Building Capacity for Academically Productive Talk: The Development of Teacher Leaders in Science Professional Development

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BUILDING CAPACITY FOR ACADEMICALLY PRODUCTIVE TALK:
THE DEVELOPMENT OF TEACHER LEADERS IN
SCIENCE PROFESSIONAL DEVELOPMENT

A Dissertation Presented

by

RENEE AFFOLTER

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2020

College of Education
Mathematics, Science, & Learning Technologies
BUILDING CAPACITY FOR ACADEMICALLY PRODUCTIVE TALK: THE DEVELOPMENT OF TEACHER LEADERS IN SCIENCE PROFESSIONAL DEVELOPMENT

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RENEE AFFOLTER

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To my supportive family who always inspire and support me.
ACKNOWLEDGMENTS

I would like to thank my advisor, Martina Nieswandt, for her years of guidance and support. I am forever grateful for her patience and encouragement throughout every step of this journey.

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I am truly honored to have been touched by the generosity and kindness of all of these people.
ABSTRACT

BUILDING CAPACITY FOR ACADEMICALLY PRODUCTIVE TALK:
THE DEVELOPMENT OF TEACHER LEADERS IN
SCIENCE PROFESSIONAL DEVELOPMENT

MAY 2020

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Despite decades of research on the type of classroom dialogue that supports collaborative student sensemaking and professional development efforts to support such dialogue, opportunities for students to incrementally deepen their understanding of science ideas through engagement in science practices and to engage in complex reasoning and argumentation through classroom talk is limited in most K-12 science classrooms (Driver, Newton, & Osborne, 2000; Lemke, 1990; Michaels, Shouse, & Schweingruber, 2008; Mortimer & Scott, 2003; C. O’Connor, Michaels, & Chapin, 2015; Reinsvold & Cochran, 2011; Scott, Mortimer, & Aguiar, 2006; Weiss, Pasley, Smith., Banilower, and Heck, 2003; Wilson, Schweingruber, & Nielsen, 2015). In order to address the bigger question of how to prepare PD Leaders to support the knowledge and enactment of new discourse practices, I used the framework of Academically Productive Talk (APT) and examined the discourse practices used by Lead Facilitators as they prepare Teacher Leaders to enact PD focused on APT. I then examined the discourse practices used by those Teacher Leaders as they enacted the PD with their teacher colleagues. Analysis revealed that, similar to the Lead Facilitators, Teacher Leaders at both Bayedge and Lakecastle used APT moves at a high rate and used the conceptual and pedagogical goals of the discussion to guide their use of those moves in discussions that were characterized by high levels of participant to participant interaction and co-construction. Moves where the Teacher Leaders were guiding the discussion by synthesizing ideas and naming the ideas they want the group to attend to were unequally taken up indicating further work is needed in supporting Teacher Leaders with moves that can support idea development while at the same time ensuring that the Teachers are doing the sensemaking. Greater attention around specific moves designed to support idea development by synthesizing the discussion along the way may support Teacher Leaders in more readily taking up those moves. Engaging in the PD themselves as learners and providing opportunities to reflect on those experiences in order to deepen content understanding, understand the goals of each activity, and to develop a culture that supports adult learners appears to be important in this preparation of Teacher Leaders to lead PD on APT.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xii</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Academically Productive Talk (APT)</td>
<td>4</td>
</tr>
<tr>
<td>1.2 Preparing Professional Development Leaders</td>
<td>5</td>
</tr>
<tr>
<td>1.3 Study Overview and Research Questions</td>
<td>7</td>
</tr>
<tr>
<td>2. DISCOURSE IN SCIENCE EDUCATION</td>
<td>10</td>
</tr>
<tr>
<td>2.1 Theoretical Framework</td>
<td>10</td>
</tr>
<tr>
<td>2.2 Discourse in Science Education</td>
<td>14</td>
</tr>
<tr>
<td>2.2.1 Science Teaching Reform and Classroom Discourse</td>
<td>14</td>
</tr>
<tr>
<td>2.2.2 Scientific Discourse, Power, and Language</td>
<td>15</td>
</tr>
<tr>
<td>2.2.3 Dialogic Discourse</td>
<td>19</td>
</tr>
<tr>
<td>2.2.4 The IRF Pattern of Classroom Discourse</td>
<td>24</td>
</tr>
<tr>
<td>2.2.5 Academically Productive Talk</td>
<td>29</td>
</tr>
<tr>
<td>2.2.5.1 Conditions that Enable and Support APT</td>
<td>30</td>
</tr>
<tr>
<td>2.2.5.2 Goals and Moves to Support APT</td>
<td>32</td>
</tr>
<tr>
<td>2.3 Summary</td>
<td>36</td>
</tr>
<tr>
<td>3. PROFESSIONAL DEVELOPMENT AND PREPARING TEACHER LEADERS</td>
<td>39</td>
</tr>
<tr>
<td>3.1 Framework for designing and facilitating PD</td>
<td>39</td>
</tr>
<tr>
<td>3.2 Key Features of Effective PD</td>
<td>41</td>
</tr>
<tr>
<td>3.3 Preparing PD Leaders</td>
<td>48</td>
</tr>
<tr>
<td>3.3.1 Facilitation of Science and Math PD</td>
<td>49</td>
</tr>
<tr>
<td>3.3.2 Preparation of PD Leaders</td>
<td>55</td>
</tr>
<tr>
<td>2.4.3 Summary</td>
<td>58</td>
</tr>
<tr>
<td>4. PROFESSIONAL DEVELOPMENT CONTEXT</td>
<td>62</td>
</tr>
<tr>
<td>4.1 Overview of NGSX</td>
<td>62</td>
</tr>
</tbody>
</table>
4.2 Teacher Pathway .................................................................64
4.3 Facilitator Pathway ............................................................67

5. METHODOLOGY ..................................................................71

5.1 Overview .............................................................................71
5.2 Rationale for Research Design .............................................72
5.3 Setting and Participants .........................................................74
5.4 Gaining entry and informed consent .....................................77
5.5 Data Collection .....................................................................78
  5.5.1 Focal Discussions ..............................................................78
  5.5.2 Interviews .........................................................................81
  5.5.3 Field Notes ........................................................................82
  5.5.4 Video Transcripts ...............................................................82
5.6 Data Analysis ..........................................................................86
  5.6.1 Analysis for RQ1a and 2a .......................................................87
  5.6.2 Analysis for RQ1b and 2b .......................................................90
    5.6.2.1 Coding Facilitator Turns for APT .................................91
    5.6.2.2 Qualitative Analysis of Transcripts and Interviews ..........97
  5.6.3 Analysis for RQ1c and 2c .......................................................99
    5.6.3.1 Coding Participant Turns for Co-Construction ..........99
    5.6.3.2 Coding Participant Turns for Depth of Response ........102
  5.6.4 Analysis for RQ3 ...............................................................105
5.7 Trustworthiness of Data .........................................................105

6. RESULTS: LEAD FACILITATORS ...........................................109

6.1 Interaction patterns ...............................................................110
  6.1.1. Working with the same Teacher Leader .........................113
  6.1.2 Teacher Leader to Teacher Leader interaction ..................115
  6.1.3 Lead Facilitator and different Teacher Leaders .................116
6.2 Academically Productive Talk Moves ....................................118
  6.2.1 APT Moves by Goal ..........................................................121
  6.2.2 Patterns in how the APT Moves were used .......................127
    6.2.2.1 Theme 1: Using moves to support Teacher Leader
             engagement and participation .......................................128
      6.2.2.1.1 Setting the table ..................................................128
      6.2.2.1.2 Using Moves to open up the discussion to
               other Teacher Leaders and ideas ..........................132
    6.2.2.2 Theme 2: Maintaining focus and direction .................137
      6.2.2.2.1 Clear segments of the discussion .........................138
      6.2.2.2.2 Focused attention around ideas to discuss ........147
      6.2.2.2.3 Moves to maintain direction, support
               convergence, and come to consensus ......................150
6.3 Nature of the Teacher Leader Turns: Reasoning and Co-Construction
6.3.1 Depth of Teacher Leader Response: Reasoning/Explanation
6.3.2 Depth of Teacher Leader Turns: Co-construction of ideas
6.4 Summary

7. RESULTS: BAYEDGE

7.1 Interaction Patterns
7.1.1 Turn Depth: Working with the same Teacher
7.1.2 Teacher to Teacher interaction
7.1.3 Teacher Leader and different Teachers
7.2 Academically Productive Talk Moves
7.2.1 Overall APT Moves and Moves by Goal
7.2.2 Patterns in how the APT Moves were used
    7.2.2.1 Theme 1: Using Moves to Support Teacher Engagement and Participation
    7.2.2.1.1 Dig deeper into Teachers’ thinking
    7.2.2.1.2 Using Moves to open up the discussion to other Teachers and ideas
    7.2.2.2 Theme 2: Maintaining focus and direction
    7.2.2.2.1 Segments of the discussion
    7.2.2.2.2 Focused attention around ideas to discuss
    7.2.2.2.3 Moves to maintain direction
7.3 Nature of the Teacher Turns: Reasoning and Co-Construction
7.3.1 Depth of Teacher Response: Reasoning/Explanation
7.3.2 Depth of Teacher Turns: Co-construction of ideas
7.4 Summary of Research Question 2 and 3: Bayedge

8. RESULTS: LAKECASTLE

8.1 Interaction Patterns
8.1.1 Working with the same Teacher
8.1.2 Teacher-to-Teacher interaction
8.1.3 Teacher Leader and Different Teachers
8.2 Academically Productive Talk Moves
8.2.1 Overall APT Moves and Moves by Goal
8.2.2 Patterns in How APT Moves Were Used
    8.2.2.1 Theme 1: Using Moves to Support Teacher Engagement and Participation
    8.2.2.1.1 Making space for participants to talk
    8.2.2.1.2 Dig deeper into Teachers’ thinking
    8.2.2.1.3 Using Moves to open up the discussion to other Teachers and ideas
    8.2.2.2 Theme 2: Maintaining focus and direction
8.2.2.2.1 Segments of the discussion .................................227
8.2.2.2.2 Focused attention around ideas to discuss ..........232
8.2.2.2.3 Synthesis and Consensus moves to maintain direction ........................................236
8.3 Nature of the Teacher Turns: Reasoning and Co-Construction .................240
  8.3.1 Depth of Teacher Response: Reasoning/Explanation ..........240
  8.3.2 Depth of Teacher Turns: Co-construction of ideas .................243
8.4 Summary of Research Question 2 and 3: Lakecastle ........................................246

9. DISCUSSION ........................................................................................................248
  9.1 Introduction .......................................................................................................248
  9.2 Similarities across sites .........................................................................................249
  9.3 Differences Across sites: Supporting Idea Development ....................................255
    9.3.1 Bayedge: Limited Goal 5 Moves and ‘Naming the That’ to Maintain Focus and Direction ........................................256
    9.3.2 Lakecastle: “Strong Facilitation” if you want to “get somewhere” .........................258
  9.4 Implications for Preparing teacher leaders .........................................................261
  9.5 Limitations ........................................................................................................266
  9.6 Future Research ..................................................................................................267
  9.7 Conclusion ........................................................................................................269

APPENDICES

A. SUMMARY OF UNITS AND FOCUS IN NGSX TEACHER PATHWAY ..........271
B. INFORMED CONSENT ..........................................................................................272
C. INTERVIEW PROMPTS ..........................................................................................276
D. RULES FOR TRANSCRIPTION .................................................................................277
E. TALK MOVES CODING MANUAL ........................................................................279
F. CO-CONSTRUCTION MOVES CODING MANUAL .............................................285
G. DEPTH OF PARTICIPANT RESPONSE CODES (P1-P3) ......................................289
H. DESCRIPTION OF FOCAL PHENOMENA AND AIR PUPPIES MODEL ..........291

BIBLIOGRAPHY ........................................................................................................294
LIST OF TABLES

