have established a shared epistemological framing and stay in it, the work we see can only be attributed to Secondary Listening. Similarly, Mary asking Dan questions in part 1 is not labeled Secondary Listening because she is trying to understanding what goal he is trying to accomplish (epistemological framing) as opposed to his understanding of code (conceptual framing).

When Dan is reluctant (line 12; hesitation to type into his workspace – interpretation supported in line 14), Mary adjusts her explanation to a level of abstraction that better connects with Dan's existing conceptual understanding (line 13). She notes that it is "the same way if you were going to plot anything," relating to Dan's construction of graphs in past assignments. Dan takes this up and adds the labels to the method call, which then generates a labeled graph. Once again, we have a secondary listening triplet of Mary providing information (line 11), Dan reacting by hesitating to start typing (probably overwhelmed by the fast procedures Mary rattled off), and Mary reacting to Dan's reaction by slowing down and adjusting her tactic (line 13).

Table 4: Secondary Listening Examples in Case 2.2

Source's original statement	**Listener's reaction**	**Source's re-statement or clarification**
8 Mary No, you have to label it first anyways. You have to put the main title, and the ylab and xlab. The teacher literally just said that.	**9 Dan** How?	**11 Mary** Yeah it does. You put it under plot x y. Right here. Plot x y Your main is your title, xlab is the name for your x, ylab is the label for your y, then the color of the points, and then you do the abline.
11 Mary Yeah it does. You put it under plot x y. Right here. Plot x y. Your main is your title, xlab is the name for your x, ylab is the label	**12 Dan** Calm down.	**13 Mary** It's the exact same way if you were going to plot anything, and then you just tell it all the stuff that you want.

for your y, then the color of the points, and then you do the abline.		

Throughout this case, Dan secondary sources, asking questions both in the excerpt above (lines 1 and 3) and below (line 9). Each question Dan asks reveals a lack of his understanding. The first and second examples ("Wait, how do you do it? Can I just drag the photo?" and **"**What is it doing?") illustrate more work on Dan's part by providing Mary some information about his lack of understanding beyond the simple "How?" he asks on line 9.

Case 3: Dan and Mary – Secondary Listening

The third case presented in this chapter also focuses on Dan and Mary but happens earlier in the year. The two students were working independently on a textbook problem about the relationship between manatee deaths and power boat registrations when the researchers' question led to a discussion about correlation versus causation.

Unlike the cases above where the students have an established positional framing, the third case begins with Dan making a claim about correlation and Mary begins to challenge him.

1 Dan I mean I could see- I could see the amount of [inflation?] contributing to the amount of like cows being born but that didn't mean anything. Like, it's two variables that correlate but there is no evidence besides numbers. I could throw numbers at you and I could prove anything.

2 Mary Well if they're wrong numbers, yeah. But right numbers I mean typically -

3 Dan I'm saying they're right numbers but they could be two unrelated things

While Dan is making bids to be the source by offering a theory about the meaning behind the numbers (lines 1, 3), Mary does not accept the position of the listener (line 2) and instead makes her own bid to be source by challenging Dan's ideas. Unlike the previous cases where positional roles were stable, Dan and Mary go back and forth making bids to be the source by challenging each other's ideas, effectively micro-switching between source and listener roles with every speaker switch.

Additionally, in the triplet above, another example of secondary listening occurs as Dan clarifies on line 3 his explanation on line 2 based on Mary's utterance on line 2. While Mary may not be accepting the position of Listener on line 2, Dan positions her as a listener in the line above and below. Despite her bid to be the source, from Dan's perspective, she is a listener.

Dan starts the conversation by epistemologically framing it as a general discussion about statistics – that correlation does not represent causation (lines 1, 3). Mary challenges Dan's claim to assert that the correlation, in the case of this textbook problem, does imply causation.

4 Mary So it's unrelated that the boats that kill all the manatees and if they're more boats there are more manatees dying?

5 Dan No, it's not that -

6 **Mary** It's unrelated?

7 **Dan** It's registration.

8 **Mary** And if it's registered, it's like a car, if it's registered, it's there.

9 **Dan** Yeah

10 **Mary** If you are using your boat-

11 **Dan** You're not listening to me. I am saying that you can have increase in manatee deaths. You could also have an increase in powerboat registrations. That doesn't mean that every single power boat going out there is mowing them down

12 **Mary** I'm not saying every single one, but this is specifically killed by boats in Florida

13 **Dan** Oh

14 **Mary** It literally says in the paragraph. Killed by boats, so you're wrong

15 **Dan** Leave me alone. God.

Their discussion includes more evidence of secondary listening. For example, in lines 6-8, Mary who struggles to understand Dan's resistance to accepting her claim of causation asks Dan if the correlated variables are unrelated. He clarifies that one of the variables is not the number of boats, but simply the registration. So Mary, who is secondary listening, further clarifies that she is using registration as a proxy for boats because "if it's registered it's like a car, if it's

registered, it's there" (line 8). One could also view Dan's clarification of line 11 as a modified explanation of line 3 based on feedback from Mary (lines 4, 6, 8), making it another example of secondary listening.

These examples of secondary listening signal that Dan and Mary are listening and trying to engage in one another's ideas. However, even to the students, it is clear that something about the listening is not working ("you're not listening to me" line 11). I argue that this is due to the mismatch of epistemological frames pointed out above – of the discussion being viewed as general versus problem-specific - that continues throughout the discussion.

Mary's epistemological framing of the conversation focuses on discussing the specific textbook problem they are working on about manatees killed by boats (lines 4, 8, 12, 14), which provides additional contextual information that supports her causal interpretation. Dan, who started the discussion talking in more generalized terms (i.e. "variables," "numbers," "evidence," "prove"), starts using contextual language when pushed by Mary (line 7: "It's registration"). Eventually, he translates his whole argument into the contextually-based language (line 11) Mary uses during the entire discussion (lines 4, 8, 10, 12, 14).

While it might seem like Line 11 marks Dan's epistemological framing switching to match Mary's, you will notice that Dan's word choice still signals he is trying to debate in generalities. Mary talks about the problem as "this" and "it" – very concretely. In contrast, Dan talks about the problem as "you can have" or "you could also have" (similar to his phrasing in line 1). As this case illustrates

nuanced differences in epistemological framings, it is not surprising that the students in the moment did not notice these small differences explicitly (as they did in case 2). One might even argue that we see so much Secondary Listening above because the two students are noticing a framing mismatch and are *trying* to address it but are failing.

Discussion and Conclusion

The cases above provide insight into when evidence of these types of listening are visible[2]. For example, when students are already in a shared epistemological framing, there is often a lack of evidence of attention to framing. If we consider case 2, when Mary gets confirmation that Dan agrees with her that the next step is to label axes, the evidence of attending to framing stops and secondary listening evidence starts. This does not mean that Mary has stopped attending to Dan's framing – we just no longer have evidence in Mary's discourse.

Turning back to the literature and theoretical framework, I call out that in my analysis, I do not consider RStudio the Source when the students get an error message (unlike Roschelle (1992) and Van de Sande & Greeno (2012) who claim the Envisioning Machine is the Source). Given the reconceptualization of Source and Listener above, since R and the Envisioning Machine cannot listen or provide different output given the same input, I claim the computer is not doing the work of trying to provide information to the students.

[2] For more illustrations of these constructs in data, see Appendix 4

This study is just the beginning of unpacking how students work together. Its limitations include only containing a few hand-picked cases from a similar context. However, it also presents interesting directions for future work on how students develop the ability to attend to framing and when students employ this skill.

We have shown that students actively work to listen and provide feedback in different ways during group work. The data also illustrates examples of students successfully doing the challenging work of attending to framing, which has previously been discussed in literature with data of undergraduates and adults. In addition, I have distilled out the types of evidence future researchers might look for when trying to understand student group work in other contexts. These clarifications of constructs and evidence of students working to be a successful group provide a robust and flexible framework for future research.

Chapter 6: How Students Work to Understand Each Other Over Time

Abstract

Previous literature presented theoretical frameworks for understanding how collaborative groups created shared conceptions (e.g., Conceptual Convergence, Joint Problem Spaces, Shared Epistemological Framings). While these theoretical frameworks are illustrated by data of students contributing symmetrically (or contributing in the same way/in the same roles), these studies along with others name the fact that student contributions to a group's shared understanding are not always symmetric (meaning students contribute in different ways/take up distinct roles). Leveraging the framework developed in Chapter 5, I track a pair of high school students over three days to explore how they construct shared epistemological and conceptual framings through both symmetrical *and* asymmetrical contributions.

Qualitative results illustrate how the pair of students flow between symmetric and asymmetric contributions while building and maintaining shared framings. Quantitative results reveal the constructs from Chapter 5 account for a minority of utterances, but that these asymmetric constructs are interspersed throughout the data - frequently appearing when looking across several minutes or longer sections of data. Both of these results situate these asymmetric constructs as a needed complement to symmetric frameworks for studying how groups are constructing shared understandings over time.

Introduction

Previous chapters and other studies with cases of students working well together reveal how they are framing[3] the problem or task in the same way to enable communication (Roschelle, 1992; Scherr & Hammer, 2009). Particularly in messy, interdisciplinary projects where there is more than one disciplinary framing, shared framings help students understand one another. Without this shared understanding, it is easy to misunderstand a peer's utterance. Consider a mathematical and computational context (like the one presented below); interpreting the word "variable" in an utterance correctly relies on the speaker and listener being in the same frame.

However, students do not wind up in these shared framings coincidentally. Chapter 4 shows that students need to attend to one another's framing in order to create and maintain a shared framing. Additionally, Chapter 5 identified constructs such as Secondary Sourcing, Secondary Listening and Attending to Framing that occurs when students are really listening to their group mates. In this study, I build on this work by tracking these previously identified constructs over time to answer the question: *How do these constructs contribute to students creating and maintaining epistemological and conceptual shared framings?*

Literature Review

Collaboration is the focus of a large body of work in the learning sciences. Below, I introduce seminal and relevant frameworks that speak to how students create

[3] For a definition of framing, please refer to the "Framing" section under "Theoretical Framework"

shared framings (or similarly conceptualized structure). Each of these frameworks have pre-requisite conditions for their application (e.g. shared epistemological framing, attempting to converge conceptual understandings). After introducing each framework, I discuss when this framework has been applied in literature or could be applied in other work.

Collaboration frameworks and when they are used.

I introduce the frameworks below in historical order as some of the later frameworks build on previous frameworks. The community still uses older versions of these frameworks as they highlight aspects more relevant to their study and so are introduced below individually instead of as previous conceptualizations.

Conceptual convergence (Roschelle, 1992).

Roschelle (1992) introduces conceptual convergence as addressing the question: 'how can two (or more) people construct shared meanings for conversations, concepts, and experiences?' (p. 236). He builds on Conversational Analysis work that argues "that conversational interaction provides a means for students to construct increasingly sophisticated approximations to scientific concepts collaboratively, through gradual refinement of ambiguous, figurative, partial meanings" (p. 237). His theory for conceptual convergence is then a process involving "an iterative cycle of displaying, confirming and repairing situated actions [and] the application of progressively higher standards of evidence for convergence" (p.237). Roschelle presents a case study of two high school girls doing work to understand a physics simulator called the Envisioning Machine and

uses it to argue "that convergent conceptual change is achieved incrementally, interactively, and socially through collaborative participation in joint activity" (p.238).

Roschelle's conceptualization and the case he presents illustrates the creation of a shared conceptual framing[4]. However, Roschelle (1992) notes that "only 6 of 14 students converged on explanations that were like scientists' explanations. The other 8 students either never converged on a stable explanation, or converged on an explanation that was incompatible with conventional science" (p.241). Roschelle presents a pair of students who are already in a shared epistemological framing[5]. Additionally, "the students responded to utterances with mutual concern for shared knowledge, exerting deliberate effort to create convergence and avoid divergence" (p. 264). This limits the applicability of the framework to pairs of students in shared epistemological framings, actively attempting to converge on a shared understanding.

This framework presents the first example of how students might go about creating a shared framing and names this process as explicit work on the students' part. The work of both students is the same - making contributions to the shared conceptual framing. This symmetric understanding of student engagement makes sense as Roschelle does not differentiate roles. Additionally, Roschelle (1992) illustrates the process as iterative, and socially built through discourse. However,

[4] For a definition of conceptual framing, please refer to the "Perspectival Framing" section under "Theoretical Framework"
[5] For a definition of epistemological framing, please refer to the "Perspectival Framing" section under "Theoretical Framework"

this framework treats groups statically as "converged" or "diverged." This seems to create an internal tension between the dynamic nature of construction through discursive utterance at a fine-grained level and this static categorization at a larger grain size which hides this dynamic discourse central to the framework.

Joint problem space (Roschelle & Teasley, 1995).

The Joint Problem Space literature talks about the accomplishment of conceptual convergence from the lens of discursive contributions. Roschelle and Teasley (1995) define a Joint Problem Space as a space "which comprises [of] an emergent, socially-negotiated set of knowledge elements, such as goals, problem state descriptions and problem-solving actions" (p.69). They propose Socially Distributed Productions as a way to build Joint Problem Spaces. For example, a 'collaborative completion' "distributes a compound sentence over discourse partners. That is, one partner's turn begins a sentence or an idea, and the other partner uses their next turn to complete it" (p. 77). Because the utterance is distributed across two participants, it is evidence they both share that understanding, and so it becomes part of the Joint Problem Space. This process over time would then add multiple facets to their shared understanding, creating the Joint Problem Space.

Similar to conceptual convergence, Joint Problem Spaces include knowledge elements, which could act as a shared conceptual framing. Unlike conceptual convergence, Joint Problem Spaces include aspects such as goals, which could act as a shared epistemological framing. Roschelle and Teasley's (1995) conceptualization of constructing a Joint Problem Space is then an

explanation of how students would construct a shared conceptual *and* epistemological framing.

Roschelle and Teasley (1995) also discuss the idea of monitoring a Joint Problem Space. They state that "narrations are a verbal strategy that enable partners to monitor each other's actions and interpretations" (p. 78). Considering the Envisioning Machine, one could see how the student modifying the simulation could be misunderstood without explaining the thought process behind their decisions. By explaining 'I just want to try this' or 'that was too low, we should make this higher,' the driver is giving their partner access to their interpretations to check for agreement and understanding.