Table | Page
--- | ---
Table 1: Four Classes of the Communicative Approach (Mortimer and Scott, 2003) | 26
Table 2: Demographics of Participating Sites, Teacher Leaders, and Study Groups | 76
Table 3: Focal Discussions for this study | 79
Table 4: Example Transcript | 83
Table 5: Duration (in minutes) of Each Discussion by Study Group | 85
Table 6: Summary of Data Sources and Analysis for RQ1 and 2 | 86
Table 7: APT Codes and Examples from Transcripts | 94
Table 8: Example of coded transcript | 96
Table 9: Participant Co-Construction Codes | 100
Table 10: Sample transcript coded for co-construction | 101
Table 11: Pimental and McNeill (2013) Coding Scheme for Students' Contributions in Discussion | 103
Table 12: Participant Reasoning or Depth of Response Codes | 103
Table 13: Sample transcript coded for P1-P3 | 104
Table 14: Lead Facilitator sample transcript, orange peak graph | 117
Table 15: Sample Transcript, Other Lead Facilitator Moves | 125
Table 16: Sample Transcript, Wait Time Lead Facilitators | 126
Table 17: Theme 1 Sub-Themes and Description for How APT Moves Were Used. | 128
Table 18: Sample Transcript, Setting the Table | 129
Table 19: Sample Transcript, Setting the Table 2 | 131
Table 20: Sample Transcript, Opening Up 1 | 132
Table 21: Sample Transcript, Result of Opening Up .......................................................... 133

Table 22: Theme 2 Sub-Themes and Description for How APT Moves Were Used .......................................................... 137

Table 23: Sample Launch 1, Lead Facilitators ................................................................. 138

Table 24: Sample Launch 2, Lead Facilitators ................................................................. 139

Table 25: Focused Segments, Lead Facilitator ................................................................. 142

Table 26: Sample Transcript, Focused Attention ............................................................ 148

Table 27: Sample Transcript, Maintaining Direction 1 ................................................. 150

Table 28: Sample Transcript, Maintaining Direction 2 ................................................. 151

Table 29: Sample Transcript, Maintaining Direction 3 ................................................. 152

Table 30: Sample Transcript, Maintaining Direction 4 ................................................. 154

Table 31: Sample Transcript, Maintaining Direction 5 ................................................. 157

Table 32: Sample Transcript, P1-P3 1 ................................................................. 160

Table 33: Sample Transcript, P1-P3 2 ................................................................. 162

Table 34: Sample Transcript, P1-P3 3 ................................................................. 163

Table 35: Sample Transcript, Co-Construction 1 ...................................................... 165

Table 36: Sample Transcript, Co-Construction 2 ...................................................... 166

Table 37: Sample Transcript, Co-Construction 3 ...................................................... 166

Table 38: Average APT Moves by Goal for Bayedge Teacher Leaders and Lead Facilitators .......................................................... 175

Table 39: Summary of Theme 1 for Bayedge .......................................................... 180

Table 40: Transcript, Bayedge Dig Deeper 1 .......................................................... 180

Table 41: Transcript, Bayedge Dig Deeper 2 .......................................................... 180

Table 42: Transcript, Bayedge Open Up 1 .......................................................... 182
Table 43: Transcript, Bayedge Open Up 2 ................................................................. 183
Table 44: Summary of Theme 2 for Bayedge ............................................................. 184
Table 45: Transcript, Bayedge Launch ..................................................................... 185
Table 46: Transcript, Bayedge Making Space 1 ....................................................... 191
Table 47: Transcript, Bayedge Making Space 2 ....................................................... 192
Table 48: Transcript, Bayedge Making Space 3 ....................................................... 192
Table 49: Transcript, Bayedge Limited Synthesis .................................................... 195
Table 50: Transcript, Bayedge Refocus .................................................................... 196
Table 51: Transcript, Bayedge Interview .................................................................. 197
Table 52: Transcript, Bayedge P1-P3 .................................................................... 200
Table 53: Transcript, Lakecastle Teacher Interaction ............................................. 210
Table 54: Transcript, Lakecastle Peak Graph ........................................................ 212
Table 55: Average APT Moves/Hour by Goal for Bayedge Teacher Leaders
and Lead Facilitators ................................................................................................... 214
Table 56: Transcript, Lakecastle Direct Question ................................................. 214
Table 57: Transcript, Lakecastle Overlap ............................................................... 216
Table 58: Summary of Theme 1 for Lakecastle ..................................................... 220
Table 59: Transcript, Lakecastle Making Space ..................................................... 221
Table 60: Transcript, Lakecastle Dig Deeper ......................................................... 223
Table 61: Transcript, Lakecastle Open Up 1 ........................................................ 224
Table 62: Transcript, Lakecastle Open Up 2 ........................................................ 225
Table 63: Transcript, Lakecastle Open Up 3 ........................................................ 226
Table 64: Summary of Theme 2 for Lakecastle ..................................................... 227
Table 65: Transcript, Lakecastle Launch ............................................................... 228
Table 66: Transcript, Lakecastle Closure ................................................................. 230
Table 67: Transcript, Lakecastle Focused 1 ............................................................ 232
Table 68: Transcript, Lakecastle Focused 2 ............................................................ 234
Table 69: Transcript, Lakecastle Focused 3 ............................................................ 235
Table 70: Transcript, Lakecastle P1-P3 ................................................................. 242

LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1: Structure of the Generations of Enactment in the NGSX PD Program</td>
<td>8</td>
</tr>
<tr>
<td>Figure 2: Goals for Productive Discussions and Nine Talk Moves (TERC, 2012)</td>
<td>34</td>
</tr>
<tr>
<td>Figure 3: Nested conceptual framework for teacher learning with PD (Lauffer, 2010)</td>
<td>40</td>
</tr>
<tr>
<td>Figure 4: Summary of Design Principles for NGSX (Reiser et al., 2017)</td>
<td>63</td>
</tr>
<tr>
<td>Figure 5: A step in an NGSX unit Supporting Teachers in Understanding Productive Talk (in Unit 4)</td>
<td>67</td>
</tr>
<tr>
<td>Figure 6: Sequence of Teacher Pathway Units and Facilitator Pathway Chapters for Teacher Leaders in NGSX Leadership Development Academies (LDA)</td>
<td>68</td>
</tr>
<tr>
<td>Figure 7: A step in an NGSX Facilitator Pathway Chapter Supporting Teacher Leaders in Analyzing Facilitation Practice (Chapter 3)</td>
<td>70</td>
</tr>
<tr>
<td>Figure 8: Data sources for RQ1 and RQ2</td>
<td>72</td>
</tr>
<tr>
<td>Figure 9: Sample CDA Peak Graph</td>
<td>88</td>
</tr>
<tr>
<td>Figure 10: Rough Analysis Using CDA Peak Graphs</td>
<td>90</td>
</tr>
<tr>
<td>Figure 11: Mean Number of Turns for Teacher Leaders and Lead</td>
<td>110</td>
</tr>
<tr>
<td>Figure 12: Percentage of Teacher Leaders Who Took at Least One Turn for Each Discussion</td>
<td>111</td>
</tr>
<tr>
<td>Figure 13: Sample CDA Peak Graph with Guidance for Each Element</td>
<td>113</td>
</tr>
</tbody>
</table>
Figure 14: Peak Graph Showing Lead Facilitator to Same Teacher Leader Turn, LDA 2 Bottle on the Table .................................................. 114

Figure 15: Peak Graph showing Lead Facilitator to same Teacher Leader, LDA 2 Biggest Sucker................................................................. 114

Figure 16: Peak Graph showing Teacher Leader to Teacher Leader exchanges, LDA 2 Bottle on Table ......................................................... 115

Figure 17: Peak Graph Showing Teacher Leader to Teacher Leader Exchanges, LDA 1 Biggest Sucker............................................................ 116

Figure 18: Peak Graph Showing Lead Facilitator to different Teacher Leader Exchanges, LDA 2 Biggest Sucker.................................................. 117

Figure 19: Lead Facilitator’s Use of APT Moves........................................... 119

Figure 20: Percentage of Lead Facilitator Turns Containing At Least One APT Move Across Discussions.......................................................... 120

Figure 21: Average APT Moves by Goal for Lead Facilitators....................... 121

Figure 22: Annotated CDA peak graph for LDA1 Soap Bubble...................... 130

Figure 23: Annotated CDA Peak Graph for LDA 1 Bottle on the Table .......... 141

Figure 24: Annotated CDA Peak Graph Showing Segments for LDA 1 Biggest Sucker ................................................................................. 145

Figure 25: Annotated CDA Peak Graph Showing Segments for LDA 2 Soap Bubble ..................................................................................... 145

Figure 26: Substance of Teacher Leader Turns Using P1-P3 codes................. 160

Figure 27: Number of Turns for Teacher Leaders and Teachers for Bayedge ...... 170

Figure 28: Bayedge Teachers with at Least One Turn .................................... 171

Figure 29: Peak graph showing Teacher Leader to same student turns, Bayedge: Biggest Sucker ................................................................. 172

Figure 30: Peak graph showing Teacher to Teacher interaction, Bayedge: Bottle on the Table ....................................................................... 173

Figure 31: Peak graph showing Teacher Leader to different Teacher turns, Bayedge: Soap Bubble ................................................................. 174
Figure 32: Average APT moves used per APT Goal for Bayedge. ......................... 176

Figure 33: Annotated CDA peak graph for Soap Bubble, LDA 2 showing moves used to maintain focus around key segments ......................... 188

Figure 34: Annotated CDA Peak Graph for Soap Bubble, Bayedge showing two larger segments but no moves to synthesize or focus the discussion into logical segments. ............................................. 188

Figure 35: Substance of Teacher turns using P1-P3 codes.............................. 200

Figure 36: Teacher Co-Construction By Move, Bayedge ............................... 203

Figure 37: Percent of Participants with at Least 1 turn.................................. 208

Figure 38: Peak graph showing Teacher Leader to same student turns, Lakecastle: Soap Bubble ................................................................. 208

Figure 39: Peak Graph Showing Teacher to Teacher interaction, Lakecastle: Bottle on the Table................................................................. 210

Figure 40: Peak Graph for Lakecastle Biggest Sucker .................................... 212

Figure 41: Average APT Moves Used per APT Goal for Lakecastle ............... 217

Figure 42: Annotated CDA peak graph for Biggest Sucker, Lakecastle showing moves used to maintain focus around key segments................. 229

Figure 43: Annotated CDA peak graph for LDA 1, Biggest Sucker showing moves used to maintain focus around key segments................. 230

Figure 44: Substance of Teacher Turns using P1-P3 codes............................ 241

Figure 45: Average Teacher Construction Moves, Lakecastle ....................... 245

Figure 46: Nested Conceptual Model for Professional Learning (Lauffer, 2010) ......................................................................................... 268
Ms. T. is launching a middle school unit on waves and energy transfer. The students gather around the front table with their notebooks. They observe a homemade record player that consists of a kitchen turntable with a record glued on top, a sewing needle, and a cone made out of paper. Students were surprised that they could hear sounds and even words or music when the record was spun under the needle. Some noticed that it sounded different depending on where they were standing.

After the students observed the record player, took notes, and shared their observations with the group, they worked individually to create a model to explain how the needle and record make sound and how that sound travels across the room to the person hearing it. The students shared their models with a partner and talked about similarities and differences in their thinking. Then Ms. T brought the group together in a circle, with their first-draft models in hand for a whole group discussion. Ms. T is planning to use the discussion to help the class figure out where their initial model ideas are in agreement and where they disagree or are not sure. The goal of the discussion is not to build complete science answers yet. In this case, Ms. T is trying to get different competing models for how sound travels shared publicly, so the students can think together about what they agree on and still have questions about.

To start, Ms. T poses the following:

*Alright, so you’ve done a lot of work alone and with a partner. So now, let’s talk together as a group. How can we model this? The question is: How can we hear sounds from across the room? Let’s see what you think, where we have similar
ideas, where our ideas are different, and what we still have questions about. Who wants to go first?

She encounters a typical response...silence. After a brief “turn and talk”, where the students practice what they want to say by turning and talking to a partner, the students are ready to share their ideas. The first student, Janelle, shares an idea that is somewhat difficult to understand. Ms. T does not want to put the student on the spot and considers moving on but instead says, “Can you say more about that?” The student does and it is more clear now but Ms. T wants to make sure she is understanding Janelle’s idea so she tries to revoice Janelle’s contribution asking, “so are you saying...?” and then checking back in with Janelle asking, “did I get that right?” Janelle agreed and added more to her response. Janelle takes three turns at talk, explaining her ideas, before the teacher then asks if someone else can put Janelle’s idea into their own words. She does this with two other students, including an English language learner to make sure that this idea is out there and understood before saying, “Ok, is there another idea that people in this class have developed to explain how sound travels across the room?” and the discussion continues.