Barron (2003) builds on this framework of Joint Problem Spaces by contributing the idea of joint attention. Unlike Roschelle and Teasley's (1995) presentation of the theory which relied more on discourse while citing evidence of student gesturing, Barron explicitly names students gesturing and gazing at shared referents in her description of the theory.

Similar to Roschelle (1992), Roschelle and Teasley (1995) consider collaboration as "the mutual engagement of participants in a coordinated effort to solve the problem together" (p.70). While the group is still attempting to solve a shared understanding of the problem, Roschelle and Teasley (1995) use the language of 'coordinated' as opposed to Roschelle's (1992) description of 'creating convergence.' Additionally, this later conception of collaboration acknowledges that misunderstandings happen. Roschelle and Teasley (1995) offer the idea of repairs to deal "with problems or troubles in speaking, hearing, or

comprehension of dialogue" (p. 78). However, their work does not directly address what happens when a misunderstanding is more complex. They do name the fact that

> *"student's engagement with the activity sometimes diverged and later converged …the introduction of successful ideas was sometimes asymmetric, although it succeeded only through coordinated action. These results point to the conclusion that collaboration does not just happen because individuals are co-present; individuals must make a conscious, continued effort to coordinate their language and activity with respect to shared knowledge" (Roschelle & Teasley, 1995, p. 94).*

This means that one student might contribute more to the joint problem space, but their peer still has to accept their proposal before it is considered included. However, the fact 'student's engagement sometimes diverged and later converged' seems almost the opposite of their claim that 'individuals must make a continued effort to coordinate'. Turning to their presented data (a pair of boys working on the Envisioning Machine), the divergence they are citing is when one boy became disengaged for a few turns of talk because he wanted to use a more systematic approach than his partner who had control over the mouse. This does not reach the level of divergence seen in many student groups over longer periods of time and still seems within the realm of coordinated as the boy waits out his partner's exploration.

The Joint Problem Spaces framework is more often applicable than conceptual convergence as it does not require an already established epistemological framing and can handle small divergences – even introducing mechanisms for monitoring and repairing shared framings. Despite this addition of acknowledgment of divergences, the conceptualization of roles is still

symmetrical and is only noted as asymmetrical in quantity of contributions. However, due to the combined nature of the conceptual and epistemological framings, it would be hard to apply joint problem spaces to interdisciplinary data where students were switching between epistemological framings. Additionally, because joint problem space literature does not have a way to repair deeper misunderstandings, this framework might be problematic in situations where groups split up to work on different parts and came back together to synthesize their contributions.

Epistemological framings in groups (Scherr and Hammer, 2009). Scherr and Hammer (2009) focus in on Epistemological Framing and answer the question of students switching between framings and also explicitly names the embodied cues of framing (similar to how Barron (2003) named Joint Attention). Scherr and Hammer (2009) identify four behavior clusters of undergraduate physics student lab groups which they link to four framings: worksheet frame, discussion frame, TA frame and joking frame. They illustrate the framings embodiment through contrasting pictures of the students hunched over their worksheets (worksheet frame) and the same students sitting up and looking at each other – one in mid-gesture (discussion frame).

Similar to how Roschelle and Teasley (1995) discussed that adding knowledge into a shared space requires a proposal and acceptance, Scherr and Hammer (2009) talk about student groups shifting frames together through a bid and acceptance. For example, if one student sits up from working on a worksheet, ready to discuss, other students will either sit up and discuss or reject this bid and

continue working on their worksheet. Just like their peers listen to these bids, noting shifts in their peer's framing, the person making the bid is also listening to whether their peers accept or reject their bid to frame switch. To continue the example, if a student sits up to discuss but none of their peers do, they would notice this and revert back to a worksheet framing.

The groups presented by Scherr and Hammer (2009) are frequently in shared framings, but the authors do not address how frequently the groups framings converged or diverged. Additionally, there is no discussion around whether certain students were contributing an overwhelming amount or if they had a shared conceptual framing in addition to their shared epistemological one. Like the other frameworks above, it is implied that all students have symmetric roles in their ability to propose and accept epistemological framing shifts.

Symmetric versus asymmetric group work.

All of the theoretical frameworks above seem to consider the students in the groups as equally able to contribute or co-construct knowledge. However, just because students are perceived as having equal access to adding knowledge to the joint problem space or all have the perceived ability to make bids to shift epistemological framings does not mean groups dynamics play out equitably.

Van de Sande and Greeno (2007) acknowledge that sometimes students in groups play different roles: "The communicative interactions in these episodes were not symmetrical – the inquirers and the informants contributed different functions to the interaction" (Greeno & van de Sande, 2007, p.17). Similarly, Roschelle and Teasley (1995) name the fact that "the introduction of successful

ideas was sometimes asymmetric" (p. 94). One reason for this might be social capital not captured by these frameworks. Engle, Langer-Osuna, and McKinney de Royston (2014) propose "a framework that models how each participant's level of influence in a discussion emerges out of the social negotiation of influence itself and the following 4 components that interact with it: (a) the negotiated merit of each participant's contributions; and each participant's (b) degree of intellectual authority, (c) access to the conversational floor, and (d) degree of spatial privilege" (p.1). Their work helps name why this perceived equal ability to contribute in these frameworks above does not mean realized equal contribution.

Even in situations where students start off on relatively equal footing, students in group projects often divide work up to be brought back together later. In the moments after divergence, each student slowly grows the disparity between their knowledge and their peers in the aspects they are working on. That means in the moments they ask their peer for help, or when they later come back together to synthesize, the students are going to be providing asymmetrical contributions to the shared group framing.

Asymmetry in group work could be seen in a number of ways (e.g., unequal contributions, inequity, undue influence). While all of these are important, I focus on asymmetry in student roles – specifically when students have created a shared positional framing with one student as source and the other as a listener. In this asymmetric positioning, there can be these other types of asymmetry. For example, the source often contributes more to the shared

framings than the listener. However, for clarity, I reserve the use of asymmetric going forward to mean a shared positional framing where one student is positioned as source, and another is positioned as a listener (Figure 8).

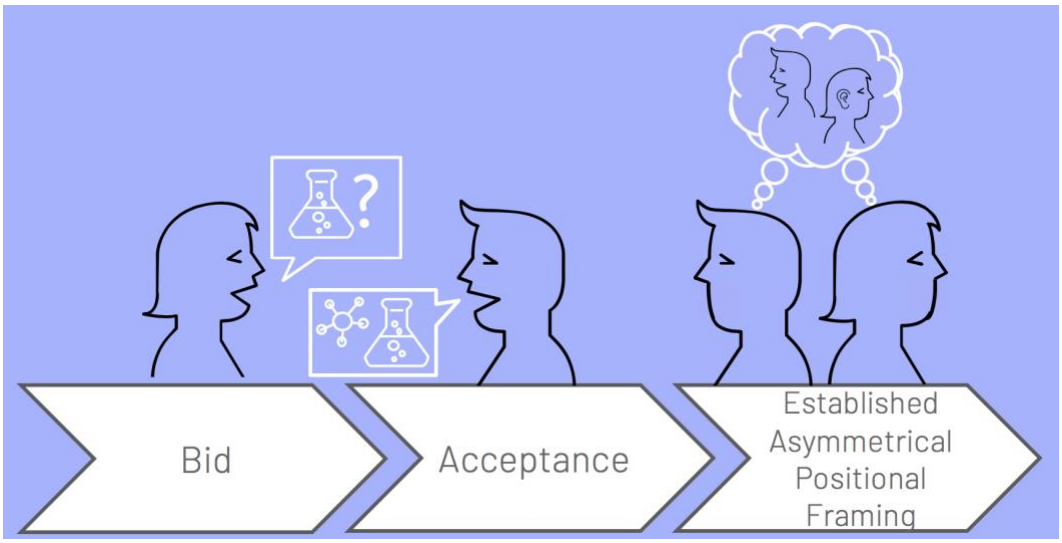


Figure 8: Process for Establishing Asymmetry (Roles of Source and Listening)

The main theoretical contribution of this paper is then situating this asymmetric framework as a complement to the theoretically symmetric collaboration frameworks exploring how groups create shared epistemological and conceptual framing (Figure 9).

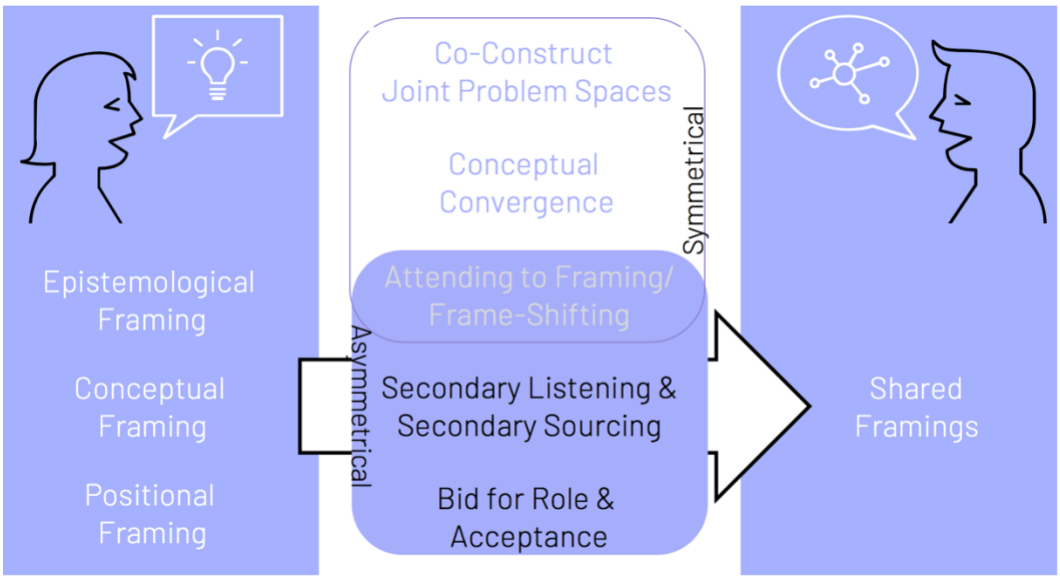


Figure 9: Positioning of Asymmetric Constructs (those built on Source and Listener roles) as Complimentary to Symmetrical Frameworks (where students have same position)

I claim that this contribution illustrates researchers' need for both symmetric and asymmetric frameworks when looking across longer time spans for group creation and maintenance of shared framings. Without this asymmetric conceptualization, work done to create shared framings in moments where students are positioned in different roles might not be understood.

Theoretical Framework

The theoretical framework introduced below is conceptualized and described in greater detail in Chapter 5. To discuss the modified version of Van de Sande and Greeno's (2012) Perspectival Framing framework, I first introduce Framing, then Van de Sande and Greeno's Perspectival Framing framework, and finally my modifications to it.

Framing.

Framing explores how people answer the question 'What is going on here?' as they participate in a social activity (Goffman, 1974). Frames are constructed based upon situational cues and shape what a person pays attention to and how they make sense of things. Frames are context dependent, and small changes to a situation may change what students perceive or expect (McCormick & Hammer, 2016).

People communicate their framings to others. This communication happens through the same utterances of discourse. Tannen (1993) explains "notions of script, frame, and schema can be understood as structures of expectation based on past experience, and that these structures can be seen in the surface linguistic form of the sentences of a narrative" (p. 53). Tannen's work (1993) illustrates a number of ways framing can be seen in discourse. For example, "a negative statement is made only when its affirmative was expected" (Tannen, 1993, p. 44). Thus, Van de Sande and Greeno's (2012) connection to framing literature contributes a methodology for identifying the three dimensions of Perspectival Framing which serves as the basis of the discourse-centered methodology introduced in the Methods section below.

Perspectival framing.

Van de Sande and Greeno's (2012) notion of *perspectival framing* emphasizes that frames are likely to differ across people as a result of the different sets of knowledge and schemata they hold based on their individual experiences and perspectives. Perspectival framing contributes analytic tools to highlight how an individual's framing of a situation influences what knowledge they bring to bear,

and how they perceive themselves and others. Van de Sande and Greeno identify three dimensions of perspectival framing: epistemological, conceptual, and positional.

Epistemological framing is "participants' understanding of kinds of knowledge that are relevant for use in their activity and the kinds of knowledge, understanding, and information they need to construct to succeed in their activity" (Van de Sande & Greeno, 2012, p.2; see also DiSessa, 1993). In deciding what knowledge is needed to succeed in an activity, students are also deciding what they perceive the activity to be. A student's epistemological framing answers the question 'What is my goal for this activity?'

Conceptual framing is "the way or ways in which participants organize information in the situation they are discussing and the problem they are working on" (Van de Sande & Greeno, 2012, p.2). Given how they frame a situation, a person will have a set of expectations about a situation that will cause them to foreground and background different knowledge resources. A student's conceptual framing answers the question 'What do I already know that can help me accomplish my goal?'

Positional framing refers to the way participants understand everyone's role in a situation. Positional framing "includes a human participant who is inquiring, which we call a listener, and a source, which may be another human participant or a non-human system" (Van de Sande & Greeno, 2012, p.1). The role of the source is to act as the main authority on the disciplinary material. The role

of the listener is fluid; the listener can be a simple recipient, a director of "the interaction, actively questioning the source," or a role was taken up "actively and jointly by more than one participant acting collaboratively" (Van de Sande & Greeno, 2012, p.40). A student's positional framing answers the question 'What is everyone's role in accomplishing the goal?' In a group setting, productive groups would have a shared understanding of everyone's role. Goffman (1979), as well as Van Langenhove and Harré (1999), talk about how people negotiate positioning. This negotiation not only consists of bids but also requires people to 'hear' or recognize the proposed positioning in order to respond.

Van de Sande and Greeno (2012) present data illustrating not only the interplay between these dimensions but also noting whether groups of students were within the same framings or not. While their work illustrates the use of Perspectival Framing on a small selection of data, there is some work to be done to apply this framework to a wider variety of group settings.

Addition to perspectival framing: secondary listening.

We propose the role of the source is a nested one; the source must act as the main authority on disciplinary material while taking up a temporary, *secondary listener* role to understand the primary listener's conceptualization of the material. This nested secondary listener role can be thought of as the listening a lecturer might do as they lecture. While the lecturer's source role is to provide information to the student listener, some sources will take this a step further to engage in secondary listening to ensure that the listener is receiving their information. A lecturer taking up the secondary listener role might ask questions during lectures or read students

work while asking themselves: Are the students (as listeners) understanding what I am saying? How does a given student listener think about this disciplinary concept?

Secondary listening might look like re-stating an explanation in a different way after hearing the listener ask questions or try to re-state it. The source might take cues from the listener's facial expressions, the tone of voice, and body language to figure out if the listener is confused or stuck. The source might see evidence of the listener's understanding of answers on a worksheet or code on a computer screen.

Addition to perspectival framing: secondary sourcing.

In addition to this nested secondary listener role, I also propose a *secondary source* role. A listener who is actively asking questions, trying to re-state explanations or give other kinds of feedback to the primary source would serve as a source of their understanding. While the primary source is the source of information for the discipline, the listener taking up the role of secondary source is the source of evidence of the listener's understanding. We consider the attempts to incorporate what the primary source is saying and giving feedback, particularly asking questions, to be active work.

Addition to perspectival framing: attending to framing.

In addition to secondary listening and secondary sourcing, I also add *attending to framing* to conceptualize how students are "hearing" their peer's framings. Attending to framing could be thought of as the receiving part of Bateson's idea of meta-messaging. Bateson discusses signs that these metacommunicative

messages are transferring between two monkeys playing in a zoo: "this phenomenon, play, could only occur if the participant organisms were capable of some degree of metacommunication, i.e., of exchanging signals which would carry the message 'this is play'" (Bateson 1987, p. 179). Translating this back to humans in an educational context, I explicitly call out the type of *attending to framing* that a student might do, such as reading facial expressions, listening to voice pitch, or trying to identify the underlying conceptual conflict behind a question (as opposed to just answering it).

These pre-requisite efforts of attending to framings do not always lead to successful framing alignments – but they should be recognized as the beginnings of important group work skills. Even when student framings do not align, attending to framings can reveal opportunities to negotiate framings along certain dimensions.

By combining the construct of 'attending to framing' to perspectival framing, we can not only see the multiple dimensions that students are negotiating and if they have managed to align frames, but also illuminate the work the students are doing to hear meta-messages from their peers. In addition, by calling out the 'secondary listener' and 'secondary source' roles, I equip the reader with tools to productively analyze examples of students listening to one another. Following the methods section are three cases where students appear to be listening to one another. Through the application of these theories and the corresponding methods, different student discursive actions emerge.

Methods

Research context.

The CodeR4Stats project brings computing into a non-AP statistics course in a New England, urban high school. By replacing graphing calculators with the R programming language, 12th graders were able to engage with both statistical context and core computational practices such as modeling, data, and analysis. Data were collected any time course instruction asked students to use R programming or class time was spent on a project that had a programming part. Data were collected via webcams on students' computers, screen recordings of students' computers and audio recorders placed between students' computers.

Data for this paper are drawn from a 6-day unit towards the end of the year where student groups were asked to select a data set, develop a research question, and answer it through a statistical analysis coded in the R programming language. A small overview of the project days is presented in Table 5.

Table 5: Research project overview

Day 1 Friday	Day 2 Monday	Day 3 Tuesday	Day 4 Wednesday	Day 5 Thursday	Day 6 Friday
Picking data set and asking question	Import data, start programming	Continue programming and peer critique	Finish programming	Write up findings	Post-Test

Data Selection and Context.

The Jess and Susan (pseudonyms) pair was selected because during data collection they appeared to be both highly interactive and highly functional when compared to the other pairs. This data were selected because it was the

first three days of the students programming (shown in Table 5 as Days 2-4). Due to the numerous struggles the students experienced while programming in earlier assignments, I focused my analysis on the programming days thinking that when students got stuck programming they would be likely to interact with one another around complex content.

Jess and Susan selected the "Star Wars" data set which consisted of survey data collected by FiveThirtyEight.com[6]. Their research question was "Are more women becoming fans of Star Wars and Star Trek as time goes on? In other words, are there more younger female fans of both franchises than older?" The data below starts with Susan being caught up to speed on the whole project as Jess had picked the data set and question on day 1 when Susan was absent. Jess told the researcher that Susan would be her partner the following day, and conversation indicated that Jess selected the data and question with Susan in mind.

Analysis.

I captured the group's discourse from the programming days of the project (referred to as Monday, Tuesday, and Wednesday) then analyzed it for both epistemological framing and the constructs of Secondary Listening and Secondary Sourcing from Chapter 5. I synchronized and transcribed the multiple media sources (video, screen recordings, and audio recordings) from the group. Sections of the transcript which were off task, included interactions with non-group

[6] https://github.com/fivethirtyeight/data/tree/master/star-wars-survey

members (such as other student groups or the teachers), were excluded from analysis as the focus is students' on-task interaction with their group mates.

Next, the on-task, group data was coded for *shared positional framings*. After reviewing Van de Sande and Greeno's (2012) text around source and listener roles, the author and a coder labeled each turn of talk that indicated positioning of the speaker into one of those roles. We also coded whether a framing was shared between the pair. Shared positional framing was coded when one speaker made a bid to be either source or listener, and the other speaker on the next turn accepted to other role. For example, if the first partner asked a question, making a bid to be a listener, and the second partner responded with an answer to the question posed, this would be seen as accepting the position of the source, and the two would be seen as in a shared positional framing from the second utterance. Shared positional framings ended when discourse stopped indicating the established positioning of the students. After three passes with discussion in between each pass, the author and coder reached 82% agreement (.642 Cohen's kappa) on whether the students were in a shared positional framing or not on 22% of the data. The author and coder were in 100% agreement on which student was in the source and listener positions within transcript coded as shared positional framing.

The author and a coder then analyzed the shared positional framing transcripts for instances of *Secondary Sourcing* and *Secondary Listening*. The author created summary evidence of the constructs (Table 8 in Appendix 3) that both used as a reference while coding. After two passes with discussion in

between the passes, the author and coder reached 84% agreement (.549 Cohen's kappa) on 45% of the shared positional framing data. After two passes, the author and coder reached 92% agreement (.622 Cohen's kappa) on the same 45% of the shared positional framing data.

Additionally, the pair's *epistemological framing* was coded based on Tannen's (1993) methodology to identify a person's framing through linguistic markers in their discourse). First, the author distilled four framings with some discussion with the future coder. These framings were summarized into a table (Table 7 in Appendix 2) that both the author and coder used as a reference while analyzing student discourse. Each line of the transcript could be coded as anywhere from none of the framings to all four framings represented by the table. After the first pass, the author and coder reached 86% agreement on 33% of the on task, group data. A Cohen's kappa was not calculated since the framings are not mutually exclusive.

Before moving on to what the codes were used for, it is important to note that the coding was done as a way to gain perspective on when and how often these constructs showed up. No statistical tests were run on these codes – they were primarily used to (1) generate timelines (in Findings section below) used to illustrate the large data set in a concise way for the author and future readers and (2) refine constructs and their corresponding methodologies. Because of the limited statistical use, there should not be concern about the artificially low

Cohen's Kappa due to small sample size or relatively low agreement[7]. These low agreement measures are actually useful in illustrating that these are highly contextualized and nuanced constructs, which are not straightforward to identify. This motivates the qualitative investigation into these identified instances to both verify that the developed methodologies are identifying examples of the constructs and to investigate the interaction between these constructs which were coded in isolated passes.

The qualitative case presented below was selected because it had the highest density of Secondary Listening and Secondary Sourcing codes. The reader can look in Appendix 4 for four excerpts that are relatively or absolutely representative, but note that the presented case is *not* and was picked due to its unique structure.

Findings

Findings are broken into Qualitative Results and Quantitative Results below. The Qualitative Results section presents a case illustrating how students flow between symmetric and asymmetric positionings while building and maintaining shared framings. The Quantitative Results section addresses *when* and *how often* the constructs identified in Chapter 5 appear in student group discourse. These findings combine to illuminate the need for the asymmetric framework presented in Chapter 5 and demonstrate its use when looking across a group over time.

Qualitative results.

[7] Some researchers would argue that even with high agreement indicators, one should not run statistics on quantified data as it is too far removed from the data itself and skewed by the biases of the coders (Hammer & Berland, 2013).

The purpose of the following qualitative results is to illustrate how groups flow between symmetric and asymmetric roles while navigating shared framings. This illustration supports my claim that asymmetric conceptualizations of student roles are needed to capture the work students do to understand each other. The data presented below spans a little over five minutes during the second of the three days I analyzed (referred to in Quantitative results as Tuesday). By this point, the two students have taken up different tasks (and the corresponding epistemological framings) within the project. Susan has focused on completing the handouts for each day of the project while Jess has focused on using the computer for generating graphs (needed for the project deliverables).

This case starts with Jess working on attempting to make a bar graph while Susan is working on other parts of the assignment. The bar graph Jess manages to make before the case is shown in Figure 10 and the bar graph the pair eventually creates by the end of the day is shown in Figure 11.

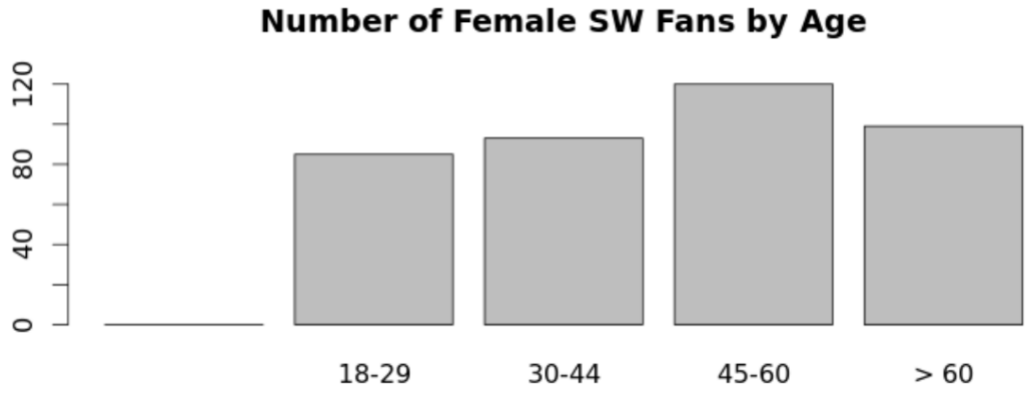


Figure 10: Bar graph produced just before start of case

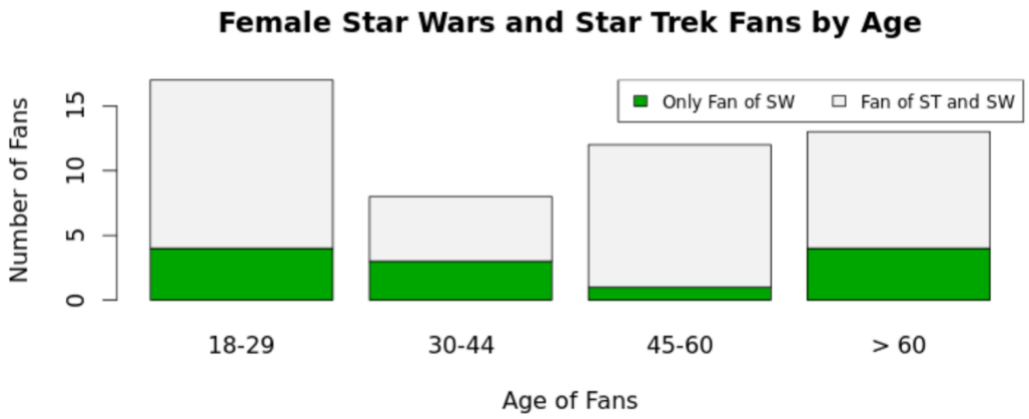
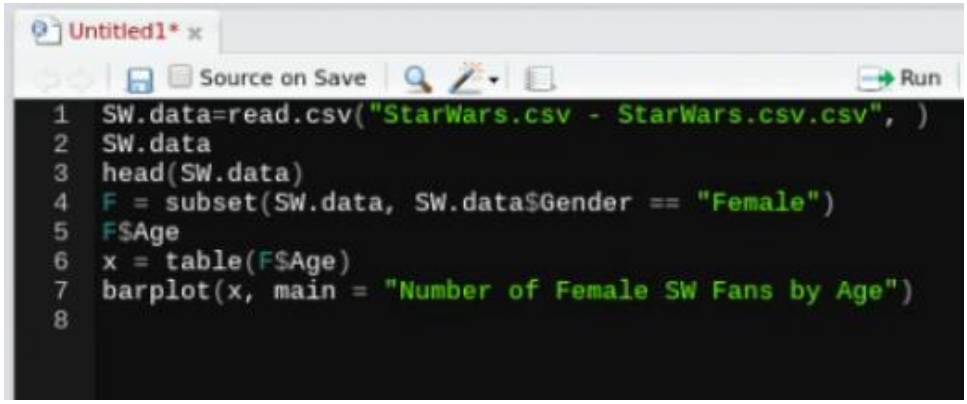


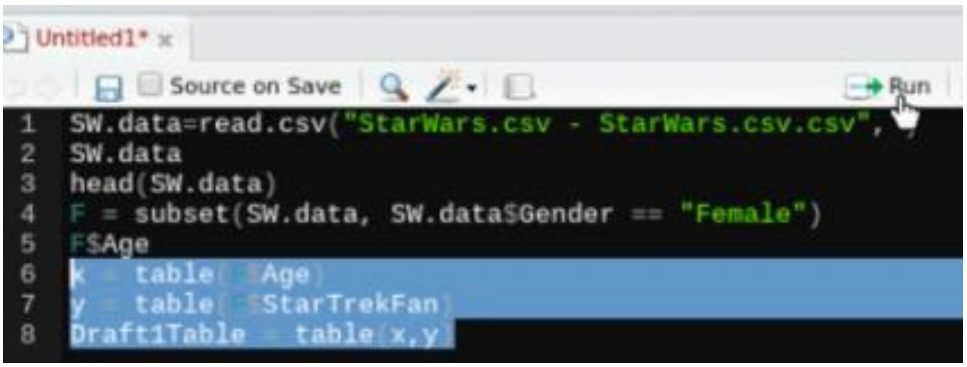
Figure 11: Bar graph produced by the end of the class period

Screenshots of Jess's code just before and after this piece of transcript are provided in Figure 12 and Figure 13 for context. Additionally, the error refenced in line 57 is shown in Figure 14.