In this constructed example, students were trying to explain a complex phenomenon that allowed for differing perspectives. The teacher worked for multiple turns with one student, getting a clearer sense of what the student was trying to say but also making it clear that she wanted to understand her contribution. Ms. T left room for the student to accept or reject the revoicing of her idea, and made sure others were

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1 This is a constructed example based off of classroom discussions and developed as part of the Next Generation Science Exemplar (NGSX) project.
listening and could restate the idea in order to be able to work with it before soliciting alternative ideas. Discussions like these can be transformational in positioning students as thinkers and holders of ideas versus those who are simply trying to get the right answer. I have seen teachers transform their practice through shifting how they lead discussions, amazed at what their students are capable of when given the chance to reason and think with their peers. But despite decades of research on the type of classroom dialogue that supports collaborative student sensemaking and professional development efforts to support such dialogue, opportunities for students to incrementally deepen their understanding of science ideas through engagement in science practices and to engage in complex reasoning and argumentation through classroom talk is limited in most K-12 science classrooms (Driver, Newton, & Osborne, 2000; Lemke, 1990; Michaels, Shouse, & Schweingruber, 2008; Mortimer & Scott, 2003; C. O’Connor, Michaels, & Chapin, 2015; Reinsvold & Cochran, 2011; Scott, Mortimer, & Aguiar, 2006; Weiss, Pasley, Smith., Banilower, and Heck, 2003; Wilson, Schweingruber, & Nielsen, 2015). Instead, observations of science classrooms show instruction that is characterized by passive learning, a lack of connection between the activities and the science ideas, limited use of questioning and discourse that moves student thinking forward, and a portrayal of science as static rather than dynamic and revisable based on new evidence (Weiss et al. 2003; Wilson et al., 2015). This study will examine an approach to Professional Development (PD) designed to support the knowledge and skills needed to shift to more coherent, phenomenon-based, student-centered, discourse-rich science instruction.
1.1 Academically Productive Talk (APT)

Leading discussions centered around phenomena where multiple ideas are elicited and valued while at the same time helping the group move towards targeted conceptual understandings is challenging but necessary to meet the shifts in science teaching and learning called for in the National Research Council’s Framework for K-12 Science Education (Framework) and the related Next Generation Science Standards (NGSS) (National Research Council, 2012; NGSS Lead States., 2013b, 2013a). Among the shifts called for is a focus on a relatively small number of disciplinary core ideas (DCIs) that have broad explanatory power, using these DCIs to move from learning facts to explaining phenomena, and the central role of science and engineering practices to build and use knowledge. In order to develop the depth of understanding called for in the NGSS and to apprentice students into the practices of science, teachers will need to provide many opportunities for students to make their thinking public to the classroom community, reason about complex ideas, and develop arguments and evidence-based explanations. Small-group and whole-group discussions built around a culture of public reasoning provide students with such opportunities. But leveraging these discussions will require a new kind of classroom talk culture, one that promotes discussion and making thinking public in order to support student sensemaking, argumentation, and collaborative knowledge building around modeling and explanation of phenomena in the natural and designed world.

One approach to classroom talk, referred to here as Academically Productive Talk (APT), is talk that leads to deep conceptual understanding and is respectful, equitable, and focused on reasoning (Chapin & O’Connor, 2003, 2007; Michaels, O’Connor, &
Resnick, 2007). Teaching that is more dialogic in nature, such as APT, helps students access and communicate their ideas, reflect on their current understanding, and to reason scientifically (Michaels & O’Connor, 2012; Michaels et al., 2008; Windschitl, 2013). It also has been shown to impact student learning including transfer of knowledge and skills across academic domains (Adey & Shayer, 2001; Bill et al., 1992; Chapin & O’Connor, 2004; Mercer et al., 2004, 1999; Resnick et al., 2015; Shayer, 1999). Leading discussions using APT that focus on student thinking and help students develop conceptual understanding while including as many students as possible within the limited time teachers have available is not a trivial task. Because students are being asked to do the hard work of constructing understanding, and teachers must follow and guide the discussion even when students may be formulating their ideas as they are speaking, these discussions are challenging to lead. Teachers must make principled decisions about when and what to interject, which ideas to help explicate further, and how to keep the discussion equitable for all students. Given this complexity, teachers will need support in learning how to shift the ways they orchestrate talk in order to provide these opportunities.

1.2 Preparing Professional Development Leaders

Because of the complexity of productive talk, it is not enough to just give teachers a new curriculum. If we hope to support teachers in leading complex discussions, then the PD will need to match the complexity of this kind of ambitious instruction (Hirsh, 2012; Moon, Michaels, & Reiser, 2012; Wilson, 2013; Windschitl, Thompson, Braaten, & Strope, 2012). However, research on models of PD that support classroom discourse
in science are limited and there is even less known about how to prepare the PD leaders charged with leading this PD (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Luft & Hewson, 2014; Wilson et al., 2015).

Just as a skilled teacher is essential to support students in a classroom, a skilled facilitator of PD who possesses the knowledge and skills to support their teachers in shifting their practice is key (Borko et al., 2017; Borko, Koellner, & Jacobs, 2014; Elliott et al., 2009; Jacobs, Seago, & Koellner, 2017). A consensus study by the National Academies of Sciences, Engineering, and Medicine examined how to provide support for K-12 teachers’ learning in light of the new vision for science as laid out in the Framework and NGSS (Wilson et al., 2015). Among their recommendations for practice and policy is to “develop internal capacity” for supporting science teaching with a call for supporting the development of PD leaders. They note a gap in the research on teacher PD regarding the preparation and development of teacher educators, PD leaders, and teacher leaders (Wilson et al., 2015).

While there is a wide body of research that examines PD for teachers, Heller and colleagues (2012a) state, “no published research examines the role and expertise of science professional development providers and facilitators”. In their 2014 review of research on teacher professional development programs, Luft and Hewson (2014) note only two studies that look at the development of teacher leadership skills in science education (Hofstein, Carmeli, & Shore, 2004; Howe & Stubbs, 2001) but neither addresses preparing those to facilitate professional development. Luft and Hewson (2014) call for an examination of “how to prepare and support those who work with science teachers” as an important area for further research (p. 903). If teachers are going
to need to experience new kinds of learning themselves, then those who provide professional development will also need support in enacting the new vision for their adult learners. As Wilson et al. (2015) state, “Learning to teach teachers is related to but distinct from learning to teach. Research documenting and explaining how skilled teacher developers acquire relevant knowledge and practice would help improve the quality of professional learning across the myriad settings in which it takes place” (Wilson et al., 2015, p. 231). Following this call for research, this study will provide insight on (i) the type of PD necessary to develop Teacher Leaders’ knowledge about and skills to lead whole-group discussions using APT, and (ii) how these Teacher Leaders implement their knowledge and skill in science PD focusing on APT.

1.3 Study Overview and Research Questions

This study addressed two gaps or challenges in the work on professional learning for science education; 1) the need to build capacity for teachers to orchestrate productive talk, and 2) the development of PD leaders to do this work. I examined an approach to PD designed to develop Teacher Leaders’ capacity to support the knowledge and enactment of new discourse practices with their teacher colleagues. Specifically, I analyzed the discourse practices Teacher Leaders used as they enacted PD that focuses on APT and reform-based science instruction.

In order to address the bigger question of how to prepare PD Leaders to support the knowledge and enactment of these new discourse practices, I examined two “generations” of enactment of identified key whole-group consensus discussions in the Next Generation Science Exemplars (NGSX) PD Program. Generation 1 included the
Teacher Leaders (labeled as Teacher Leader) in Leadership Development Academies (LDAs) engaging in the NGSX Teacher Pathway and Facilitator Pathway led by a National Lead Facilitator (labeled as Lead Facilitator). Generation 2 includes the Teacher Leaders as NGSX Facilitators (labeled as Teacher Leaders) leading or co-leading their own NGSX study groups (of 15-30 Teachers) through the Teacher Pathway. Figure 4 illustrates these generations.

**Figure 1: Structure of the Generations of Enactment in the NGSX PD Program**

In generation 1, the Teacher Leaders engaged in multiple whole-group consensus discussions as adult learners themselves. They then led the same discussions with their own study groups in Generation 2. By examining both generations, I was able to compare what the Teacher Leaders experienced in their own professional learning (how Lead Facilitators enacted the discussions) to what they enacted when they were leading...
the same discussions themselves. More specifically, this study focused on the following questions:

1. **What are the characteristics of talk when Lead Facilitators enact whole-group consensus discussions with Teacher Leaders during science PD?**
   a. What academically productive talk moves do Lead Facilitators use and how do they use them? What rationale do they provide?
   b. What are participants doing in terms of reasoning and co-construction of ideas?
   c. What talk patterns are evident in the ways participants interact with the facilitator and each other?

2. **What are the characteristics of talk when Teacher Leaders enact whole-group consensus discussions with teachers during science PD?**
   a. What academically productive talk moves do Teacher Leaders use and how do they use them? What rationale do they provide?
   b. What are Teachers doing in terms of reasoning and co-construction of ideas?
   c. What talk patterns are evident in the ways Teachers interact with the Teacher Leader and each other?

2. **How does the facilitation of these whole-group consensus discussions by the Lead Facilitators compare to the Teacher Leaders’ enactment of the same discussions?**

Patterns or themes regarding the discourse tools and strategies used, how they compared between Lead Facilitators and Teacher Leaders, and why they made the moves they did provide insight into the tools, strategies, and PD structures that can support the development of skilled PD providers.
CHAPTER 2
DISCOURSE IN SCIENCE EDUCATION

2.1 Theoretical Framework

The premise of this study, grounded in social constructivist learning theory, holds that social interaction and collaboration is important in building understanding. Constructivism as a learning theory has a long history in educational theory and research and has large implications for science learning and instruction as well as for professional learning for teachers. At its most basic level, constructivism holds that knowledge is actively constructed by the learner based on their experiences and knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Savasci & Berlin, 2012). This is in stark contrast to objectivism, which “posits that knowledge of the world results from experiencing our world and representing it in an increasingly accurate way. Knowledge is believed to exist independently of the learner and then to become internalized as it is transferred from its external reality to an internal reality of the learner that corresponds directly with the outside phenomenon.” (Applefield, Huber, & Moallem, 2000, pp. 36-37). In this view, learning centers on the passive acquisition of these objective facts, knowledge, and truths (Mayo 2010; Tam, 2000). It is believed that the role of education, then, is to transmit a known set of knowledge to the learner (Tam, 2000). Perhaps Tam (2000) says it best when she states, “constructivism emphasizes the construction of knowledge while objectivism [is concerned with] mainly with the object of knowing” (p. 51).
Vygotsky’s socio-cultural, constructivist stance focuses on the interpersonal nature of cognitive development (Mayo, 2010). According to Vygotsky, knowledge is built as the learner interacts with and learns from more able others (Applefield et al., 2000; Mayo, 2010; Vygotsky, 1986). Mayo (2010) further describes Vygotsky’s influential view that what learners can do socially is a more accurate indication of their development than what they can do individually and stresses the need for social interaction in order to construct knowledge. The concept of helping students work within their “zone of proximal development” (ZPD) which is the distance between what students can do on their own and what they can do with the support of a ‘more able other’ has important implications for instruction. (Applefield et al., 2000; Mayo, 2010; Vygotsky, 1978). Constructivist learning theory speaks to the need for learners to actively construct understanding, whether individually or collaboratively (and often both), and presents important learning principles that can be applied to instruction (Mayo, 2010). Ultimately, students need to be actively engaged in learning and provided opportunities to uncover, confront their thinking, and struggle with ideas. Social interaction, including small group and whole group discussion, plays an important role in this active process.

Through discourse, activity, and support by more able others, knowledge is constructed (Driver et al., 1994). This points to an important role for the teacher to provide opportunities for students to puzzle through problems together as well as to structure activities that help the learner internalize scientific processes and concepts. Driver and colleagues (1994) emphasize the importance of this social element of knowledge construction in science stating that if knowledge construction is seen only as an individual process, then science learning would be more like discovery learning. The
authors propose learning science to include both social and individual processes and state, “learning science involves…becoming socialized to a greater or lesser extent into the practices of the scientific community with its particular purposes, ways of seeing, and ways of supporting knowledge claims. Before this can happen, however, individuals must engage in a process of personal construction and meaning making” (p. 8). Ford (2007) asserts that the “the process of learning science…should in some ways parallel the process by which scientists construct knowledge” (p. 404). However, there is a tension between giving students the authority to construct scientific ideas on their own and supporting students in understanding the canonically accepted scientific knowledge (Ford, 2007). Ford (2007) argues that students can gain a “grasp of scientific practice” by engaging in construction and critique of claims by making sense of “novel scientific content in ways that reflect both disciplinary authority and accountability” (p. 411). Much of this critique happens through discourse.