Line	Explanation
1	Read in/Import data file
2	Print out entire data set
3	Print out first several rows of data set
4	Make a subset of rows representing female responders and put in variable F
5	Print the age column of subset F
6	Store the age column of subset F in variable x
7	Make a bar plot of x (shown in Figure 10)

Figure 12: Code before Line 53 of transcript with line-by-line explanation



Line	Explanation
1-6	*Same as above (Figure 12)*
7	Store the column indicating whether responder identifies as Star Trek Fan into variable y
8	Creates 2D table of Age vs. Star Trek Fan of female responders

Figure 13: Code after Line 56 of transcript with line-by-line explanation

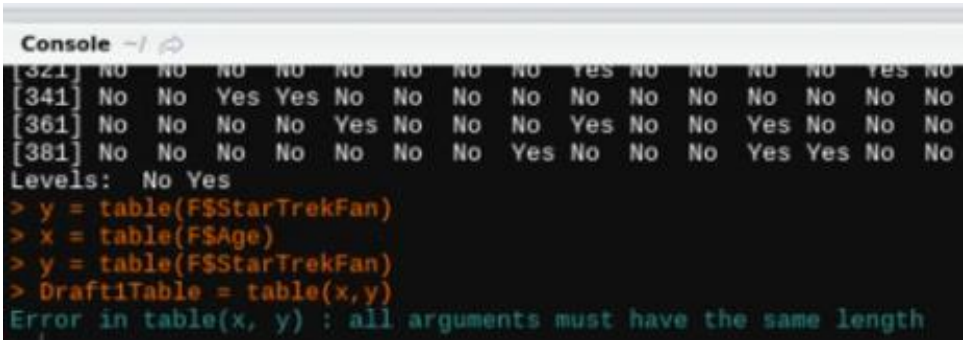


Figure 14: Error printed in green on Console, corresponding to code line 8 (Line 57 of transcript)

Turn	Speaker	Transcript
53	J	Now we need to figure out... those that like Star Trek and thos e that don't. So f, dollar sign... Star Trek fans...run
54	J	[writing line 7] y = table f $ scroll Star Trek fan.... run! [runs line 7]
55	J	How do I make it [the bar graph] stacked? [pulls up tutorial]
56	J	Oh I just do table [writes code line 8 – see Figure 13]
57	J	[runs lines 6-8] The fuck do you mean all arguments must have the same length.
58	S	Same what?
59	J	Same length.

In the video segment represented by transcript above, we see that both students are working rather independently – Jess on programming (as we can see in the

transcript), and Susan is slowly filling out the worksheet that goes along with Day 3 of the project. Jess's narration of her actions and thoughts could possibly be understood as giving Susan a way to monitor her framing of the task. Additionally, Susan could be monitoring Jess's framing, which is an interpretation supported by the fact Susan steps in when Jess gets frustrated on line 57.

The group dynamics at this point have shifted from students working in a parallel or diverged state (transcript lines 53-57) to the two students working in a more converged way (transcript lines 58-59). The two students seem to have established a shared epistemological framing of attempting to resolve the computer error by Susan shifting her attention from the worksheet she was working on to Jess's computer screen (transcript line 58).

We see Susan continue to engage and attempt to help Jess though both seem to be a little lost and positioned as co-constructors trying to make sense of the computer. For a look at the code they create over the next two transcript chunks, refer to Figure 16**Error! Reference source not found.**.

Turn	Speaker	Transcript
60	S	Is that the thing with the zeros, remember how she [the researcher] said... you can set all the zeros like insert NA for zero or something and then remove all the NAs. *(referencing earlier instruction on how to remove incomplete rows – notes about this still on front board)*
61	J	Damn
62	J	Alright.
63	S	Is that the problem?
64	J	NA... yeah let me just... and I'll do it up here... *(reading from board and typing on line 1 – see* Figure 15*)* NA dot strings equals c parentheses... comma NA.
65	S	Close quote.
66	J	Yeah

Figure 15: New code (in rectangle) added to line 1 after transcript line 66

Susan provides a suggestion (line 60)– possibly thinking that maybe the error (Figure 14) means not all rows have the same length because some are incomplete. However, Susan is not positioned as the source by herself, citing the researcher as the source ("she" in line 60). Jess barely responds to Susan looking for confirmation (line 63), and attempts to try her suggestion ("I'll do it up here" line 64) without directly answering that she agrees with Susan's suggestion. While there are indications of Jess taking up Susan's suggestion (lines 64 and 66), it still is unclear who is positioned as the source – Susan or the researcher.

As Jess continues to work on the potential fix, she positions herself as the Listener by asking Susan for clarification (line 67). *This signals a shift from a symmetric positioning to an asymmetric positioning.*

Turn	Speaker	Transcript
67	J	But what's in the middle of that second quote? [end of code line 1 in Figure 15]
68	S	Nothing, it's a blank space because you're inserting like nothin gness.
69	J	Because it's meant to be
70	J	And then, *(accidently hits enter)* no...*(deletes new line)* and then insert.
71	S	*(reading from board)* And then data equals NA dot omit.
72	J	Star Wars data equals NA dot omit.
73	S	*(reading from board but changing 'data' to 'Star Wars data')* Parentheses Star Wars data.
74	J	We'll see if this works. [runs first 3 lines of code – see **Error! Reference source not found.**] Alright, so I think it worked. [see Figure 17 for output]

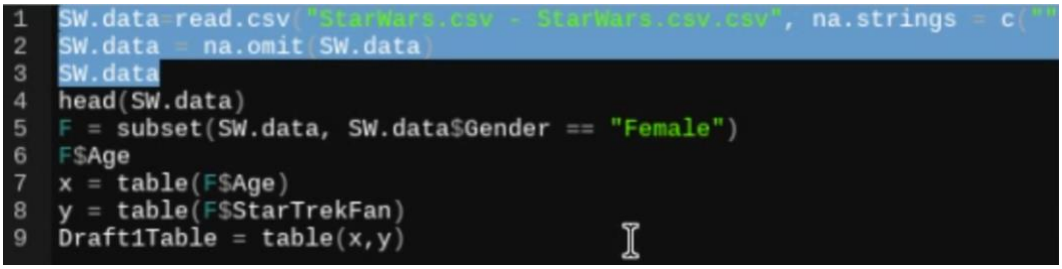


Figure 16: Screenshot of three lines of code Jess ran on first attempt (line 74)

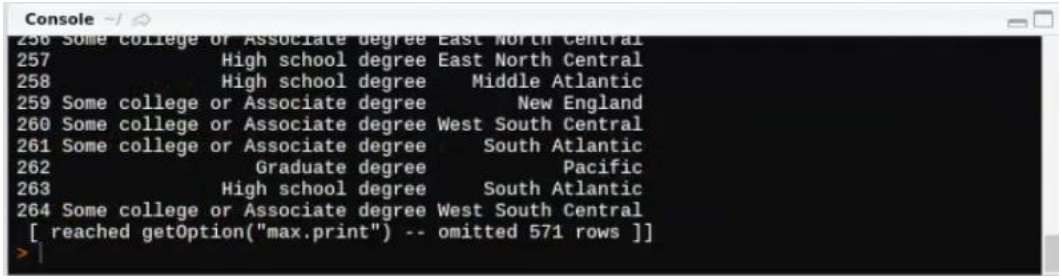


Figure 17: Output after transcript line 74

Susan takes up this positioning as Source at the beginning of this transcript chunk (line 68) by answering Jess's question about what is in the middle of the quotation marks written on the board (line 67). These first two lines (67 and 68) also contain examples of Secondary Sourcing and Listening. In line 67, Jess has identified a hole in her conceptual framing – she is either missing or unable to make sense of a small piece of the command to remove incomplete rows - and so asks Susan a very specific question ("But what's in the middle of that second quote?" line 67). You can almost see this conceptual hole if you look back a few lines of the transcript (line 64) where Jess stops narrating the command when she gets to the empty set of quotation marks. Similarly, Susan provides evidence of Secondary Listening by contributing an explanation in direct response to the listener's question (*"Nothing, it's a blank space because you're inserting like nothingness"* line 68). In this short interchange we see how within this asymmetric positioning

of source and listener, the students are still doing work on their shared conceptual framings which they were leveraging in their symmetric positioning before.

Susan continues acting as Source by providing commands from the front board (line 71 and 73). After hearing that their data is called “Star Wars data” in line 72, she adjusts the rest of the instruction in line 73. In line 74 we see Jess run the code without an error appearing (see Figure 17) and declare that “I think it worked” – ending her positioning as Listener.

The girls look at the error-free console with different reactions.

Turn	Speaker	Transcript
75	S	Yay!
76	J	So we're gonna try it again.
77	S	Omitted 571 rows wow.

Above the two girls are no longer positioned asymmetrically. The fact both are engaged in the activity and offering their thoughts (lines 74 - 77) without the asymmetrical positioning of source and listener - indicating the pair is symmetrically positioned as co-constructors, trying to move forward on cleaning up the data so that they can generate a graph.

Without any errors hindering their progress and the data now free from incomplete rows of data, the pair of students try running the entire code again in an attempt to make a stacked bar graph of female Star Trek fans by age (see Figure 11 for bar graph they are trying to make). Unlike the attempt to run before where Jess only ran the first three lines of the code (see the selection in Figure

16**Error! Reference source not found.**), she attempts to run the entire script (see the selection in Figure 18).

Figure 18: Screenshot of Jess running all of the lines of code on the second attempt (line 78)

This second attempt to run the code includes the line of code that caused the error back on transcript line 57. The code results in the same error it did the previous time they attempted to run it (Figure 14).

Turn	Speaker	Transcript
78	J	Fuck.
79	S	What! Why did it work the first time?

Jess reacts to seeing the same error (line 78) while it seems like Susan does not understand something about the second run (line 79). While Susan is naming a gap in her conceptual framing and making a bid to be Listener ("Why did it work the first time?"), Jess does not respond and instead attempts to run only the first three lines of code again by selecting them (as seen in Figure 16**Error! Reference source not found.**) but accidentally drags them, inserting lines 1-3 into the middle of line 4, rendering the new lines 2-4 as syntactically wrong (Figure 19).

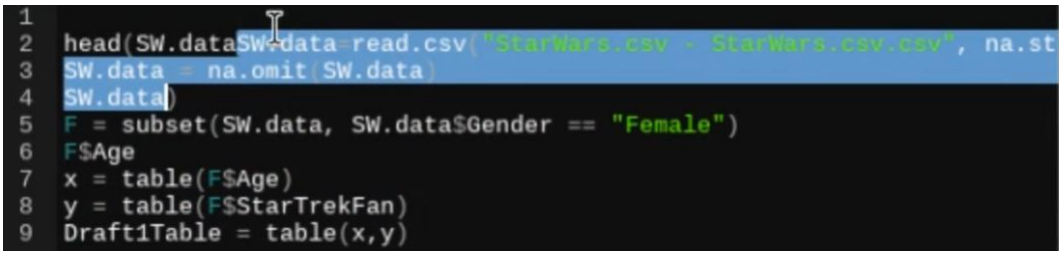


Figure 19: Screenshot of code Jess accidentally moved when attempting to run (line 80)

Confused about what exactly just happened on her screen, Jess starts to panic – her pitch gets higher, and she starts speaking much faster. Susan attempts to help her undo the accidental code scrambling, but is also unsure of what is going on.

Turn	Speaker	Transcript
80	J	Ah, what did I do what did I do what did I do?!
81	S	What what what.
82	J	I don't know what I did.
83	S	Command z[8]. What where what.
84	J	Command z what?
85	S	Yeah, command z. Did you delete something?
86	J	No, I moved it.

Susan attempts to figure out the problem (line 81) but since Jess is not quite sure ("I don't know what I did" line 82) she offers a suggestion ("Command z" line 83). Unlike above where Susan is positioned as Source (transcript lines 67-74), she is less confident and does not make a bid to be Source when making this suggestion – she immediately continues asking for clarification after making the suggestion (line 83 "What where what"). Jess rectifies the accidental code movement. While an asymmetric shared positioning is almost established in lines

[8] Command z or Control z is the standard hot key combination for "Undo"

84 and 85, the problem is resolved so quickly (line 86) there is not enough evidence illustrating that Susan was positioned as Source.

Jess, now calm (speech returned to normal), runs the first three lines of code again (line 87 – same lines of code as Figure 16).

Turn	Speaker	Transcript
87	J	Let's run this again. (*runs code as shown in Figure 16**Error! Reference source not found.***)
88	J	Something happened, I saw an error message. *(Jess starts scrolling through output of entire data set)*
89	S	Greedo? [Star Wars character name]
90	J	Don't ask. (*reruns only first two lines of code – error sho*wn in Figure 20) Unexpected parenthesis...
91	S	Oh then just scroll back up [in the code] I think [the extra parenthesis is] there.
92	J	Yeah I think its that last one....*(deletes a close parenthesis at the end of line 1)* and we're gonna-
93	S	Just [run] those two [lines of code] yeah. Oh crap. *(Reacting to old error in console)*
94	J	*(Noticing orange completed commands now in console)* No it worked it worked... okay, we're good
95	S	Alright whoa.

Jess notices an error message (line 88) and starts scrolling up the console full of data printed by the last line of code run. Susan questions a word in the data (line 89) but gets shut down as Jess turns her attention to the error she finds by re-running only part of the code (line 90 and Figure 20). Susan offers another suggestion (line 91) which Jess agrees with (line 92) while maintaining their symmetric positioning.

Figure 20: Error in Console (line 90)

The closing of the two girls coming together to fix the above computer error of an extra parenthesis happens as Jess clarifies that "we're good" (line 94) and Susan accepts this assessment by saying "alright" (line 95). We see that in the next few lines, Jess returns to her state of narrating her actions without Susan's assistance, still trying to get the code to produce the stacked bar graph she wants.

Turn	Speaker	Transcript
96	J	So now I'll try the f subset.
97	J	That worked, I think. Now we have ages...
98	J	We still have all arguments must have the same length...
99	J	Let's take a look at this again...*(re-creates age bar graph but the bar heights are now different)* this is interesting.

Despite the comment in line 98 that "we still have all arguments must have the same length…" (the error that started this whole exchange) Susan does not re-engage with Jess until after the researcher in the next turn of talk asks her "what's interesting". The discussion then moves on to the problem of the mysteriously changing bar graph, ending the current case.