As Hmelo-Silver and Barrows (2008) note, the goal of these constructivist-based classrooms is knowledge building where the aim is collective knowledge advancement (Scardamalia & Bereiter, 2006) that requires co-construction of knowledge among and between both students and the teacher (Hmelo-Silver & Barrows, 2008; Scardamalia, 2002; Scardamalia & Bereiter, 2006). Scardamalia and Bereiter (2006) note that “knowledge building pedagogy is based on the premise that authentic creative knowledge work can take place in school classrooms…” (p. 100). To do this, they argue that knowledge advancement needs to be seen as a community achievement towards idea improvement through a particular type of discourse. Knowledge building discourse, as defined by Scardamalia and Bereiter (2006), has a “commitment to progress”, a
“commitment to seek common understanding rather than merely agreement”, and “a commitment to expand the base of accepted facts” (p. 109). It follows that only certain discourse formats and approaches will meet these commitments.

Social interaction can help engage students in the actual practices of science in order to build knowledge. This important idea of knowledge building in science by engaging in key practices with others is at the core of the conceptual shifts proposed by the Framework and NGSS (National Research Council, 2011; NGSS Lead States., 2013b). Discussion between students can provide opportunities to see flaws in their own thinking, a pre-requisite for conceptual change. However, the act of discussing and interacting, alone, does not mean that learning will happen. Argumentation and discourse skills need to be explicitly taught (Michaels et al., 2008) and the teacher needs to provide relevant and authentic tasks and formative feedback to move learning forward (Applefield, et al., 1994).

Given these instructional implications, what is the role of the teacher? The teacher in a constructivist, knowledge building environment is seen as a facilitator who works to provide opportunities for students to co-construct their understanding through interaction with other students and with challenging problems (Applefield et al., 2000; Tam 2000). Teachers have clear learning outcomes and must determine where their students are in relation to the outcome and plan accordingly. This may look different for each group of students and the plan to meet the goal is constantly assessed and revised, making this approach complex. Teachers must also develop the challenging and relevant problem or task and be willing to work with the students to determine what needs to be learned and how they can demonstrate their understanding (Applefield et al., 2000). The
teacher needs to develop a culture in the class that values a variety of perspectives and approaches and encourages some level of disequilibrium. Finally, teachers need to have strong content knowledge in order to give feedback to students to keep the learning moving forward (Applefield et al., 2000).

2.2 Discourse in Science Education

2.2.1 Science Teaching Reform and Classroom Discourse

Why focus on classroom talk? Engagement in the science and engineering practices in order to construct deep understanding requires collaborative engagement with others and is carried largely through well-guided discourse (talk and writing) (Michaels & O’Connor, 2015b; O’Connor & Michaels, 1996). Recent reforms in science teaching and learning call for, “engaging students and teachers in scientific practices such that the goal of science education shifts from students knowing scientific facts, concepts, or ideas, to students developing and using these understandings as tools to make sense of the world” (Berland et al., 2016, p. 1082). This shift from “learning about” to “figuring out” scientific ideas will require shifts for teachers in how they view science teaching and learning, shifts for students in the work that they engage in in the classroom, and shifts in the types of classroom interactions needed to support this knowledge building (Reiser et al., 2017). Taking Science to School (NRC, 2007) states that students need to be able to:

• know, use, and interpret scientific explanations of the natural world;
• generate and evaluate scientific evidence and explanations;
• understand the nature and development of scientific knowledge; and
• participate productively in scientific practices and discourse. (National Research Council, 2007, p. 2)
This emphasis on explanations and engaging in scientific practice and discourse to develop, use, and revise such explanations is built on and expanded in the *Framework for K-12 Science Education* and the Next Generation Science Standards (NGSS) (National Research Council, 2011; NGSS Lead States., 2013b, 2013a). Helping students develop explanatory models of phenomena, over time and iteratively, is a key part of building scientific literacy, and a prominent conceptual shift in the NGSS. Therefore, students will need opportunities to engage in disciplinary learning and teachers will need support in doing this. However, Miller and colleagues (2018) warn that, “unless the field tackles significant questions around precisely how students can be active agents in knowledge construction, we will likely continue to implement learning environments that position students as receivers of scientific facts and practices, even as classrooms adopt NGSS” (p. 1056). Shifting the roles of students so that they are “epistemic agents” who “shape and evaluate knowledge and knowledge building practices in the classroom” is a challenging task (Miller et al., 2018, p. 1057). Classroom discourse is a central aspect of knowledge building where students can be positioned with epistemic agency (or not). Therefore, in the following sections I will first discuss scientific discourse, power, and language and how that relates to traditional patterns of classroom discourse. I will then shift to discuss dialogic discourse and its impact on student learning, and one particular approach, Academically Productive Talk.

### 2.2.2 Scientific Discourse, Power, and Language

School science can present a narrow view of what it means to do science. Carlone (2004) discusses the “socio-historical legacy of science” where science is viewed as
purely objective and where the dominant culture of science as male, white, and middle class is reinforced. One way that this view is reinforced is through science instruction that presents the processes and methods used to communicate and debate scientific information (scientific discourse) as masculine and objective (Brotman & Moore, 2008).

Lemke (1990) asserts that there are two sets of beliefs about science that are reinforced in education and society: the ideology of the objective truth and the ideology of the special truth of science. First, science is often presented to students as authoritative and as a series of facts that do not reflect the underlying biases that were part of their creation. Next, science is presented to students as a “special truth” that is difficult and only available to experts who have special talents. These restricted views of science, “tend to insure that only people whose backgrounds have led them to already talk a bit more like science books do, to already learn in a particular style and a particular pace, to already have an interest in a certain way of looking at the world and certain topics and problems, will have much chance of doing well at science” (Lemke, 1990, p. 138). Lemke goes on to say that those who are successful tend to be like the male, white, middle and upper class, English speaking, scientists who “define the ‘appropriate’ way to talk science”. He argues that all can learn science and the language of science, which is no more complex than any other language or subject; it may just be less familiar or presented in such a way that feels too far removed from one’s experiences and interests.

If we are to interrupt this dominant view of science and help all students develop an identity as those who can do science, instructional practices that give those who do not reflect the “culture of power” (Carlone, 2004) access to the ways of knowing and learning, must be provided (Brotman & Moore, 2008).
First, classroom structures and culture related to discourse can undermine students, reinforcing the culture of power and dictating who can contribute and what is valued. As Michaels and colleagues point out, “In discourse, meaning, status, and power are inextricably linked” (Michaels, O’Connor, & Sohmer, 2004, p.3). Science classrooms often feature a traditional teacher dominated talk called the Initiation-Response-Evaluation (IRE) pattern of classroom talk (Mehan, 1979). Lemke (1990) called this format “triadic dialogue” where the teacher initiates the conversation (I), the student responds (R), and the teacher evaluates that student’s response (E). While this form of dialogue might be useful for reviewing previously taught information, Lemke states that this triadic dialogue gives the teacher, “almost complete control over the classroom dialogue and social interaction” and that it is mistakenly believed to encourage student participation (p. 168). This triadic dialogue is the “default pattern” of classroom talk (Cazden, 1988), and characteristic of what many refer to as “recitation” – where the teacher asks questions with a single correct answer in mind, and students attempt to “get” the right answer. Michaels et al. (2008) point out the limitations in this approach to helping students engage in complex reasoning or development of evidence-based explanations. If we are to broaden the view of those who can do science we need to provide opportunities for students to “talk science” and co-construct ideas with the teacher and peers (Clement, 2008b; Lemke, 1990), and shift from recitation to reasoning-based talk and discussion.

It is important, therefore, that we provide access to and participation in these different forms of specialized discourse. Michaels, O’Connor, and Sohmer (2004) note that different discourse structures are needed depending on the domain and the setting.
Cazden (1988) concurs noting that students must "learn to speak within the structure" (p. 54) of the typical discourse pattern for that context. This means that the “rules” and norms for a particular type of talk must be explicitly taught so that all can have access to the ways of “talking science” (Lemke, 1990).

Furthermore, learning the language of a discipline is an important part of being seen as literate in that field (Gee, Michaels, & O’Connor, 1992; Guzzetti, 2001). Examining how language in use can disrupt the typical patterns of classroom discourse that perpetuate the notion that science is only for some and positions the teacher as knower and the students as receivers is important. If we are to disrupt this limited view of and access to science then we need to provide opportunities that promote “talk in the service of access, equity, and high levels of academic learning” (Michaels et al., 2004, p. 2).

Drawing on the fields of linguistics and socio-linguistics, Michaels et al. (2004) explain the importance of looking at language in context if we are to understand classroom discourse. Gee (2005) goes on to explain that context refers to “an ever-widening set of factors that accompany language in use. These include the material setting, the people present (and what they know and believe), the language that comes before and after a given utterance, the social relationships of the people involved, and their ethnic, gendered, and sexual identities, as well as cultural, historical, and institutional factors” (p. 57). Additionally, discourse is multifunctional in that it can carry many meanings at once (e.g. informational, interpersonal, ideological; (Eggins, 2004; Michaels et al., 2004; Young & Fitzgerald, 2006). Therefore, discourse is never
neutral in value with “meaning, status, and power…inextricably linked” (p. 3; Michaels et al., 2004)

It follows, then, that by looking at the language that is used in classroom discourse closely, in context, we can reveal how that language positions students. Michaels et al. (2004) explain how the IRE pattern of discourse positions students as passive learners trying to get the right answer for the teacher. By shifting the patterns of discourse and the norms of who can contribute what and when, students can be positioned as thinkers and knowers with epistemic agency (Miller et al., 2018). In the next section I will discuss the research on approaches to classroom discourse that can work to support positioning students as knowledge builders.

2.2.3 Dialogic Discourse

In response to the limitations of the IRE format in helping students reason, another body of research focuses on and expands upon what “dialogic discourse” or “dialogic teaching” means and is enacted, how it can open opportunities for all students to engage in knowledge building, and how it provides opportunities for learning that are not supported by more traditional “monologic” or non-dialogic discourses that dominate classrooms (Mehan & Cazden, 2015; O’Connor & Michaels, 2007; Scott et al., 2006; Wells, 2007). Kim and Wilkinson (2019) use Alexander’s extensive work to define dialogic teaching as a “pedagogical approach that capitalizes on the power of talk to further students' thinking, learning, and problem solving” (Alexander, 2017; Kim & Wilkinson, 2019, p. 72). They compare the different interpretations and pedagogical approaches researchers have used to describe dialogic teaching (e.g. Accountable Talk,
dialogically organized instruction, collaborative reasoning, and dialogic inquiry) noting that, despite their differences in the way they define talk, these dialogic teaching approaches can lead to increases in student learning and reasoning (Kim & Wilkinson, 2019; Resnick, Asterhan, & Clarke, 2015b).

Teaching that is more dialogic in nature, has been shown to impact student learning and transfer across academic domains (Adey & Shayer, 2001; Bill, Leer, Reams, & Resnick, 1992; Chapin & O’Connor, 2004; Mercer, Dawes, Wegerif, & Sams, 2004; Mercer, Wegerif, & Dawes, 1999; Resnick, Asterhan, & Clarke, 2015; Shayer, 1999). This work has been done in a variety of subject domains, with similar results. Resnick and Schantz (2015) identify three possibilities for why these particular forms of talk might “grow intelligence” and lead to transfer. First, they may help students learn argumentation skills, which can be transferred to other domains. Next, it may increase students’ confidence in their own “intellectual competence” which can motivate their engagement. Finally, these forms of talk can help socialize students “into a culture of argumentation” that makes it safe to contribute and values reasoning over the one right answer (Resnick & Schantz, 2015, p. 444). Some examples from science and math are provided below.

Chapin and O’Connor (2004) found that students engaged in a math curriculum that involved challenging material and opportunities to engage in discussions that utilized talk moves, significantly outperformed comparison groups in both math and English Language Arts standardized test measures. Talk moves are specific strategies and questions that help students participate in productive academic discussions (Anderson et al., 2011; Michaels & O’Connor, 2015; O’Connor, 1996). The authors have identified a
series of talk moves that serve different goals of productive discussions. For example, talk moves that serve the goal of helping students share, expand, and clarify their own thinking include moves such as, “Can you say more about that?” or a revoicing move such as, “So let me see if I’ve got what you’re saying. Are you saying…?” Moves to support the goal of helping students connect with the ideas of others include “Who thinks they can explain what Tom means when he says that?”. In an in vivo2 study designed to examine more closely the impact of these talk moves on student learning gains in math, O’Connor and colleagues (2015) conducted a controlled study for two conditions: an Academically Productive Talk (APT) condition where talk moves were used and a direct instruction condition where the teacher presented material and used the IRE format extensively. Productive talk moves (such as “Can you say more about that?” or “What do others think? Do you agree or disagree and why?”) were not used. Aside from the talk patterns, the content of the mathematics was kept strictly the same. They found that students performed significantly better when learning in a classroom where the teacher used academically productive talk moves and whole group discussions compared to the same teacher using direct instruction methods.