Throughout the case we see the girls come together from a more diverged, parallel state and share an epistemological framing of fixing the computer error throughout the entire case (though the error they are working on changes). While the two start in a symmetric positioning with both in the role of co-contributor, they flow into an asymmetric positioning of source and listener, and back into a symmetric positioning – all the while maintaining a shared epistemological framing and repairing gaps in their conceptual framings. There are even moments later on where the pair almost slips back into an asymmetrical positioning of source and listener (lines 84-86). These qualitative results illustrate researchers'

need for both symmetric and asymmetric frameworks when looking across time spans as short as a few minutes for group creation and maintenance of shared framings.

Coding results.

To address *how often* the constructs identified in Chapter 5 occur, the results of the various coding passes on the entire three days of Jess and Susan programming are summarized in Table 6 with both raw counts and percent of the dataset being coded; for qualitative examples of the codes in Table 6, see Appendix 4. You will notice that Secondary Sourcing[9] only occurs in 5% of the on task discourse and Secondary Listening[10] only occurs in 2%. This result makes sense given that only 23% of the on task time are students in a shared positional framing. This means that the other 77% of the data is better addressed through theoretical frameworks such as joint problem spaces where there is no clear source and listener but instead two equal co-constructors of knowledge.

Additionally, Table 6 indicates that the distilled epistemological framings, school assignment, data science and computer as tool, make up 97% of coded student epistemological framing of this project[11]. This result could raise concerns if viewed as only 26% of the transcript indicated students framing the project as data science, but one could also view it as 65% of the transcript indicated students were authentically engaging in disciplinary practices as opposed to just trying to complete a school assignment.

---

[9] See Appendix 3 for Table 8: Secondary Listening and Secondary Sourcing Coding Table
[10] See Appendix 3 for Table 8: Secondary Listening and Secondary Sourcing Coding Table
[11] See Appendix 2 for Table 7: Epistemological Framing Coding Table

Table 6: Summary of Quantified Codes before and after each analytical pass

Turns of Talk	**Filter / Coding Process**	**Results**			
	Off Task / Teacher / Other Groups	*On Task Turns of Talk*			
1384 turns	789 turns removed	595 turns on task 43% of the total transcript			
	Shared Positional Framing	*Secondary Listening*		*Secondary Sourcing*	
595 turns on task	139 codes 23% of on task	14 codes 10% of shared positional framing 2% of on task		32 codes 23% of shared positional framing 5% of on task	
	Epistemological Framing	*School*	*Data Science*	*Real World*	*Computer*
595 turns on task	640 total codes	226 codes 35% of on task	164 codes 26% of on task	18 codes 3% of on task	232 codes 36% of on task

As noted above, timelines (Figure 21, Figure 22, and Figure 23) were created to illustrate *when* these constructs appeared over time. Excluded segments of transcripts were labeled as "Off Task" and collapsed into a single turn so that the reader would see where the flow of discourse and framings were interrupted without taking up too much space on the timeline. Timelines for Monday and Wednesday were scaled so that they matched the scale of Tuesday – giving each timeline the same scale along the x-axis.

Looking across the timelines of coding, we see that this 23% of shared positional framing, where students are asymmetrically positioned, is spread throughout the duration of the project. This finding supports the idea that to understand how students are creating and maintaining shared framings over time;

a researcher would need a way to address these asymmetric moments in addition to the symmetric frameworks more commonly discussed in the literature.

Across the three days, it is also apparent that the duration of these asymmetric moments and what is happening during them (epistemological framing) changes. This is to say that while students are not necessarily in a shared asymmetrical positional framing for the majority of the time, they are frequently in a shared asymmetrical positional framing.

As I introduce each timeline, I highlight trends in the codes and tie them to context to help explain why students were in these asymmetric positions.

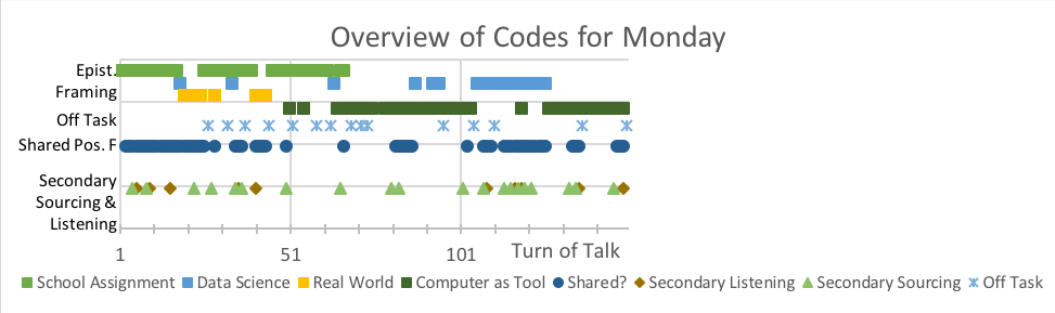


Figure 21: Overview of Epistemological and Positional Codes found in Monday Transcript

During Monday (Figure 21) we see a lot of Off Task transcript causing the timeline to be artificially short. Throughout the class, the two students are frequently in a shared positional framing and often Secondary Source and sometimes Secondary Listen. While the class period starts off as mostly discussing the assignment, students later start to spend large amounts of time engaging with data science and computational principles.

These trends are probably caused by the fact that Susan was absent on Friday, so the first part of the class was Jess catching her up on the assignment and what has already been done. This also positions Susan as frequently the

listener, possibly explaining the relatively large amount of time in a shared positional framing.

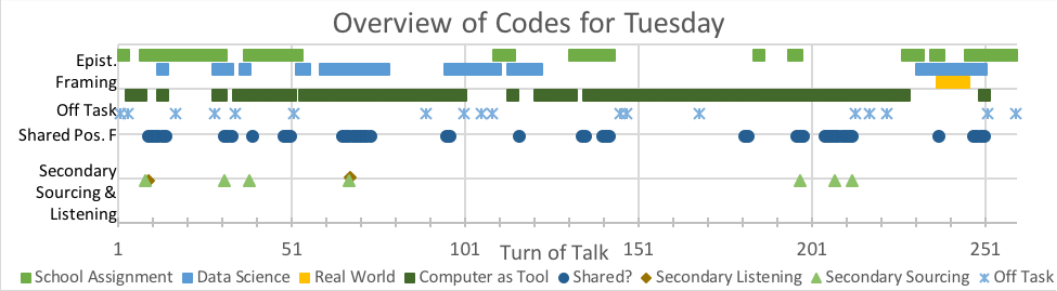


Figure 22: Overview of Epistemological and Positional Codes found in Tuesday Transcript

(The case presented above is from turn 53 to 99)

During Tuesday (Figure 22) we see a lot of time is spent engaging with the computer with bursts of interaction with the assignment. These bursts of interacting with the assignment could be due to the fact that Susan would ask the other for pieces of the project she needed in order to fill out that day's worksheet. This interpretation is supported by the fact that there is often a shared positional framing in conjunction with the school assignment interjections.

Towards the first half of the day, while the students are still figuring out what they are doing, we see bursts of data science coding indicating breaking down big tasks and filtering data. The data science coding at the end of the class period overlaid with real world coding is the students trying to interpret the graph they finally got out of RStudio.

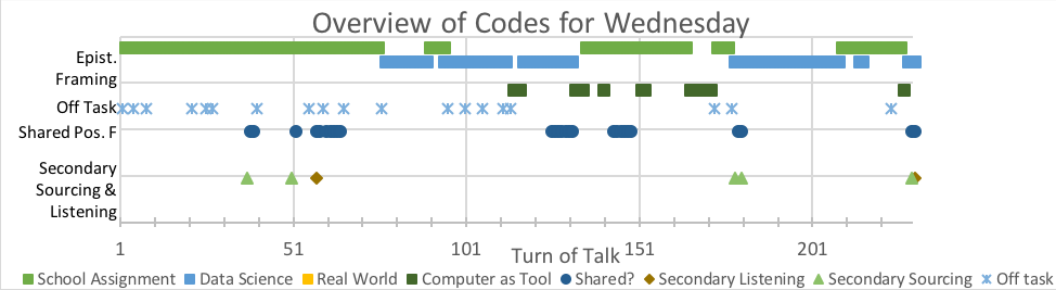


Figure 23: Overview of Epistemological and Positional Codes found in Wednesday Transcript

During Wednesday (Figure 23) we artificially lose a lot of turns of talk because part of the assignment was to share your research question, statistical test and any generated graphics with another group. As described in the Methods section above, all transcript including interactions with non-group members was removed before the analysis, resulting in many turns of talk being excluded.

Unlike the previous two days where there was quite a bit of framing the problem through a computational lens, data from Wednesday reveals the students are framing the project as a school assignment and a data science problem. This is probably due to the fact they realized they had not yet run a statistical test and instead had been really focused on generating a graph. This realization started a lengthy discussion around which statistical test they should choose based on their research question and if their research question was actually testable.

This confusion led to only a few moments where the pair were in a shared source-listener positional framing as often they were both positioned as confused and working to co-construct an answer to their statistical test selection dilemma. This lack of shared positional framing led to only five secondary source codes and two secondary listening codes. This does not mean they were not working well together – instead, it indicates that they were both positioned as co-constructors

which is addressed in the literature by frameworks such as joint problem space creation.

These coding findings help support my claim that an asymmetrical understanding of collaborative interactions is needed in the literature – not because of students constantly being entrenched in un-even positioning but because of moments that lead to unique knowledge needing to be shared with a partner. In the first day, we see a lot of asymmetries as one student catches up with the other who was absent the day before. The following day, moments of requesting data for the assignment showed that as students take up distinct roles on projects, they will often come together in asymmetric ways. On the final day we see that even in situations that are primarily framed as co-constructors, as students offer their personal understandings or guesses to one another, there are moments of asymmetric positioning.

Discussion

Looking across the concepts identified in Chapter 5 as they are exemplified in this data (both above and in Appendix 4), I consider how they contribute to creating or repairing shared framings. Attending to framing is an asymmetrical contribution where one student is either (1) switching framings to match the other – single-handedly creating a shared epistemological framing, or (2) explicitly asking the other about their framing – attempting to repair the dissonance between their epistemological framings. Attending to framing seems to occur with epistemological framings, possibly because conceptual framings are addresses through other means.

Secondary Sourcing is an asymmetrical attempt to repair either conceptual or epistemological shared framings. Whether the listener is asking a question, re-stating something the source said or trying to extrapolate, by secondary sourcing the listener is giving the source access to potentially conflicting aspects of their framing. The asymmetry here is interesting in that secondary sourcing is almost a bid to have the source repair the shared framing as opposed to a direct repair.

Secondary Listening is an asymmetrical attempt to repair conceptual shared framings. Whether it is providing an explanation for a question, adding a new conceptual piece of knowledge or changing emphasis, secondary listening acts as a way to address gaps in the listener's conceptual framing. It should be noted that while we have seen in the data above and theoretically it makes sense for secondary listening to happen in response to secondary sourcing, there are occurrences seen in the coding results where secondary listening happens in isolation.

As described above and easily seen in Table 6, these three constructs do not occur throughout the duration of the three days. Connecting these constructs back to the literature, we see there are moments where students are completely diverged and not really talking to one another, moments where these asymmetrical constructs apply, and also moments where the two girls are both positioned as co-constructors of knowledge as in the frameworks described in the literature review. Looking across this longer selection of data which still does not represent the lifespan of this pair, we need to leverage a variety of symmetrical

and asymmetrical contribution frameworks in order to understand the pair as they converge and diverge into and out of shared framings.

Conclusion

Similar to the existing symmetric frameworks, the asymmetric framework conceptualized in Chapter 5 illustrates how shared epistemological and conceptual framings are constructed. By contributing this framework for asymmetric contributions, researchers now have a wider variety of tools to understanding the converging and diverging nature of groups over long periods of time.

Chapter 7: Contributions and Implications

In this dissertation I addressed the question *How do students work to understand their group mates?* through three empirical studies set in an interdisciplinary context. Chapter 4 illustrated the frameshifting work students do to navigate the different disciplines and illuminated the listening required to do this. Chapter 5 named this listening *attending to framing* and also identified *secondary sourcing* and *secondary listening* as other types of listening that happens in groups. Chapter 6 illustrated how these listening efforts contributed to creating and repairing shared framings that allow for students to understand one another.

Theoretical Contributions

The primary theoretical contribution of this dissertation is the modified Perspectival Framing framework which allows researchers to identify students various listening efforts regardless of whether or not they succeeded in reaching mutual understandings. In Chapter 2, I identified the following work necessary to focus Perspectival Framing on student listening: (1) understanding how two individual framings relate to one another (e.g., framing alignment, shared framings, etc.), (2) refining Van de Sande and Greeno's conceptualization of positional framing to illuminate the negotiated nature of positioning more fully and (3) conceptualizing how exactly students are listening or attending to their peers' framings.

Research conceptualizes how two individual framings relate to one another in a few ways. In previous literature, shared framings are constructed (Roschelle, 1992; Roschelle & Teasley, 1995) and groups collectively switched

between them (Scherr & Hammer, 2009). Van de Sande and Greeno (2012) noted that in the case one student had a productive framing and the other did not, the first student or source either could activate a similar framing in the other student or help the other student construct a similar framing. While I agree with this previous work, I also caution that researchers should not be hasty to assume students are in a shared framing. There can be nuanced differences that are hard to identify (as seen in Chapter 5, case 2 where Dan and Mary are discussing correlation versus causation) or insufficient evidence to make a claim for one interpretation over another. As I have done in my analysis above, I think the most conservative way to decide whether students are in shared framings is first to categorize the individuals framing on each line, and then look for trends of agreement over time.

The second part of modifying Perspectival Framing to address student listening involved reconceptualizing positional framing. There are two main parts to this re-conceptualization: (1) positions are established through negotiation of bids and acceptances and (2) inanimate objects should not be included in positional framing. The first part is seen throughout the empirical studies – one student makes a bid to be the source, and the other student has the option to either accept this bid by taking up the position of the listener or reject this bid by making a bid to be source. While Van de Sande and Greeno (2012) mostly discuss positional framings this way, the majority of examples in their study have almost all positional bids being accepted. The one example where a student does not take up the listener position, they say she "persisted" and that this caused "an

interruption of the mechanism of reaching mutual understanding" (p. 12). In contrast, Dan and Mary's debate around correlation versus causation (Chapter 5, case 2) illustrates how students can make repeated bids to be source while still listening to their group mate and attempting to reach a mutual understanding.