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2 The term in vivo study refers to a research methodology proposed by the Pittsburgh Science of Learning Center’s (PSLC) LearnLab that seeks to test a small, well defined instructional variable (versus a whole curriculum) in a real classroom setting. In that way it is different from lab testing because it is with real students, content setting etc. and from randomized field studies in that it only emphasizes changing one principle.
focused on classroom discourse would improve teacher use of dialogic practices as well as students’ learning motivation and interest. Teachers in the intervention group utilized recorded video footage of discussions from their own classrooms while control group teachers participated in a traditional professional development program on classroom discourse. Teachers in the intervention group showed a significant increase in constructive feedback and decrease in simple feedback as a function of the treatment. Students in the intervention group significantly increased their perceived autonomy, competence, and intrinsic learning motivation as compared with those in the control group.

Work by Adey and Shayer (1993) looked at middle and high school students using an approach they call Cognitive Acceleration which asks students to articulate and explain their solutions to various science problems through discussion. What they call “Thinking Science” lessons were taught about once every two weeks. Results showed that students performed significantly better than control groups on British national achievement tests in science and that these changes persisted on tests taken three years after the end of the program. This study also showed large differences in mathematics and English exam scores.

Additionally, Mercer, Wegerif and Dawes (1999) working with upper elementary students on ‘exploratory talk’ found improvement in individual non-verbal reasoning on Raven’s non-verbal reasoning tests compared to students from control classrooms. Exploratory talk is a “way of using language effectively for joint, explicit, collaborative reasoning” where “knowledge is made publicly accountable and reasoning is visible in the talk” p. 97. Mercer and colleagues (2004) expanded the work on ‘exploratory talk’ by developing an experimental curriculum to support exploratory talk and found that
students in the intervention group significantly outperformed control groups on science content tests as well as on both group and individual reasoning.

Dialogic teaching can highlight student reasoning and opportunities to explain ideas (Resnick & Schantz, 2015). However, not just any talk will lead to deep student understanding where the students are positioned as thinkers and students and teachers co-construct ideas (Anderson et al., 2011; Michaels & O’Connor, 2015b; Michaels et al., 2008). In dialogic teaching the teacher’s questions and moves (defined as the specific strategies the teacher utilizes), work to encourage multiple student ideas and result in “longer and more complex replies from individual students, including evidence based reasoning, and challenges and questions from students directed at their peers” (Mehan & Cazden, 2015, p. 29). Therefore, in contrast to IRE or a monologic stance, a teacher’s initiation move in dialogic discourse results in “extended discussion across many students and turns at talk” (p. 29). This approach challenges the assumption that only some students can engage in dialogue with their peers to come to a higher understanding. According to Resnick and Schantz,

“recitation pedagogy fits well with assumptions that only some people can think and reason at high levels, while the rest can, at best, only acquire a fixed body of knowledge. Recitation pedagogy also reinforces the idea that certain cultural styles and forms of speech are the only ones that support intelligent reasoning. Dialogic pedagogy challenges these assumptions.” (2015, p. 442)

In other words, dialogic pedagogy can open up the dialogue and position all students as capable of engaging in academic discourse focused on conceptual learning. Dialogic pedagogy can provide opportunities for all students to engage in rigorous academic talk which can help interrupt the “pedagogy of power” (Haberman, 1991) where students
from low socioeconomic status backgrounds are not given the opportunity to engage in higher level reasoning, but rather receive watered down instruction that focuses on the “basics”. Haberman describes this pedagogy as one in which, “learners can ‘succeed’ without being involved or thoughtful” (1991, p. 291). A more dialogic approach to classroom talk can help move beyond IRE and position the students as knowers and thinkers as they work with others to deepen their understanding of complex material (Michaels & O’Connor, 2012; Michaels et al., 2004). Mehan and Cazden (2015) refer to this focus as a switch from “recitation to reasoning” where there is a movement away from IRE sequences which feature the common “known answer question” where the teacher is doing the “heavy lifting” to one where the students are positioned as knowers and learners (p. 20). Those in the dialogic discourse camp argue that it is not the format of typical classroom discourse that needs to be challenged but also the content and purpose with reasoning that should be at the center of classroom dialogue. Therefore, an examination of alternatives to the IRE approach is needed.

2.2.4 The IRF Pattern of Classroom Discourse

As mentioned, the IRE (Initiation – Response – Evaluation) format can be useful for certain purposes (e.g., topics which are factual or algorithmic) and, as Cazden (1988) notes, “any one event structure is suitable for only some educational purposes. Rather than argue about the general value of lessons as a kind of classroom discourse, we should consider which purposes they fit well and which they don’t” (p. 50). So, while classrooms reflect and require many different forms of discourse, it is not useful to pit one form against another (Mehan & Cazden, 2015; O’Connor & Michaels, 2007; Wells,
However, we need to be aware of when there is an over reliance on these forms and the impact they might have on students.

While Lemke argues a move away from such dependence on triadic dialogue, others hold that this form of dialogue can serve a purpose, and, with variations, may still be useful in monitoring student understanding, guiding student learning, and initiating discussion (Viiiri & Saari, 2006). Sinclair and Coulthard (1975) first discussed an IRF pattern where the F stands for Feedback. The IRE was based off of this because in many classroom discussions the third turn by the teacher is evaluative. However, the notion of “feedback” is agnostic as to quality or kind. It totally depends on what the teacher does in this turn. Nassji and Wells (2000) found that when teachers replaced the evaluation (E) in the IRE sequence with feedback (F), extended patterns of discussion, more student thinking, and more student participation were observed. This study, which followed nine elementary and middle school teachers noted that, while the initiation question was important in impacting the pattern of discussion, the follow up move was even more influential. When the evaluation was replaced with a request for justification, a connection, or counterargument, the authors saw extended patterns of discourse such as IRFRF (Initiation-Response-Follow-up-Response-Follow-up). They found that the IRF structure could be used in a variety of ways depending on the goal of the activity.

Building on this work, Viiiri and Saari (2006) stated that the pattern of IRF is not good or bad but how it is used that is important. They argued that ways in which teachers skillfully use the triadic model need to be studied and described. In their case study of one master teacher, two experienced teachers, and four student teachers, the authors sought to describe patterns of teacher talk. They classified talk into six types: teacher
presentation, teacher guided discussion, authoritative discussion, dialogic discussion, peer discussion, and other. They found that the master teacher exhibited a variety of talk patterns and that those patterns were directly related to the content of the lesson. The novice teachers however, used simple, unvarying patterns of talk that were not clearly connected to the aim of the lesson.

Continuing with this idea of a range of talk patterns, Mortimer and Scott (2003) developed a framework for examining talk in science classrooms that examined this IRF pattern of interaction and used the ideas of authoritative or dialogic communication to look at the patterns of discourse. The framework examines teaching purpose, content, communicative approach, teacher intervention, and patterns of interaction. A focus of this framework is the communicative approach of the teacher, which identifies the ways the teacher can work with the students to address different ideas that arise in a lesson. The framework has two dimensions: dialogic-authoritative and interactive-non-interactive and is shown in Table 2.

| Table 1: Four Classes of the Communicative Approach (Mortimer and Scott, 2003) |
|--------------------------------|--------------------------------|
| **Interactive** | **Non-Interactive** |
| Dialogic | Teacher and students consider a range of ideas | Teacher revisits and summarizes different points of view |
| Authoritative | Teacher focuses on one specific point of view - “fishes” for the right answer | Teacher presents a specific point of view |

Mortimer and Scott (2006) used this framework for analyzing discourse patterns in a high school classroom and argue that there is a need for both authoritative and dialogic patterns of communication if meaningful learning is to occur. They described how these shifts might occur:
…the teacher encourages dialogic discourse to probe students’ everyday views; later she adopts an authoritative approach to introduce the scientific point of view; then she prompts dialogic discourse as she encourages students to explore and apply the scientific view, and so the shifts in communicative approach continue throughout the sequence of lessons (p. 623).

They noted that the interactive/authoritative approach is often confused with a dialogic approach; however, because there is only one idea under consideration (the accepted scientific idea) it is authoritative. The teacher in dialogic discourse assumes more of a neutral position and avoids evaluative comments which, as Nassiji and Wells (2000) point out, may lead to more interaction and student thinking. The authors suggested identifying and planning for key places to include more interactive/dialogic opportunities.

If the goal is to open up the discussion for students to reason and build knowledge, then why examine a discourse format that has been criticized as narrowing access for students? Park and colleagues (2017) argue for an examination of the “third turn moves” that follow a student response. They argue that productive talk moves (Michaels & O’Connor, 2015b; Catherine O’Connor & Michaels, 2019) in this third position (e.g. “why do you think that?”; “do you agree with his idea?”; Or “say more about that”) “forestall the teacher’s evaluation (premature evaluation, in many cases, we would suggest) and open up the conversation for students to do the heavy lifting of elaborating, clarifying, adjudicating, evaluating, arguing, challenging, or critiquing ideas of the students.” (p.19). These moves can make space for students to provide reasoning or respond to others reasoning, thereby providing opportunities to co-construct knowledge (Michaels & O’Connor, 2015b; O’Connor & Michaels, 2019; Park et al., 2017). Wells and Arauz (2006) found that while the IRF pattern remained dominant in the classrooms in their study, there was a shift to a more “dialogic stance” and argue that
the follow up move in the IRF sequence provides “assistance in a manner that jointly creates a zone of proximal development that enables students to “go beyond themselves” (p. 421).

Since this triadic discourse structure is the dominant pattern in classrooms, studying how third turn moves can be used in place of the Evaluation move in the IRE is needed to shift the discourse to more dialogic stances (Michaels & O’Connor, 2015b). One approach to dialogic discourse that focuses on how to disrupt typical patterns of classroom talk by focusing on these third turn moves is “accountable talk” or “academically productive talk” (APT) (Michaels et al., 2007; Michaels, O’Connor, Hall, & Resnick, 2002). A term that was coined by folks at the Institute for Learning (University of Pittsburgh) and developed in large part by Michaels & O’Connor, Accountable TalkSM (service marked by the University of Pittsburgh) emphasized accountability to community, knowledge, and reasoning. The term refers to practices that “support and promote equity and access to rigorous academic learning” (p. 283) and require opportunities for meaning making through scaffolded discussions where students have “the right to speak and the obligation to explicate their reasoning” to promote deep understanding (Michaels et al., 2007, p. 284). In later work by O’Connor and Michaels, they coined the term “Academically Productive Talk” to avoid any copyright issues, and to emphasize the nature and goals of the teacher follow-up moves rather than foregrounding the distinction between community, knowledge, and reasoning – accountabilities which can often overlap and can be confusing analytic distinctions for teachers to work with in the moment – in the fast-paced and improvisational talk of
classroom discussions. In the next section I will explain the approach to theses scaffolded discussions and the framework for APT that is used in this study.

2.2.5 Academically Productive Talk

Discussion between students can provide opportunities to see flaws in their own thinking, a pre-requisite for conceptual change. However, the act of discussing and interacting, alone, does not mean that learning will happen. Argumentation and discourse skills need to be explicitly taught (Michaels et al., 2008), and the teacher needs to provide relevant and authentic tasks and formative feedback to move learning forward (Applefield, et al., 1994). APT (like Accountable Talk or other terms given to dialogic teaching) is talk that leads to deep conceptual understanding and is respectful, equitable, and focused on reasoning (Chapin & O’Connor, 2003, 2007; Michaels et al., 2007). In APT (as the approach I work with), students are engaged in focused, coherent discussions that are centered on reasoning and address important content. All students are motivated and interested in sharing their thinking, even if it may not be correct, and know that it is their responsibility and right to be heard. Students listen carefully to each other and challenge their own and other’s thinking in a safe environment. Students are doing the intellectual work by going public with their ideas, reasoning with evidence, and building on the ideas of others. Finally, the teacher plays an important role in setting up the conditions and teaching the skills and norms of this kind of discourse so that students can engage with these new ways of speaking and listening (Michaels & O’Connor, 2012).