The second part of this re-conceptualization of positional framing has yet to be discussed in this dissertation. Over the course of the literature review, it has been noted that Roschelle (1992), as well as van de Sande & Greeno (2012), claim that the computer with the Envisioning Machine is the source. I challenge this statement within my modified framework as if you look closely at this data (as I did in Chapter 2) the girls have a positional framing between the two of them where one is sourcing her understanding, and the other is listening to it. Similarly, in the data I present in the chapters above, I do not consider RStudio to the Source when the students get an error message. Often, an error message resulted in the students all making bids to be a listener. However, as RStudio, like the Envisioning Machine, cannot listen or provide different output given the same input, the computer is not doing the work of trying to provide information to the students. The computer is acting just as lab equipment used to explore the natural world – as a tool that provides outputs to inputs. It is the scientist or student who interprets this output which does the work considering the context and turning the machine results into useful knowledge.

The last part of modifying Perspectival Framing was conceptualizing how students were listening to their peer's framing. This happened in two ways: (1) frame-switching and explicit question asking were identified as ways to listen to

epistemological framing, and (2) secondary listening was conceptualized as a way to attend to a peer's conceptual framing. It is also worth noting that students could "listen" to their own framing and communicate problems they identified through secondary sourcing.

These three modifications result in a framework that illustrates how student listening to framings can help create and repair shared epistemological and conceptual framings (Chapter 6). These shared epistemological and conceptual framings help the group communicate and make sense of their peer's understandings. This framework then answers my original research question by illustrating how students work at listening along these different dimensions to create these shared framings which allow group mates to understand each other.

A second theoretical contribution is positioning this new modified framework as a complement to existing frameworks. While other frameworks address how shared framings are created and repaired, these frameworks see students as co-constructors as knowledge. Additionally, the data they present shows primarily converged groups symmetrically contributing. These frameworks were developed to investigate moments where groups appear to be ideally collaborative and equal.

However, in reality, groups are not in this ideal state for their entire existence. In many cases, groups diverge or divide-and-conquer. Even in cases where two students work collaboratively, one student may be the main contributor (always positioned as source). In order to analyze these groups or even those

moments between the "ideal" symmetric group moments, we need a way to understand these asymmetric mechanisms.

Because one of the underlying requirements for secondary listening and sourcing is a shared positional framing, these constructs uniquely address situations where students are positioned in different, asymmetric, roles. These constructs also illuminate that this listening that happens in asymmetric moments can still result in the same productive shared framings.

While attending to framing as a construct does not require a shared positional framing, it is worth noting that the examples identified above all happen to be asymmetric. Whether it is frame-switching or explicitly asking about a peer's framing, one student is taking on the work of attempting to address the epistemological framing conflict.

This second theoretical contribution which highlights that groups can go through asymmetrical and symmetrical arrangements also calls to our attention that groups are dynamic systems that cannot be statically categorized by their end state of "converged" or "diverged." Consider four different groups: one that stays converged, one that oscillated and happened to end converged, another that oscillated and happened to end diverged, and a group that stayed diverged. Categorizing them based on their end stated as Roschelle and Teasley (1995) did loses sight of the work these students did. Additionally, if you were to consider attempting to analyze these four different groups, you would see different mechanisms be leveraged for the first group to stay converged (similar to what you see in Roschelle (1992)), a mixture of mechanisms in the second and third as

they converged and diverged, and finally either a lack or series of failed mechanisms in the fourth. This leads me to my next type of contribution: methodological.

Methodological Contributions

In conjunction with conceptualizing Secondary Listening, Secondary Sourcing, and Attending to Framing, I have developed methodologies for identifying these constructs in data.

Secondary Listening can be identified for coding based on Table 8 which I developed based on the examples found in Chapter 5 and iterated over while attempting to code the data in Chapter 6. The methodological challenges of secondary listening are twofold: first, you have to establish shared positional framings and second, you need to identify evidence that the Source is *reacting* to the Listener.

To establish a shared positional framing, the group must go through a two-part process. The first part of the process is for one of the group members to make a bid for either position themselves or another member as either Source or Listener. If the subsequent turns of talk accept this bid by providing evidence of a complementary positioning, this positional framing is considered shared. For example, if the first student asks a question, positioning themselves as Listener and the second provides an answer, positioning themselves as Source, a shared Positional Framing is established. This shared framing is broken when one of the students stops engaging with the other or makes a bid for a contradicting positional framing.

To identify evidence that the Source is *reacting* to the Listener, the reader can read the transcript without the Listener's utterance. By taking out the Listener's utterance, if the Source's utterances flow together, it means that the Source was not reacting to the Listener and there is no evidence of secondary listening. Conversely, if the reader takes out the Listener's utterances and the Source's utterances do not flow, it means the Source is responding to the Listener. This would support the claim that there is evidence of Secondary Listening.

Secondary Sourcing can be identified for coding based on Table 8 which I developed based on the examples found in Chapter 5 and iterated over while attempting to code the data in Chapter 6.The methodological challenges of secondary sourcing include the same challenge of establishing a shared positional framing (as described above) as well as identifying evidence the Listener is doing work to identify potential framing gaps or conflicts. In the beginning iterations of this concept, which you will see in Chapter 5, I claimed that Secondary Sourcing took the form of a question. However, there are instances of Secondary Sourcing that are not questions. These utterances are statements that do the same work of recognizing and expressing potential gaps or inconsistencies so, therefore, are evidence of Secondary Sourcing. Similarly, not all questions do this work. Simple questions like 'what?' sometimes do not support the claim that the Listener is doing work to identify gaps in understanding.

Attending to Framing is probably the least formally developed construct methodologically. In my data, we see examples of two types of evidence (1) frame-switching and (2) explicit questioning. Frame-switching occurs when one

student shifts framings to match their peer's framing. Often, this is caused by one student asking another a question, and in order to respond, the student being asked must switch framings to match the question-asker. This frequently happens when the group is diverged and working on different aspects of the project, as seen in the cases of Attending to Framing in the three empirical chapters above.

Additionally, one related type of evidence I do not show is one student making a bid to frame-switch and the other student rejecting it. While this is not shown in the data above, there were notable instances of this when the students were off task, and one student made a bid to return to the project. Many times, their partner remained off task, rejecting this bid the share framings. While this might seem like less nuanced work than the shifting of epistemological framings described above, it is nonetheless, evidence of students attending to their peer's framing.

Explicit question asking often happens when one student asks another for help, and the student being asked is unsure what their peer is doing (meaning they are unable to switch to a shared framing). This explicit question asking can end a few different ways. The first is once the help provider recognizes their peer's frame, they can switch into it. Second, the help provider can recognize their peer's frame and think that it is the wrong one – resulting in the help provider making a bid for the help seeker to switch framings. Finally, there are instances where explicit questions can fail to help identify the framing altogether. Whether the help seeker figured it out and is no longer engaging or the help provider has no

similar framing to switch into, this failure still provides evidence that the help provider, asking explicit questions, is attending to their peer's framing.

In addition to operationalizing these constructs, I also suggest that collaboration researchers look across longer time frames to better represents the groups dynamic. By consider the group even in less than ideal structures, we get a better sense of the variety of mechanisms groups use to construct, monitor and repair shared framings.

Pedagogical Implications

Reflecting on the many constructs developed and operationalized to help researchers identify the work students do in groups, and specifically in interdisciplinary contexts, there are three distinct pedagogical implications of the work above.

The first pedagogical implication is to address the teacher's understanding of what they are asking students to do in group work. Especially as we implement group and pair work at younger and younger ages, and in a variety of contexts where diverse learners might struggle to negotiate along social and epistemological dimensions, teachers need to consider how best to support their students. Teachers and curriculum developers need to give the same care and attention they give when considering how to activate useful existing conceptual resources to how to activate already existing social skills students need to succeed in a group setting. To help students navigate different epistemological framing, teachers can explain that just like before starting a game on the playground where everyone reviews the rules, groups should start by making sure everyone

understands the task. To help students remember to take turns talking and listening to their peers, teachers can remind students of the similarities of being a good friend and being a good group member. To help students act as co-constructors of knowledge and know how to contribute and engage with ideas, teachers can remind students of how playing make-believe games involves accepting and building off playmates ideas (similar to improv). In situations where teachers are unable to explicitly name these skills or see the need for more scaffolding, teachers can model what these skills look like when applied in the classroom context. This shift in mindset where educators explicitly attend to the skills needed in group settings will help ensure that students are getting the benefits of group work.

Similarly to above, the second pedagogical implication is that once a lesson with groups has begun, there are ways to "hear" students in groups in order to determine if there is enough scaffolding for that group. For example, walking over and hearing students in two different epistemological framing should be a signal to the teacher that these students are either unable to recognize the other framing or are unaware there is another framing they could be leveraging. Similarly, teachers might notice that one student is struggling to understand a conceptual part of the work but also hear that their partner is doing the work to secondary listen and the teacher should allow the group space to converge on its own.

This leads to an important note mentioned above: group dynamics shift. Teachers should not check in with each group once and then focus on the groups

that have diverged – or frame the groups that have diverged as problematic. Multiple check-ins are necessary to understand the group's trajectory, what listening skills they are implementing, and helping a teacher predict when they might need some on-demand scaffolding (for example when a group that has been diverged for a while is attempting to converge). It is essential that teachers *first* listen and understand what is happening in the group *before* inserting themselves. This is particularly of note because as mentioned in Chapter 6, teachers have much more special privilege than students in a classroom and what they say will be given undue attention by the group. This means teachers are at risk for de-railing productive conversations or causing a group schism if they do not first take time to understand the dynamics of the group.

Limitations

Throughout this dissertation, all data came from the same research project with a highly specific context. Due to the context-dependent constructs and methods, it is hard to know precisely how applicable this work will be in other spaces or what modifications will need to be done to apply them to different datasets. Additionally, the work above is limited to three small groups. While these groups were considered over long periods of time, it is still not a large enough data set to generalize this work to universal constructs.

As discussed above, the theoretical framework above is only applicable in asymmetric situations, and most useful when a shared positional framing is established. As we see in Chapter 6, this does not cover the span of a group. This

means that this framework, as discussed above, needs to be used in conjunction with other theoretical frameworks already in the literature.

Appendix 1: Chapter 4 Full Transcript

Day 4 Full Transcript – RStudio Only

4.01 Grace: We're doing out of...

4.02 Sara: We're doing what what?

4.03 Grace *mumbling while typing 690+700+690 into Google* so the bottom 25th percentile is 2080

4.04 Sara: So we'll put - we can put just 2000. Make life easy

4.05 Grace: I don't feel like that would make life easier cause it's not like we're doing any arithmetic

4.06 Sara: So you just made it higher than - okay, okay 2080

4.07 Grace: Cause that's their bottom

4.08 Sara: Yeah

4.09 Grace: i

4.10 S+Grace: else

4.11 Sara: I don't know what's- I forget what's supposed to be over here

4.12 Sara: Umm... so we need to repeat that

4.13 Sara: How many students are we admitting?

4.14 Grace: Umm... I don't know

4.15 Grace: What did we say for GPA? *mumbling while typing into Google*

4.16 Sara: I wanna say 4.18 is the average

4.17 Grace: Let's see what the internet says

4.18 Sara: So here it says they admitted 2142. For (inaudible)

4.19 Grace: Yeah, I just wanna know like the bottom like...

4.20 Sara: I don't think they put (inaudible) up

4.21 Grace: It's true

4.22 Sara: We could do like 3.8 or something

4.23 Grace: okay

4.24 Sara: Cause that's still like an A

4.25 Grace: Does this [pointing to for loop cutoff] mean how many students apply or how many students are admitted?

4.26 Sara: I wan-

4.27 Grace: Cause both of...

4.28 Sara: I know, that's a really good question. Umm, because they admitted 2142

4.29 Sara: I know, 2142 is what they admitted and they had 42497 for applicants

4.30 Sara: Oh, it says here that 1% were admitted with a GPA below 3.7 so

4.31 Grace: Okay, I'll change this to 3.7 - for now. Extracurriculars? We gave the value of-

4.32 Sara: We said at least 2, right?

4.33 Grace: Greater than 2

4.34 Sara: So greater than 1

4.35 Grace: Why?

4.36 Sara: Because it's -

4.37 Grace: I think we said like 3 or something

4.38 Sara: I know we said 2 at one point. I don't know if we changed it. Cause we said 2, put if they were like long term commitment but we can't see that on the graphs

4.39 Grace: Cause I feel like they want more than that

Day 5 Full Transcript – RStudio and Google Docs

5.01 Grace: So I shared the code with you so [directed to Sara]

5.02 Sara: Ok

5.03 Grace: Because I put it on a GoogleDoc and it's exactly the same

5.04 Sara: So we don't lose it?

5.05 Grace: Yeah and that way so if you...

5.06 Sara: Or so if you're not here

5.07 Grace: Yeah. Or so like we can all work on it together because it's kind of awkward if like everyone is like typing on the same keyboard

5.08 Sara: Let me... I will like copy it into my R too [“R” references online IDE]

5.09 Grace: And I saved my copy just because I am paranoid and I am like

5.10 Sara: No, R messes up

5.11 Grace: But it still says object ‘students’ not found

5.12 Sara: Is it capitalized?

5.13 Grace: Is it supposed to be?

5.14 Sara: Oh, it's up there - you didn't - this one, I think - does that need to be capitalized?

5.15 Researcher: Oh, yeah. So every time you have like ‘students’, that should be the ‘arraySTUDENTS’ array

5.16 Grace: so...

5.17 Researcher: Cause I just called mine ‘students’

5.18 Sara: Do capitals matter?

5.19 Researcher: I think so

5.20 Sara: Ok

5.21 Researcher: I think capitals do matter

5.22 Sara: Okay, I'll change them on the other one too

5.23 Grace: Let's see if this works. *runs code* It's not doing anything. It's still not working

5.24 Sara: Let me ask her Geography(inaudible)

5.25 Grace: Okay, I'm going to delete this. Ah, no

5.26 Sara: So like geography wise we want like...

5.27 Grace: I'm deleting some of this temporarily just so I can see if what we have right now works

5.28 Sara: Or do we want it numbered by region? No, I don't like that.

Day 6 Full Transcript – Google Docs Only

6.01 Grace: Okay, now this is the old code. This this down here is the new code

6.02 Sara: New code

6.03 Grace: Let's see. List umm...

Grace: list

6.04 Grace: array students. Geography. Okay, but where do I go from here?

Grace: list(arraySTUDENTS[[‘Geography]]

Victor: list(arraySTUDENTS[[‘Geography’]]

6.05 Victor: Wait, why do we have geography?

6.06 Grace: Umm, because they do consider where you're from

6.07 Victor: So you-

6.08 Grace: Cause they want like a diverse class so like, they don't want like everyone to be from like California and New York, - from like North Dakota and stuff. It also makes them look better - like we have people from every state in the country. Even like Wyoming

6.09 Victor: Yeah, but would you say like geography has to be from - like how would you write that in code?

6.10 Grace: Well umm we're listing them 1 through 52, 51 being Washington DC, 52 being other countries. I don't know where to go from here. *mumbling* List array students geography

6.11 Grace: *typing into Google* ascending

6.12 Sara: *looking at generated data* So we need to talk about some stats. I assume a 1 means 1 generation. I don't see any twos. Unless a 1 just means they have (inaudible)

6.13 Grace: Umm... *typing*order

Grace: ~~list~~order(arraySTUDENTS[[‘Geography’]]

6.14 Grace: Okay... umm. I still don't know how to do this

6.15 Sara: Did you go to <WEBSITE>?

6.16 Sara: So Letters. Oh, hold on. Letters

Sara: if(arraySTUDENTS[[‘LETTERS_best’][i]<6)

(inaudible)

Grace: newdata(arraySTUDENTS[[‘Geography’]]order(Geography),]

6.17 Grace: I still think it's wrong.

Appendix 2: Epistemological Framing Coding Table

Table 7: Epistemological Framing Coding Table

Code/Framing	Description	Example
School Assignment	Talking about completing assignment	S: You didn't answer B or C or J: We weren't supposed to!
	Turning things in	J: I turned it in thinking it was due on Sunday
	Classroom norms around graphs (having titles, labels, legends, etc.)	S: Should label this.
Data Science	Breaking apart the open-ended task	J: So the basic thing is we have three things to look for. Number of female fans, then ages, then compare it to fan data.
	Cleaning Data	S: Is that the thing with the zeros, remember how she said... you can set all the zeros like insert NA for zero or something and then remove all the NAs.
	Filtering Data	J: Ok so we've got something. Now we need to figure out... those that like Star Trek and those that don't.
	Interpreting Results	S: Yeah, more women are becoming fans of both of Star-, as time goes on.
Real World	Star Wars Knowledge	I definitely know who the Star Wars fandom there's a lot of sketchy male fans and they tend to shame female fans which can result in a lower data pool, could be problematic.
		When did the original trilogy come out? I keep forgetting. 1970-. So these girls would have been... anywhere from...these are the people who were born from, 1972 to 1986. The original trilogy came out 77, 80, and 83. So they were all born around the time that the movies came out. But, there were definitely not nearly as many fans... but the new fan base, coming from, um, 1987 to 1999 is stronger.
Computer as Tool	Inputting Data	J: Alright how do I upload.... Top right click file download...
	Generating Graphs	J: Let's try making a bar plot.
	Addressing Compilation Errors	J: Dollar sign operator is invalid for... what the fuck is atomic vector?
	Data Variables	J: Young adult equals subset... subset f... f dollar sign h equals equals 18, 29.
	State of Data	J: No, this is just the summary, we need to take that and use it now, because we need to see how many Star Trek fans are there in this age bracket, in this age bracket, in this age bracket, so... what do we wanna call the age brackets.
	Filtering Data	J: So f, dollar sign... Star Trek fans... y equals table... f dollar sign... scroll...
	Cleaning Data	S: Is that the thing with the zeros, remember how she said... you can set all the zeros like insert NA for zero or something and then remove all the NAs.

Appendix 3: Secondary Listening and Secondary Sourcing Coding Table

Table 8: Secondary Listening and Secondary Sourcing Coding Table

Code	Descriptions	Examples
Secondary Listening	Answering a question with an explanation (as opposed to simple 'yes' or 'no')	J: But what's in the middle of that second quote? S: Nothing, it's a blank space because you're inserting like nothinginess.
	Adding a new piece of information to the conversation	J: We need to add a legend. S: Ok. Wait, really? Oh I get it, died and survived. Okay. So the green is fan? Fan of Star Trek. J: No fans are not... 'Cause the majority of people were fans, so... legend... add a legend, so that's a separate command...
	Adding or changing emphasis in an explanation (could include nonverbal)	J: How do we go from... where'd we go... no sent mail, sent mail... we went from this, to that by getting rid of the zeros what happened? S: Yeah well that's because , the new data... J: Yeah but what happened here and what happened here?
Secondary Sourcing	*conceptual evidence* which includes questions about the concepts at hand	So the green [bars on bar plot] is fan? Fan of Star Trek.
	re-stating something conceptual in their own words	
	trying to extrapolate based on their understanding	J: I need to make it smaller. S: Can we move it?
	epistemological evidence which includes questions about what the task is	J: Ok. We don't need that. So now what do we do, what do we do.
	re-stating the task in their own words	S: that's what we're trying to determine? If that grea- if that difference is significant.
	trying to extrapolate their role or some other facet of the task based on their understanding	Do we both need to import the data?

Appendix 4: More Examples of New Constructs in Chapter 6 Data

In the qualitative results in Chapter 6, I present cases to illustrate (1) the interaction between Secondary Sourcing/Listening and Attending to Framing as well as (2) the chaining of Secondary Sourcing/Listening. Chapter 5 has illustrated that students use frame-switching and explicit question asking to attend to one another's framings. Looking across the Quantitative Results, we see that in some but not all cases, epistemological frames shift in conjunction with a Secondary Sourcing and Secondary Listening code. Below, I discuss the interaction between frame switching and secondary sourcing as well as the potential conflict between the concept of explicitly asking a peer's framing and being in a shared positional framing (a requirement for secondary sourcing and secondary listening).

Additionally, looking across the Quantitative Results in Chapter 6, we see clusters of Secondary Listening and Secondary Sourcing. Throughout the data there are both single instances and these chains of Secondary Sourcing and Listening. Since there are examples of one-off Secondary Sourcing in the Attending to Framing cases, below I present an example of how the pair of students chained together these constructs.

Attending to Framing: Frame Switching

The following five turns of talk illustrate a lot of epistemological frame switching (see Figure 24).

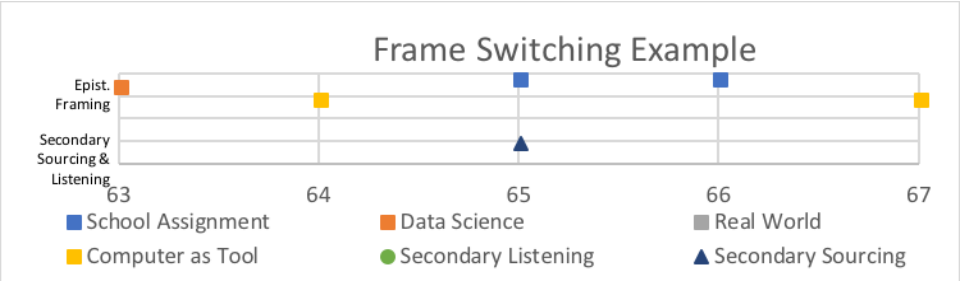


Figure 24: Coding of Frame Switching Example from Monday about 15 minutes into class

The example starts with Jess narrating her thoughts (lines 63 and 64 in Table 9) before Susan interjects on line 65. You will notice that while Jess is working on importing their data into RStudio, Susan is working on the written assignment they are turning in.

Table 9: Transcript of Frame Switching Example from Monday about 15 minutes into class

Turn	Speaker	Transcript
63	J	Alright how do I upload Google Sheets into RStudio?....
64	J	Top right click file then download as...
65	S	So this day one planning thing is like you already turned in.
66	J	Yes so we're good we don't have to worry about it.
67	J	CSV

Susan's interruption on line 65 causes Jess to frame-switch (line 66) to answer Susan's question. However, Jess promptly continues with her task and narration in the following line (line 67). This fluid frame-switching of Jess's looks like simply answering a question, but previous work (Chapter 5) and the Secondary Listening and Secondary Sourcing example below illustrates that without Jess attending to Susan's framing, they could be talking past one another.

Line 65 is interesting along a Positional Framing dimension as well. Not only is line 65 a bid from Susan to engage Jess in the written part of the assignment, but it is an example of

Secondary Sourcing. From line 65 we see Susan doing the work of trying to understand her role or task in the moment. She is clarifying that the day one assignment has already been turned in – implying that she should NOT work on it. Jess sees to understand this implication by responding that "we don't have to worry about it." As the day two assignment was assigned at the start of class, this might also be understood as confirmation that Susan should begin work on day two. The work Susan is doing in this utterance would fall under the description of "trying to extrapolate their role … based on their understanding" (see Table 8 in Appendix 2).

In contrast, towards the end of Tuesday when Jess is once again narrating her thoughts, this time interpreting a bar graph she just created, Susan asks a question about the assignment, causing Jess to frame switch in a similar fashion. However, Susan's role at this point, completing the written assignments, has already been established. So in this instance we see the same shape of frame switching but *without* Secondary Sourcing (Figure 25).

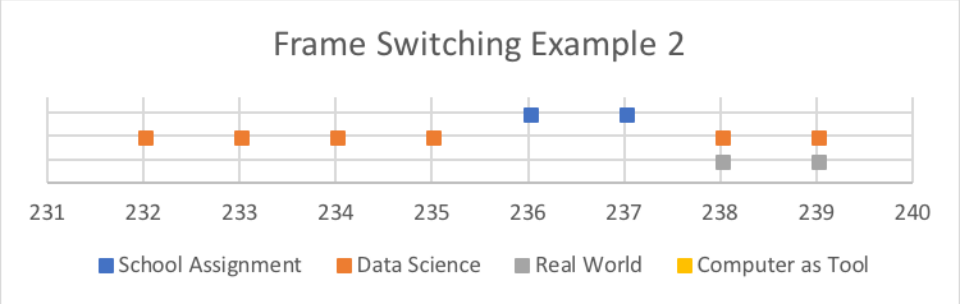


Figure 25: Coding of Frame Switching Example 2 from Tuesday about 37 minutes into class

Table 10: Transcript of Frame Switching Example 2 from Tuesday about 37 minutes into class

Turn	**Speaker**	**Transcript**
232	J	So how do we... interpret this?

233	J	So our hypothesis basically was that a lot of women... it wou ld be that women, it's become more popular, it certainly has become more popular in general, um, over time.
234	J	But our problem is, and it has remained relatively proportion al. What I'm surprised is that 30, in ages 30-44...
235	J	calculator...
236	S	How did we get unstuck?
237	J	Uh, trial and error?
238	J	When did the original trilogy come out? I keep forgetting thi s.
239	J	1977. So these girls would have been... anywhere from...

Once again, we see Jess narrating her thoughts (lines 232-235) when Susan interjects (line 236). This question, "how did we get unstuck", is from the written assignment ("*Are you still stuck/confused? If not, how did you get un-stuck or un-confused?*"). Similarly to the first example, Jess switches into the Assignment frame that Susan is in (line 237) to answer her question, before continuing her narration (lines 238-239) about the graph.

Unlike Susan's question above, line 236 is a shortened version of the assignment and not an attempt to understand Susan's role in the task. The fact that there is no follow up to Jess's tentative and vague response ("Uh, trial and error?" line 237) indicates that Susan is not asking for her understanding (which would indicate secondary sourcing), but instead is attempting to fill in the blanks of the worksheet.

Attending to Framing: Explicit Question Asking

Unlike the nuanced attending to framing in the frame switching examples above, below I illustrate two examples of a student explicitly asking their peer about their epistemological

framing. In the first example, we see the student get re-directed after responding (similar to Chapter 5), whereas the second example illustrates what it looks like for the student who asked the question to simply slip into the named framing.

Towards the beginning of Monday when Jess is catching Susan up on the project (as Susan was absent the Friday before), we see the first example of explicitly asking about what the other is doing. Before this piece of transcript, the two students are off task. Jess started the transcript by looking over at Susan and asking "What are you doing?" (line 45 in Table 11).

Table 11: Transcript of Explicitly Asking about Framing Example from ~10 minutes into class on Monday

Turn	Speaker	Transcript
45	J	What are you doing?
46	S	Trying to page down dammit! [arguing]
47	J	No go back I have to point out the graph to you!

In this example, similar to the example presented in Chapter 5, once Jess hears what Susan is attempting to do (page down on the document Jess is explaining), Jess makes a bid for a framing she views as more appropriate – understanding the graph.

In contrast, on Tuesday when Jess is narrating her feelings about how hard it was to generate a graph, she stops herself and asks what Susan is doing (line 227).

Table 12: Transcript of Explicitly Asking about Framing Example from ~35 minutes into class on Tuesday

Turn	Speaker	Transcript
227	J	What are you doing?
228	S	I'm just copying the code.
229	J	Oh just copying it cause...code... we already have mos t of the code I already gave it to you.
230	S	Yeah, I'll just fill in the... like...

Susan, who is working on inserting code into the written assignment, replies (line 228). However, unlike above and in Chapter 5, Jess accepts this framing and moves from thinking about her graph to thinking about the assignment (line 229). This allows Susan to continue in her framing and work (line 230) unlike the other two examples where Susan (and in Chapter 5, Dan) were re-directed.

In neither of these explicitly asking examples do we see interactions with Secondary Sourcing or Secondary Listening. This is probably in part because in these examples the students do not (yet) agree on the framing (and shared positional framing is a prerequisite for Secondary Sourcing and Secondary Listening coding). As these are the only two cases of explicitly asking framing across the three days, this is both representative of the data as a whole and might imply that Secondary Listening and Secondary Sourcing cannot co-exist with explicitly attending to framing.

These examples of attending to framing illustrate how students create or join their peer in a shared epistemological framing. While the examples above are illustrate active changes in framing, there are probably efforts that are harder to identify of students attending to framing in order to monitor that the group's framings are still shared.

Secondary Listening and Secondary Sourcing Interactions

As you can see from the coding results and examples of attending to framing above, Secondary Sourcing and Secondary Listening do not occur very frequently. The timelines in the coding results do show that when these constructs do appear, they frequently appear in clusters. While

one might say this is because students must be in a shared positional framing for these constructs to occur, it makes sense they appear in clusters, it is important to note that there are both instances of shared positional framings without any secondary listening or secondary sourcing codes and some instances of shared positional framings where only one instance occurs. To investigate this clustering, I present the dense cluster from the end of Monday.