Leading such discussions that focus on content and student reasoning while including as many students as possible within the limited time teachers have available is
not a trivial task (O’Connor & Snow, 2018; Park et al., 2017). Sarah Michaels, a sociolinguist who has studied productive talk (in its various names, and across a variety of subject domains) for over 35 years describes this challenging work as “unscripted but principled”. These kinds of discussions are unscripted because students are being asked to do the hard work of reasoning and constructing understanding, and teachers must follow and guide the discussion even when students may be formulating their ideas as they are speaking. But yet, teachers must make principled decisions about when and what to interject, which ideas to help explicate further, and how to keep the discussion equitable for all students.

Work on APT relates the moves teachers make more specifically to the positioning of students as thinkers and collaborative knowledge-builders. A move is defined as a specific statement or question that the teacher utilizes during a discussion. This work examines how such moves shift the positioning of students in discussion with respect to the teacher, their peers, and disciplinary content (Michaels & O’Connor, 2015a; O’Connor & Michaels, 2019; O’Connor & Michaels, 1993, 1996). I will first lay out the structures and conditions that must be in place to support APT and then I will discuss the specific “Talk Moves” that have emerged from the classrooms of skilled teachers and how these moves have impacted teacher practice and student learning.

### 2.2.5.1 Conditions that Enable and Support APT

Michaels and O’Connor (2012) note conditions that must be in place in order to achieve rigorous discussion. First, underlying all of this practice, the teacher must believe that all students can contribute and learn from rich discussion with a commitment to deep
conceptual learning (Resnick & Nelson Le-Gall, 1997; Sohmer, 2012). Next, norms for
discussion and a culture where it is safe to share ideas must be established and explicitly
taught and modeled. If we want students to talk to each other, then the physical set up of
the classroom must also be addressed. If the class is arranged with all the desks facing
forward, then the emphasis is more likely to be on the teacher as the sole source of
knowledge which discourages students from interacting (Applefield et al., 2000).
Changing this physical structure (with students seated in small groups or in a circle)
coupled with utilizing moves that shift the authority of the classroom may lead to more
opportunities for students to make meaning through talk. Teachers must also provide a
rich enough framing question that gets students talking about the “why” and “how” not
just a sharing out of ideas, or a focus on getting one simple, correct answer.

Additionally, in order to co-construct the conceptual ideas, teachers must have
clear academic purposes for the discussion and strong content knowledge to know when
and how to guide the discussion towards the target understanding. Understanding and
being clear about the academic purpose includes knowing the purposes of different types
of discussions. Different PD programs label these discussions differently including
gathering ideas discussions, data analysis discussions, and making meaning discussions
(Worth, Winokur, Crissman, Heller-Winokur, & Davis, 2009), elicitation discussions,
consolidation discussions, data discussions, and explanation discussions (Michaels &
O’Connor, 2012) and sharing initial ideas, building understanding, and consensus
discussions (Michaels & Moon, 2014). Regardless of the name, each discussion type has
specific characteristics and goals. For example, an elicitation discussion’s goal is to
surface students’ initial ideas and reasoning and is characterized by participants listening
to and building off of others’ ideas as they propose initial explanations. It is not a brainstorming session nor a quiz about what students know but rather a first attempt at making sense of a phenomenon or to prepare for an investigation (Michaels & Moon, 2014; Worth et al., 2009). Building Understandings and Consensus Discussions, in contrast, have the goal of helping the group deepen their understanding based on investigatory evidence or come to consensus and draw conclusions about an investigation, a model, or an explanation. In these discussions, students share claims based on evidence and provide reasoning that explicitly links their claims and evidence or counterarguments. They analyze and debate ideas and are guided to come to a collective agreement for where the group is at that point in time in their understanding (Michaels & Moon, 2014; Worth et al., 2009). These discussions are not a simple sharing out of what they did nor are they a teacher led review session (Worth et al., 2009). The different goals for these discussions impact the moves the teacher makes. Teachers must also provide a range of talk formats including small group, partner talk and whole group to allow students multiple opportunities to process and make meaning.

2.2.5.2 Goals and Moves to Support APT

In addition to the conditions mentioned above, Anderson (2011) and Michaels and O’Connor (2012, 2015a) identify four goals or challenges of academically productive discussions that must be worked on in order to get the rigorous discussions focused on reasoning called for in APT: (1) Help individual students share, expand, and clarify their own thoughts; (2) help students listen carefully to one another; (3) help students deepen their reasoning; and (4) help students engage with others’ reasoning.
First, in order to lead to deeper understanding, students need to be willing to go public with their reasoning and, because students are most engaged when they are involved with the discussion, this sharing of ideas needs to come from many students, not just the ones that typically share their ideas. This leads to the second goal/challenge; helping students listen carefully to one another. APT calls for students to go beyond just sharing their thoughts one by one in an unconnected way, but rather carefully listening to the reasoning of others and trying to understand what they are saying and how it connects to their own ideas. However, even if students are willing to go public with their ideas and they are truly listening, discussions can still fail to deepen student understanding.

The third goal, that of helping students deepen their own reasoning, involves helping students be comfortable digging deeper into their own understanding and requires the teacher to facilitate that deepening through pressing students for evidence, reasoning, and helping make connections in their arguments. Finally, APT involves getting students to go beyond their own reasoning and working with the reasoning of others. In meeting this fourth goal, the pieces of collaborative knowledge building really come together, as students build on and critique the ideas of others. The authors state that without attention to these goals and the moves that support them, the discussions may remain superficial and may not lead to deepening understanding (Michaels & O’Connor, 2012, 2015a).

And, each of these goals needs to be intentionally addressed and revisited to achieve the challenging goal of APT.

O’Connor and Michaels’ extensive work with teachers and qualitative research has led to the development of a small set of all-purpose “talk moves” – specific strategies (a set of simple comments and questions) that help students participate in productive
academic discussions (Anderson et al., 2011; Michaels & O’Connor, 2012, 2015b; O’Connor & Michaels, 2019; O’Connor, 1996). Figure 2 shows a teacher resource from the Inquiry Project and Talk Science (two linked projects funded by NSF: see https://inquiryproject.terc.edu) that is used in the Teacher PD for this study and links these talk moves to the goals mentioned above (Michaels & O’Connor, 2012; TERC, 2012).

Figure 2: Goals for Productive Discussions and Nine Talk Moves (TERC, 2012)
Michael’s and O’Connor (2015a) describe these talk moves as tools that can be used to meet the particular goals or challenges described above. For example, the “say more” talk move is in service of getting students to go public with their thinking. These talk moves may be part of the expanded curricular supports for leading discussions that Alozie and Krajcik (2009) called for in order to move the teachers past triadic dialogue. These moves seem to, “take the conversation from recitation to reasoning, opening up the conversation, helping students listen carefully to one another, and supporting them as they built on and critiqued the ideas and arguments of their peers” (Michaels & O’Connor, 2015b, p. 3).

The use of these talk moves has been shown to influence student learning. As described above, Chapin and O’Connor (2004) found that students engaged in a math curriculum that involved challenging material and opportunities to engage in discussions that utilized these talk moves, significantly outperformed comparison groups in both math and English Language Arts standardized test measures. Additionally, O’Connor and colleagues (2015) found that students performed significantly better when learning in a classroom where the teacher used academically productive talk moves and discussions compared to the same teacher using direct instruction methods. These moves have also been shown to influence young children’s oral communicative competence (van der Veen, de Mey, van Kruistum, & van Oers, 2017). Finally, a recent study of whole class discussions in mathematics where the teachers used these talk moves found that the teacher who used talk moves that requested reasoning resulted in students providing reasoning on their written assessments and in discussions showing that the “students’
contributions echoed the emphasis of the teacher talk moves” (Tabach, Hershkowitz, Azmon, & Dreyfus, 2019, p. 526).

These talk moves are a central part of professional development resources aimed at supporting teachers in leading academically productive talk in math and science (Anderson et al., 2011; Chapin & O’Connor, 2003; Michaels & O’Connor, 2012). For example, preliminary evidence for the Talk Science Program shows that teaching talk moves as tools can help teachers begin to utilize them in reasoning-based discussions (Michaels & O’Connor, 2015b). However, the study showed that not all talk moves were taken up equally. For example, the restating move designed to get students to listen carefully to each other was often not utilized. Additionally, although teachers in the study used more productive talk moves, “simply opening up the conversation to student thinking was not enough to ensure coherence in a discussion” (2015b, p. 12). As a result, Michaels and O’Connor emphasize the need to know more about how to help teachers know when to use certain moves, what an appropriate progression is for learning about talk tools, and the relationship between teachers’ content knowledge and use of talk moves. My research falls in the realm of these needs for new knowledge. Its overarching goal is to examine how to support teachers in leading student centered academically productive discussions in science.

2.3 Summary

The idea of knowledge building in science by engaging in the practices to develop deep understanding with others is at the core of the conceptual shifts proposed by the Framework and NGSS (National Research Council, 2011; NGSS Lead States., 2013b).
This shift from “learning about” to “figuring out” scientific ideas will require shifts for teachers and students in how they orchestrate classroom talk (Michaels & Moon, 2014; Michaels & O’Connor, 2017; Reiser et al., 2017). Knowledge building discourse requires co-construction of knowledge among and between both students and the teacher (Hmelo-Silver & Barrows, 2008; Scardamalia, 2002; Scardamalia & Bereiter, 2006). However, traditional classroom structures and culture related to discourse such as the IRE are dominant and can reinforce narrow views of who can do science (Carlone, 2004; Lemke, 1990; Michaels et al., 2004). Shifting the roles of students so that they are “epistemic agents” who “shape and evaluate knowledge and knowledge building practices in the classroom” is a challenging task (Miller et al., 2018, p. 1057). However, well-structured classroom discourse provides an opportunity where students are central to the knowledge building and can shift how students are positioned as either learners trying to get the right answer for the teacher, as in the IRE format, or as thinkers and knowers (Michaels et al., 2004; Young & Fitzgerald, 2006).

Dialogic teaching strategies that highlight student reasoning and opportunities to explain ideas through teacher moves that encourage this reasoning can work to position students in this way (Mehan & Cazden, 2015; Michaels & O’Connor, 2012; Michaels et al., 2004; O’Connor & Michaels, 2007; Resnick & Schantz, 2015). Teaching that is more dialogic in nature, has been shown to impact student learning and transfer across academic domains (Adey & Shayer, 2001; Bill, Leer, Reams, & Resnick, 1992; Chapin & O’Connor, 2004; Mercer, Dawes, Wegerif, & Sams, 2004; Mercer, Wegerif, & Dawes, 1999; Resnick, Asterhan, & Clarke, 2015; Shayer, 1999). One approach to dialogic discourse that focuses on how to disrupt typical patterns of classroom talk by focusing on
the third turn moves in the IRF discussion format is APT (Michaels et al., 2007, 2002). The Framework for APT and its associated Talk Moves have been shown to impact student learning, reasoning, and oral competence (Chapin & O’Connor, 2004; O’Connor et al., 2015; Tabach et al., 2019; van der Veen et al., 2017). However, since these approaches are limited in most classrooms, we need to better understand how to help more teachers take up and use these moves.
CHAPTER 3

PROFESSIONAL DEVELOPMENT AND PREPARING TEACHER LEADERS

3.1 Framework for designing and facilitating PD


To reach these targets, science education will need to change – for educators at all levels as well as for students, and for networks as well as individuals. The necessary transformations in classrooms will require time, resources, and ongoing attention from state, district, and school leaders. (National Research Council, 2015, pp. 1–3).

A key component of this effort is sustained support and professional development (PD) for teachers around the key instructional shifts called for. Because of the complexity and improvisational nature of productive talk, it is not enough to just give teachers a new curriculum. Teachers have to learn how to conduct productive talk; they require professional development (PD) that matches the complexity of the ambitious instruction called for (Hirsh, 2012; Moon, Michaels, & Reiser, 2012; Wilson, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). However, research on models of PD that support classroom discourse are limited and there is even less known about how to prepare the PD leaders charged with leading this PD (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Luft & Hewson, 2014; Wilson et al., 2015). Therefore, PD leaders will need to learn both about APT as well as how to guide others in engaging in it and learning about it in PD settings.
In an effort to inform the relationship between PD and the reform-oriented classrooms that the PD aims to address, Lauffer and Lauffer (2009) developed a framework for examining the relationship between student learning, teacher (adult) learning, and PD leader learning. Figure 3 shows this nested conceptual framework.

![Nested conceptual framework for teacher learning with PD](Lauffer, 2010)

**Figure 3: Nested conceptual framework for teacher learning with PD (Lauffer, 2010)**

This model builds on Cohen, Raudenbush & Ball’s (2003) work in mathematics education that describes teaching as the interactions between teachers, students, and content within a particular environment or context. There must be coherence between the levels in order to impact change in the student’s domain (Lauffer, 2010). The innermost circle represents the relationships involved in teaching and learning including between the teacher and student, teacher and content and the student and content. As you move to the middle circle, the teacher becomes the learner, the content is how and what to
teach, and the PD leader is in the role of teacher. The PD leader must understand the triadic relationship of the innermost circle as well as the how to help her adult learners engage with and learn the content of teaching. Finally, the outermost circle requires knowledge of both the inner and middle circles and opportunities to reflect on and build skills of leading professional development. This model is designed to build coherence by embedding the vision for student learners in the professional learning model for teachers as well as for PD leaders and can, therefore, have implications for the design of PD at all levels.

This study is centered around the middle circle and includes an examination of what supports (outermost circle) the enactment of the professional development. It is not the purpose of this study to determine any effects between the PD approach focusing on APT and changes at the classroom level. The purpose of this study is to examine what happens on the PD leader level (middle circle) as well as what happens in the preparation of these PD leaders (outer circles).

In this section I will first discuss the characteristics of effective PD in science which relates to the middle circle. Then I will shift to reviewing the limited research on preparing PD leaders in science as well as math.

3.2 Key Features of Effective PD

In general, research on PD focuses on how PD leads to improved teacher knowledge and skills, changes in teacher practice, and ultimately student learning (Borko, Liston, & Whitcomb, 2007; Cochran-Smith & Zeichner, 2005). Examining the effect of PD on these different levels of learning and enactment has informed the field about the
elements of effective PD (Borko et al., 2007; Desimone, 2009). Over the past decade, there has been agreement on some key features of effective professional development (Desimone, 2009; National Research Council, 2015; Whitworth & Chiu, 2015; Wilson, 2013). These core features, which are referred to as the ‘consensus model’ (Roth et al., 2017; Wilson et al., 2015), have influenced the design of PD and include content focus, active learning, coherence, duration, and collective participation (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). The 2015 National Academy of Sciences report, Science Teachers’ Learning: Enhancing Opportunities, Creating Supportive Contexts, reviewed the research on science professional development and found that well designed and implemented PD in science that incorporates many of these features can lead to changes in teacher knowledge, beliefs, and instructional practice (Wilson, Schweingruber, & Nielsen, 2015). However, it is less clear which of these features are most important in enhancing knowledge, beliefs, and practice. Additionally, as others have argued before (e.g. Borko, 2004; Guskey, 2003; Yoon et al., 2007), there are fewer empirical studies that use a control or comparison group to examine the impact of PD on student learning. However, based on their review, Wilson and colleagues (2015) added a preliminary list of PD program characteristics in science that lead to improved teacher and student learning outcomes (Wilson, Schweingruber, & Nielsen, 2015). When combined with the consensus model (Desimone, 2009), the key features of effective PD in science include:

- Learning opportunities focused on intertwining science content knowledge and pedagogical content knowledge.
- Opportunities for analysis of student learning and science teaching using artifacts of practice.
• Focus on specific, targeted teaching strategies.
• Sufficient duration to allow repeated practice and/or reflection on classroom experiences.
• Coherence and collaboration.
• Learning is scaffolded by knowledgeable professional development leaders

First, effective PD in science requires a strong and specific content focus as well as a focus on how students learn that content. Teaching requires specialized knowledge including “the content of the disciplines, of students, and of a variety of instruction and assessment strategies” (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). A number of studies from a range of empirical designs support the idea that PD that focuses on subject knowledge can impact teacher knowledge and impact instruction (e.g. Birman, Desimone, Porter, & Garet, 2000; Desimone, 2009; Garet et al., 2001; Heller et al., 2012a; Roth et al., 2011). Closely linked to content knowledge is the need for the specialized pedagogical content knowledge (PCK) in order to change teaching practice and impact student learning (Loucks-Horsley et al., 2010; Shulman, 1986). Loucks-Horsley and Matsumoto explain Shulman’s concept of PCK as “the knowledge and abilities…that includes concepts in a discipline that are most appropriate for students at a certain age, how students come to understand those concepts, what naïve conceptions or misconceptions they are likely to have, and what representations, examples, and experiences help them learn” (Loucks-Horsley & Matsumoto, 1999, p. 262). Both strong subject matter content knowledge and PCK specific to the ways of knowing and learning science are needed in order to realize the recommended conceptual shifts (Wilson et al., 2015; National Research Council, 2015). Therefore, professional learning opportunities should be designed such that teachers grapple with both the science itself and how
students think and learn about that science (Wilson et al., 2015). In a recent meta-analysis of pre-K-12 STEM professional development and curriculum programs, Lynch et al. (2019) found that programs that focused on improving teachers’ content knowledge, pedagogical content knowledge, and/or how students learn led to stronger student learning outcomes. This suggests that teachers will need opportunities to construct their understanding by engaging in learning content using the same learning approaches they will use with students (Loucks-Horsley et al., 2010).

In addition to a focus on content by experiencing it themselves, effective PD for teachers also needs to be connected to their own classroom practice with opportunities to analyze classroom cases around specific issues of practice, including analyzing student work and examples of effective instruction with opportunities to apply these ideas to their own practice (Borko, 2004; Garet et al., 2001; Heller et al., 2012a; National Research Council, 2015; Roth et al., 2011). In a study on the Science Teachers Learning from Lesson Analysis (STeLLA) project by Roth and colleagues (2011), a group of teachers engaged in content focused PD with half of the participants also participating in video analysis in the summer and throughout the school year. Teachers with the added video analysis made greater gains in content, and implemented the practices and strategies addressed. Additionally, students of those teachers showed greater learning gains than the comparison teachers. Heller and colleagues (2012a) found that content learning alone is not enough and needs to be integrated with analyzing teaching and learning in order to improve both teacher and student knowledge. Loucks-Horsley and colleagues note that “when teachers experience and reflect on how students learn, they are better able to understand why certain instructional strategies are more effective than others, thus
enabling them to provide powerful learning experiences for their students” (2010, p. 53).

Additionally, Wilson and colleagues (2015) note that shifts in instruction are closely linked to aspects of instruction that are emphasized in the PD. For example, Grigg and colleagues (2013) found that teachers engaged in PD focused on science inquiry increased their use of questioning strategies and helping students construct explanations using evidence that were both emphasized in the PD. There was no change in aspects such as connecting explanations and reasoning which were not emphasized in the PD. This suggests that direct attention to the specific aspects of practice we hope to influence is important.

Just as students need multiple opportunities to learn over time, effective PD requires substantial time, both in terms of amount (duration) of PD and how it is sustained over time (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Desimone, 2009; Garet et al., 2001; National Research Council, 2015). In order to meet the shifts indicated for science in the NGSS, teachers need to engage in learning opportunities that result in “changes in deeply held beliefs, knowledge, and habits of practice” (Thompson and Zeuli, 1999, p. 342, as quoted in Loucks-Horsley, 2010). A key component of these transformative learning experiences described by Thomson and Zeuli is creating a high level of cognitive dissonance that disrupts teachers’ existing ideas and beliefs around teaching and learning. This requires “sufficient time, structure, and support for teachers to think through the dissonance they experience” (p. 69) (Loucks-Horsley et al., 2010; Rogers et al., 2006). While there has been conflicting research on the exact duration of PD that impacts teacher and student learning, there is general agreement that short, one-shot learning opportunities are not successful in improving
teacher or student learning (Darling-Hammond et al., 2009; Guskey & Yoon, 2009; National Research Council, 2015; Yoon et al., 2007). Yoon and colleagues (2007) in their review of PD programs and their effect on student achievement found that programs that were longer than 14 hours showed significant gains in student achievement. Additionally, this study highlighted the importance of follow up activities that provide support as teachers apply their learning to the classroom noting improvement in student learning for those programs that “included significant amounts of structured and sustained follow-up after the main professional development activities” (Guskey & Yoon, 2009; Yoon et al., 2007, p. 497).

Building on constructivist learning theory, learning opportunities in effective PD for these new shifts should be collaborative, providing opportunities for teachers to make sense of and apply new learning together (Garet et al., 2001; Wilson, 2013). Putnam and Borko (2000) identify the need to engage teachers in “critical, reflective discourse communities” (p. 11) identified by Deborah Ball in order to help teachers teach in new ways. This collaboration needs to provide opportunities to struggle with new ideas and the support needed in order to change practice (Putnam & Borko, 2000).

Coherence is also noted as a necessary feature of effective PD (Garet et al., 2001). Professional development opportunities that are aligned and integrated with other initiatives or components such as curriculum and assessment as well as with teachers’ existing knowledge and beliefs have been shown to be important in supporting effective change (Desimone, 2009). Garet and colleagues (2001) found that “activities that are linked to teachers’ other experiences, aligned with other reform efforts, and encouraging of professional communication among teachers appear to support change in teaching
practice “(p. 936). For implementation of the NGSS this means teachers will need support in exploring “what a coherent system of student learning, classroom instruction, assessment, and curriculum materials needs to achieve and work on coordinated changes across these corresponding parts of a system” (National Research Council, 2015, pp. 4–5).

Finally, the review suggests the importance of skilled PD leaders (Wilson et al., 2015). For example, Roth and colleague’s STELLA project (2011) was led by the researcher developers and university faculty and, as they have scaled up, have accounted for their successful results in part because of their attention to preparing skilled teacher leaders to spread the work (Roth et al., 2017). However, more research is needed to know how to prepare these PD Leaders to scale up quality PD (Heller et al., 2012a; Luft & Hewson, 2014; Wilson et al., 2015).

In short, effective PD programs in science require a focus on content as well as specific, targeted teaching strategies with opportunities to analyze effective instruction and apply learning over time. While there is an increase in content specific PD, science teachers report receiving more general PD than science specific opportunities (Wilson, 2013). Additionally, science PD does not identify specific instructional strategies that teachers need to master nor enough time and practice with these specific strategies (Wilson, 2013). The Guide to Implementing the NGSS (2015) warns of not underestimating the shifts needed regarding teacher and leader learning to implement the NGSS. The shifts called for are not small and the changes needed will require an understanding of the Standards’ “emphasis on knowledge building, social interaction, and discourse, analysis and reasoning as part of scientific and engineering practices”
(National Research Council, 2015, pp. 4–6). As Linda Darling-Hammond warns us, “without paying attention to helping teachers learn how to teach kids well, the reform fails” (Darling-Hammond, n.d.). If we are to support teachers, and ultimately students, we will need to pay attention to how we approach PD which is “the most powerful strategy school systems have at their disposal to improve teacher effectiveness” (Hirsh, 2012). High leverage instructional strategies needed to achieve a knowledge building classroom culture, such as engaging students in APT (Michaels et al., 2008; National Research Council, 2015), will need to be studied to see how they impact teacher knowledge and beliefs, instructional practices, and student learning.

3.3 Preparing PD Leaders

Reforms in science education will require PD for teachers at scale (Tekkumru-Kisa & Stein, 2017b; Wilson et al., 2015). Therefore, there is a need for supporting the development of PD leaders (Wilson et al., 2015). Facilitating PD for adult learners, much like teaching students in a classroom, is complex where the PD leaders must balance a number of different goals and needs of participants and make decisions on the fly to best support those needs (Jacobs et al. 2017). As Wilson et al. (2015) state, “Learning to teach teachers is related to but distinct from learning to teach. Research documenting and explaining how skilled teacher developers acquire relevant knowledge and practice would help improve the quality of professional learning across the myriad settings in which it takes place” (Wilson et al., 2015, p 231). However there is limited research on the role, expertise, or preparation of PD leaders in science (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012b; Luft & Hewson, 2014). In this section I will review the limited
literature on the preparation of science PD leaders. Given the limited amount of research in this area, I will also review recent studies in mathematics PD leader preparation and then summarize the current findings around preparing PD leaders in math and science.

3.3.1 Facilitation of Science and Math PD

First, two studies examined the enactment of science PD with a focus on the facilitation; Zhang, Lundeberg, and Eberhardt (2011) and more recently, Tekkumru-Kisa and Stein (2017).