At this point on Monday, Jess has caught Susan up on the project, imported the data into RStudio, and has just managed to filter out only the female data points. This example starts with Jess narrating her thoughts and declaring that "we need to separate those" (line 112).

Table 13: Transcript of Secondary Listening and Secondary Sourcing Interaction Example from about 35 minutes into class on Monday

Turn	Speaker	Transcript
112	J	So we have the female data, and now we need to figure out how, we have the numbers of... but we need to separate those, we need to separate those.
113	S	Further?
114	J	Yeah.
115	S	Into what?
116	J	By each age bracket.
117	S	Isn't that what they are?
118	J	No, this is just the summary, we need to take that and use it now, because we need to see how many Star Trek fans are there in this age bracket, in this age bracket, in this age bracket, so... what do we wanna call the age brackets.

While it is a little unclear whether Jess addressing Susan in line 112 or if she is simply narrating, Susan engages with Jess on line 113. This is the first case of Secondary sourcing – by asking "Further?" Susan is indicating that she was unaware that aside from filtering on gender, they had more filtering to do. Jess's response of "Yeah" in line 114 does not clear up this confusion so

Susan re-asks the question on line 115 (“into what?”) still secondary sourcing by providing evidence that she is missing this step in her epistemological framing of the task. This question gets a more illuminating response.

Jess clarifies on line 116 that she is talking about splitting the data “by each age bracket.” By providing an explanation to address a question, this is the first example of secondary listening. This first example is rather weak, however the utterance is doing a little more work than it first appears. Contrast “by each age bracket” against the more simple response of “age” which would have been the equivalent of a yes or no (and thus not an example of secondary listening). This utterances clarifies not only by what dimension the data is going to be filtered, but also relates it back to the fact the data does not have concrete ages but instead age brackets.

This allusion to the data leads Susan to her next question – “Isn’t that what they are?”. Susan’s secondary sourcing has slightly shifted due to Jess’s response. Before, she was unclear that there was another dimension they were filtering on. Now her question is about the state of the data. This utterance illustrates a gap in understanding by conflating the fact that because the data contains this information of age bracket, the code can immediately turn this into a graph. This conflation might be due to the fact that age is typically a quantitative field easily graphed directly. However, because this data has age brackets, the age dimension is actually categorical in this instance.

Jess hears this conceptual gap in the state of the data and the lack of understanding of the next step and responds with a fuller explanation (line 118). This second example of secondary listening is more convincing as the utterance not only answers the question with an explanation

but also inserts into the conversation the idea of "summary" versus the actual state of the data – the conceptual piece that Susan was missing.

Jess ends her utterance by asking what they should call the age brackets. This is probably the moment their epistemological framings most clearly illustrate dissonance. Jess, in utterance 118, is trying to come up with variable names so she can filter the data for each age bracket into its own variable (similar to how she filtered out the female data into a variable called "f"). However, Susan does not seem to pick up on this, which is clearly indicated in her next confused utterance.

Table 14: Transcript of Secondary Listening and Secondary Sourcing Interaction Example from about 35 minutes into class on Monday

Turn	Speaker	Transcript
119	S	They have names?
120	J	Well they have to have names.
121	S	Other than 18 to 29?
122	J	Well we need to come up with something.
123	S	Ok uh, Jesus this is weird I don't know, uh, young adult I guess? You know in the Greek ideal you're an infant until you turn 30. You're a man from 30 to 50, you're an old man from 60 up.
124	J	Ok they were lucky to live to 50, so anyways.
125	S	So young adult I guess?
126	J	Young adult equals subset... subset f... f dollar sign h equals equals 18, 29.

While Susan continues to secondary source by asking questions to illustrate her confusion (lines 119 and 121), Jess's answers no longer resemble explanations. This indicates she has stopped secondary listening and is not attending to Susan's stated confusion.

On line 123, Susan, still uncomfortable (indicated by "this is weird") simply answers Jess's requests for a name ("uh, young adult I guess?"). While there is a slight diversion, Jess brings them back on topic ("so anyways" line 124), causing Susan to re-state her proposed name ("So young adult I guess?" line 125). We clearly see from the next line where Jess starts narrating, that Jess uses this proposal as a variable name ("Young adult equals subset…" line 126).

Throughout the majority of the episode, Susan is confused and attempting to resolve this by asking Jess questions. While Jess eventually provides explanations, Susan does not understand these and Jess stops attending to her confusion. Giving up, Susan answers the question Jess is asking. This cluster of secondary sourcing and secondary listening then indicates the dissonance between the two students' understandings and illustrates the work they do to attempt to rectify this divergence.

It is particularly helpful to consider this case through the lens of Secondary Sourcing and Secondary Listening. If you consider this case simply through conceptual framing, you would see the dissonance, but not the work that the students are doing. In particular, while it would be noted that Jess has some conceptual pieces that Susan does not, the reader would miss the fact that not only does Susan recognize these missing pieces in her understanding but she is actively doing work in order to rectify these gaps.

These chains or interactions between secondary listening and secondary sourcing codes are probably indicators of students doing work to repair their shared epistemological and/or conceptual framings.

Appendix 5: Video of Data Presented in Empirical Chapters

Please click on the following links to access the videos.

Chapter 4

Day 4 - https://tufts.box.com/s/n2fu9kb6xks97ewzblj18q02fz3iv88z

Day 5 - https://tufts.box.com/s/wggmrf6hhhq5992v8x2gc2oe9kl50bgd

Day 6 - https://tufts.box.com/s/bykrthupatlv6l4muogz5f33shcnjhuw

Chapter 5

Case 1 - https://tufts.box.com/s/92sg5c02hw888cu7oxocliofgk2vofel

Case 2 - https://tufts.box.com/s/bfi93wzi14asfp9d9xapkt6qvb2ir2t9

Case 3 - https://tufts.box.com/s/hg7s7v1rsqsl8kje7vp8cps4oqn99pbu

Chapter 6

Qualitative Results - https://tufts.box.com/s/n26gytqyvhne0n1tq29e3j3inukh3pxd

Bibliography

ABET. (n.d.). CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS, 2016 – 2017. Retrieved September, 2017, from http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/

Azlina, N. N., & Nik, A. (2010). CETLs: Supporting collaborative activities among students and teachers through the use of Think-Pair-Share techniques. International Journal of Computer Science Issues, 7(5), 18-29.

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: what is Involved and what is the role of the computer science education community?. *Acm Inroads*, *2*(1), 48-54.

Barron, B. (2000). Problem solving in video-based microworlds: Collaborative and individual out- comes of high achieving sixth grade students. Journal of Educational Psychology, 92, 391–398.

Barron, B. (2003). When smart groups fail. The journal of the learning sciences, 12(3), 307-359.

Barron, B., Martin, C. K., Mercier, E., Pea, R., Steinbock, D., Walter, S., ... & Tyson, K. (2009, June). Repertoires of collaborative practice. In Proceedings of the 9th international conference on Computer supported collaborative learning-Volume 2 (pp. 25-27). International Society of the Learning Sciences.

Bateson, Gregory. (1987). Steps to an ecology of mind : Collected essays in anthropology, psychiatry, evolution, and epistemology. Northvale, N.J.: Aronson.

Bossert, S. T. (1988). Chapter 6: Cooperative activities in the classroom. Review of research in education, 15(1), 225-250.

Chizhik, A. W. (2001). Equity and status in group collaboration: Learning through explanations depends on task characteristics. *Social Psychology of Education*, *5*(2), 179-200.

Cockburn, A., & Williams, L. (2000). The costs and benefits of pair programming. Extreme programming examined, 223-247.

Cohen, E. G. (1994). Restructuring the Classroom: Conditions for Productive Small Groups. Review of Educational Research, 64(1), 1–35. http://doi.org/10.3102/00346543064001001

Cole, K. A. (1995, October). Equity issues in computer-based collaboration: Looking beyond surface indicators. In The first international conference on Computer support for collaborative learning (pp. 67-74). L. Erlbaum Associates Inc..

CSTA Standards Task Force. (2016). [Interim] CSTA K-12 Computer Science Standards. Technical Report.

Deitrick, E., Wilkerson, M. H., & Simoneau, E. (2017, August). Understanding student collaboration in interdisciplinary computing activities. In *Proceedings of the 2017 ACM Conference on International Computing Education Research* (pp. 118-126). ACM.

DiSessa, A. A. (1993). Toward an epistemology of physics. Cognition and instruction, 10(2-3), 105-225.

Dookie, L. (2014) A Case Study Examining the Microdynamics of Social Positioning within the Context of Collaborative Group Work. Proceedings of the 2014 Annual Conference of the Learning Sciences. Boulder, CO. Boulder, CO.

Dookie, L. (2015). Examining Marginalizing Acts of Social Positioning in Mathematical Group Work: Towards a Better Understanding of how Microaggressions and Stereotype Threat Unfold in Intergroup Interactions (Doctoral dissertation, University of Toronto).

Esmonde, I. (2009). Ideas and identities: Supporting equity in cooperative mathematics learning. *Review of Educational Research*, *79*(2), 1008-1043.

Greeno, J. G., & Van De Sande, C. (2007). Perspectival understanding of conceptions and conceptual growth in interaction. *Educational Psychologist*, *42*(1), 9-23.

Goffman, E. (1974). *Frame analysis: An essay on the organization of experience*. Cambridge, MA, US: Harvard University Press.

Goffman, E. (1979). Footing. Semiotica, 25(1-2), 1-30.

Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. Transfer of learning from a modern multidisciplinary perspective, 89.

Hammer, D., & Berland, L. K. (2013). Confusing claims for data: A critique of common practices for presenting qualitative research on learning. *Journal of the Learning Sciences*, *23*(1), 37-46.

Johnson, D. W., & Johnson, R. T. (1974). Instructional goal structure: Cooperative, competitive, or individualistic. *Review of educational research*, *44*(2), 213-240.

Johnson, D., & Johnson, R. (1982). The study of cooperative, competitive, and individualistic situations: State of the area and two recent contributions. Contemporary Education: A Journal of Reviews, 1, 7-13.

Johnson, R. T., & Johnson, D. W. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. Psychological Bulletin, 89(1), 47–62.

Lewis, C. M., Titterton, N., & Clancy, M. (2012, September). Using collaboration to overcome disparities in Java experience. In Proceedings of the ninth annual international conference on International computing education research (pp. 79-86). ACM.

Lewis, C. M., & Shah, N. (2015, July). How Equity and Inequity Can Emerge in Pair Programming. In Proceedings of the eleventh annual International Conference on International Computing Education Research (pp. 41-50). ACM.

McCormick, M. E., & Hammer, D. (2016). Stable Beginnings in Engineering Design. *Journal of Pre-College Engineering Education Research (J-PEER)*, 6(1), 4.

NGSS. (2013, April). APPENDIX F – Science and Engineering Practices in the NGSS. Retrieved September, 2017, from http://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20%20FINAL%20060513.pdf

Nokes-Malach, T. J., Richey, J. E., & Gadgil, S. (2015). When is it better to learn together? Insights from research on collaborative learning. Educational Psychology Review, 27(4), 645-656.

Oliveira, A. W., & Sadler, T. D. (2008). Interactive patterns and conceptual convergence during student collaborations in science. Journal of Research in Science Teaching, 45(5), 634-658.

Phillips, A. M., Watkins, J., & Hammer, D. (2017). Problematizing as a scientific endeavor. Physical Review Physics Education Research, 13(2), 020107.

Radoff, J., & Hammer, D. (2015). Attention to student framing in responsive teaching. Responsive Teaching in Science and Mathematics, 189.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. The journal of the learning sciences, 2(3), 235-276.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In *Computer supported collaborative learning* (pp. 69-97). Springer, Berlin, Heidelberg.

Scherr, R. E., & Hammer, D. (2009). Student behavior and epistemological framing: Examples from collaborative active-learning activities in physics. *Cognition and Instruction*, 27(2), 147-174.

Shah, N., Lewis, C., & Caires, R. (2014). Analyzing equity in collaborative learning situations: A comparative case study in elementary computer science. In Proceedings for the 11th International Conferences of the Learning Sciences (ICLS) (pp. 495-502).

Sullivan, F. R., & Wilson, N. C. (2015). Playful talk: Negotiating opportunities to learn in collaborative groups. *Journal of the Learning Sciences*, *24*(1), 5-52.

Tannen, D. (1993). What's in a frame? Surface evidence for underlying expectations. *Framing in discourse*, *14*, 56.

Tannen, D., & Wallat, C. (1987). Interactive frames and knowledge schemas in interaction: Examples from a medical examination/interview. *Social psychology quarterly*, 205-216.

van de Sande, C. C., & Greeno, J. G. (2012). Achieving alignment of perspectival framings in problem-solving discourse. *Journal of the Learning Sciences*, *21*(1), 1-44.

Van Langenhove, L., & Harré, R. (1999). Introducing positioning theory.

Webb, N. M. (1982a). Student interaction and learning in small groups. *Review of Educational Research*, *52*(3), 421-445.

Webb, N. M. (1982b). Group composition, group interaction, and achievement in cooperative small groups. *Journal of Educational Psychology*, *74*(4), 475.

Webb, N. M. (1984a). Sex differences in interaction and achievement in cooperative small groups. *Journal of educational psychology*, *76*(1), 33.

Webb, N. M. (1984b). Stability of small group interaction and achievement over time. *Journal of Educational Psychology*, *76*(2), 211.

Webb, N. M. (1985). Verbal interaction and learning in peer-directed groups. *Theory into practice*, *24*(1), 32-39.

Webb, N. M. (1989). Peer interaction and learning in small groups. *International journal of Educational research*, *13*(1), 21-39.

Webb, N. M. (1991). Task-related verbal interaction and mathematics learning in small groups. *Journal for research in mathematics education*, 366-389.

Webb, N. M., Troper, J. D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of educational psychology*, *87*(3), 406.

Wilkerson, M., Deitrick, E., & Simoneau, E. (2017). Integrating computational thinking in high school statistics through data modeling with R. (2017). Chicago

Williams, L. A., & Kessler, R. R. (2000). All I really need to know about pair programming I learned in kindergarten. *Communications of the ACM*, 43(5), 108-114.

Williams, L., & Upchurch, R. L. (2001, February). In support of student pair-programming. In ACM SIGCSE Bulletin (Vol. 33, No. 1, pp. 327-331). ACM.