Zhang et al. (2011) examined the strategies that experienced facilitators used to promote productive discussion about problems of teaching practice among science teachers in problem-based learning (PBL) PD. Facilitators who led discussions about particular problems of practice made moves to promote PBL discourse, to establish a learning community, to maintain the group process, and to model the study group practice. They found that facilitators made a number of moves with questioning and revoicing being the most common moves. The authors found that a variety of discourse strategies worked together to achieve participant engagement and idea progression and argued for analyzing discourse strategies working together versus identifying single successful strategies. They also found that sometimes questioning and revoicing strategies were disruptive instead of productive when they were not carefully and selectively used to solicit and highlight important ideas. Their findings suggest the need for facilitators to use moves such as revoicing and questioning selectively, monitor how much they are interjecting, monitor group dynamics and “provide or fade scaffolding”
depending on the group’s needs, and to be aware of their own discourse patterns and their effectiveness.

Tekkumru-Kisa and Stein (2017a) describe a framework for how PD leaders planned and enacted a PD program centered around using video clips of science instruction to support teachers’ learning. The authors adapted the Five Practices Framework, originally used in math classroom instruction (Stein, Engle, Smith, and Huges, 2008; Smith and Stein, 2011), to both science and PD facilitator preparation contexts. They examined discussions of teacher and student video led by skilled PD leaders and found that the facilitators used “monitoring moves” such as clarifying, redirecting, or distributing participant ideas in order to monitor participant thinking as they engaged in the video analysis. Additionally, they found that the facilitators worked to “select” participant responses to share or highlight in order to support progress towards the intended goals for teacher learning through pressing, lifting up, or highlighting. Selecting moves were used less frequently than monitoring moves. Additionally, facilitators made moves to help connect instances of learning to big ideas of teaching science. Beyond identifying a framework for supporting facilitators’ work, the authors noted that being clear on the goals of the PD activities was important both for impacting the moves the facilitator made as well as in analysis of the those moves. Examining facilitator moves in light of the PD goals by identifying what ideas were being selected for (not just that selection was happening) allowed the authors to identify facilitator choices in the moment that might have otherwise gone unnoticed. Finally, the authors identified the idea of teacher learning as a progression and propose this as an important
lens through which PD providers can plan for and implement PD (see also Jackson (2015).

While there are a limited number of studies that examine the facilitation of PD in science, there is a growing body of research in mathematics education which may inform the science PD.

First, Elliott and colleagues (2009) examine the development of PD leaders in math with a particular focus on the ability to lead whole group discussions where teacher participants are doing math. They specifically examined the use of two frameworks: sociomathematical norms (norms for mathematical reasoning); and practices for orchestrating productive mathematical discussions, supported PD leaders. To understand how the PD leaders used the frameworks and to understand their work as leaders the authors analyzed observations from the summer seminars for the PD leaders as well as well as pre- and post-surveys and interviews. They then analyzed observations of PD sessions with pre- and post-observation interviews to see how the PD leaders were using the frameworks when they led PD on their own.

PD leaders found the frameworks to be useful tools in helping learn to lead math-rich discussions. However, while leaders indicated that they were comfortable using the ideas in the frameworks such as uncovering potential confusion with students, there was tension in pushing for mathematical reasoning and voicing confusion with adult learners. They had to “learn how to navigate the fine line between being a colleague and facilitating learning” (p. 373). The PD leaders also noted the importance of managing teacher positioning in regards to their math competence. Additionally, the PD leaders noted the importance of experiencing the mathematical task themselves in order to be
able to anticipate and highlight solutions to be shared. The authors also found that being clear on the purpose when leading a mathematical task discussion is both important and challenging. Identifying goals for a discussion required the negotiation of competing factors and, if the mathematical goal for a discussion was not clearly articulated, the leaders had a hard time knowing which mathematics ideas to highlight and pursue with the group. Ultimately the authors argue that PD leaders in math need knowledge of sociomathematical norms and practices for leading discussions in order to develop teachers’ specialized knowledge of mathematics for teaching.

Borko et al. (2014) examined teacher leaders’ facilitation of PD sessions focused on math content and instructional practices that utilize classroom video through a PD program called the Problem Solving Cycle (PSC). They analyzed enactment of the PD sessions first to see if the program was enacted with integrity to its key characteristics and then which aspects were enacted well and which were challenging to enact. Through analysis of videotaped sessions, interviews, and field notes, the authors found that the teacher leaders did enact the program with integrity to the goals and design of the PD. They found that teacher leaders were successful with establishing and maintaining a climate of respect and developing a professional learning community of collaborative learning, a pre-requisite for helping teachers reflect on and improve their teaching. They were also successful in identifying video clips of teaching that could foster rich discussion. Helping their teacher participants dig deeper into the analysis of the video clips to focus on mathematical reasoning, student reasoning, and instructional practice was found to be more challenging. The authors argue that teacher leaders need a deep understanding of mathematics as well as the ability to notice and respond in the moment
by being very clear on the goals and aspects of the work they hope to highlight. They suggest that understanding Mathematical Knowledge for Professional Development (MKPD) that includes specialized content knowledge and pedagogical content knowledge from a PD leader perspective as well as the ability to establish a learning community for adult learners is critical and needs to be identified and understood in order to support the development of PD leaders. While this study found that others beyond those who developed the program can lead the PD, they did raise questions about the scalability of this time and labor intensive preparation program and called for more work in identifying the knowledge and skills leaders need as well as which experiences PD leaders need in order to be able to enact PD with other teachers.

Jackson and colleagues (2015) examined three math leaders who were designing and implementing math PD. The leaders showed evidence of developing some skills and attitudes about teacher learning over time. For example, leaders began to approach teacher learning as a progression as opposed to fixing or filling in teacher understandings, and began to design PD activities that were more connected and more focused on key instructional features. However, they struggled with pressing on teachers’ ideas and facilitating the activities in ways that reflect the core instructional practices they hoped to highlight. They point to features of the leader training that involved analyzing video of teacher PD and then jointly planning as important in supporting leader progress towards the stated goals. They suggest adding a focus on how teachers learn new practices; modeling and practice with helping push on teachers’ ideas; addressing how to use video effectively; and highlighting productive PD activities to the leader training.
Jacobs, Seago, and Koellner (2017) examined the fidelity of enactment for a successful video-based PD program for secondary math. Their study gives a detailed view of how one experienced facilitator with strong content knowledge prepares for and implements a particular PD program. They found that the facilitator implemented the program with few modifications to the activities except for time spent on the activity which varied from the time allotted. She implemented with high fidelity to the PD program’s mathematics and mathematics knowledge for teaching goals, with modifications made based on the PD context. They point to the importance and necessity of facilitator adaptations likening the work to the “improvisational performance” (Barker and Borko, 2011; Borko and Livingston, 1989) of teaching in the classroom (p. 11). Given this necessary and demanding skill of “disciplined improvisation” they argue that tools for examining fidelity need to be able to capture the nature and rationale for modifications made in order to determine if the modifications are “productive, no impact, or fatal” and to determine if facilitators are truly enacting with fidelity to the goals and intentions of the program. This study only examined one facilitator who engaged in extended planning and preparation. In order to scale up, they argue for focused support for facilitators who will need “a deeper and more sophisticated knowledge base than the adults they work with” through explicit learning goals and resources for facilitators as well as opportunities to rehearse during preparation.

These studies examine various aspects of enactment of successful PD programs. They examined discussion leading strategies leaders utilized (Elliott, Kazemi, Lesseig, Mumme, Carroll, Kelley-Petersen, et al., 2009; Tekkumru-Kisa & Stein, 2017a; Zhang et al., 2011), fidelity of implementation (Hilda Borko et al., 2014; Jacobs et al., 2017), and
how leader facilitation changed as they engaged with the leader training (Jackson et al., 2015). However, there are only 2 from science and they range in the scope and design of the studies. An additional set of papers examines the preparation of PD leaders in successful PD programs.

### 3.3.2 Preparation of PD Leaders

First, Perry and Boylan (2017) examined the preparation of professional development facilitators (PDFs) in secondary science through an action research study which sought to identify the needs and activities that are effective in supporting the professional learning of PDFs. They found that collaboration with peers, use of video analysis of themselves leading PD, and a focus on theoretical models of professional learning supported the PDFs’ work. PDFs in the study identified professional learning needs in facilitation skills and knowledge as well as in knowledge about professional development. PDFs did not note needing support in knowledge and skills for teaching, a factor that the authors contend is a prerequisite for facilitating PD, which may be due to lack of opportunity to discuss such needs in this study’s program. They contend that more opportunities for PDFs to collaboratively reflect, analyze and improve their facilitation practice is needed.

Additionally, Roth et al. (2017) describe the design principles that guided the development, implementation, leadership, and scale up of the successful Science Teachers Learning from Analysis (STELLA) PD program. The authors argue that STELLA is one of the few studies of teacher PD that rigorously tested the effectiveness of their program. They found significant impact on elementary teachers’ science
teaching practice and their students’ learning which held true even when the program was scaled up to include new geographic areas and led by PD leaders outside the original program development team (Wilson et al., 2016). The authors argue that examining the design principles of this successful case can strengthen the consensus model for what effective PD involves. They hold that one of the keys to their success in scaling up the successful PD is the development of teacher leaders to lead the PD. Therefore, they identify design principles around program leadership, scalability, and sustainability that address the development of PD leaders. First, they argue that the PD Leader plays a key role in deepening teacher learning. Additionally, they identify PD leader knowledge and decision-making abilities as central noting that PD leaders must have and draw on Pedagogical Content Knowledge for PD Leaders in order to inform their practice. They note the importance of facilitator skill in making in the moment decisions while leading discussions to help participants dig deeper in their analysis of video cases of teaching. In order to support scalability and sustainability, STELLA designed a program to build capacity of PD leaders and identified the following goals and activities of the program: 1) taking on a leadership identity which may be new for teacher leaders; 2) learning how to use the program strategies; 3) helping leaders learn how to balance supporting and challenging teachers; 4) helping leaders build a community of learners; 5) addressing working with adult learners and understanding change; 6) deepening PD leaders’ science content knowledge; 7) deepening pedagogical content knowledge; 8) practicing facilitation, and 9) working with video cases. They also noted the importance of articulating, and supporting PD leaders in understanding, the learning goals for each PD session as well as the PD program as a whole.
While in their previous study Borko (2014) examined the degree to which the PSC PD program was enacted with integrity, Borko et al. (2017) lay out the elements of their Mathematics Leader Preparation (MLP) program which prepares Teacher Leaders to lead PD sessions using the PSC described earlier. Teacher leaders attended a summer institute where they experienced the PSC by working on math tasks; engaged in video-based discussions (VDBs) themselves; analyzed video of facilitators leading VDBs with teachers; rehearsed portions of the workshops they would lead; planned for implementation; and received support and feedback on their facilitation as they enacted their sessions. As part of their Design Based Implementation Research project the authors sought to understand how both the PSC and the MLP programs were adapted to support district goals. In order to better support leadership development, they adapted the MLP program to address the teacher leaders’ limited experience by helping teacher leaders better understand the PSC themselves; increasing support for what it means to be an instructional leader; and increasing opportunities for modeling and debriefing activities. They highlight the approach of modeling/experiencing the PD for themselves as learners, debriefing the facilitation, and then planning for and rehearsing the VDB as important aspects of preparing teacher leaders to lead PD.

Finally, Lessig et al. (2017) examined the leader preparation of a large group of leaders using video cases of math PD, and analyzed leaders’ pedagogical reasoning as they engaged with the videos. Drawing on the research base of teacher noticing in the classroom they hold that in order to support PD leaders they need chances to notice facilitation skills and resources in action. In the first phase of the design of leader PD they found that while the frameworks provided were useful in planning for math rich
discussions, they needed more opportunities to intentionally experience mathematical ideas themselves and identify the unique needs of teachers as learners. In phase 2, they implemented changes to address these needs. Like many others, identifying the mathematical goal for teacher learning and then designing a task towards that goal became central to their leader prep framework with skills for orchestrating discussions in service of these subject matter learning goals. They found that leaders in phase 2 were more focused on how facilitators advanced teacher learning with a particular focus on the math of the video case and interpretation of facilitation moves in light of those goals. They argue that being able to link facilitation moves to the mathematical purposes supports PD leaders in being able to respond, in the moment, to advance the mathematical thinking of the group. In order to support PD leaders in this charge they argue for three design principles: 1) Center the leaders’ mathematical work on clear learning goals for teachers; 2) design tasks for leaders that specifically target specialized content knowledge; and 3) analyze video cases where math ideas are being pursued by teachers to better understand the work of the PD leader.

### 2.4.3 Summary

This collection of papers begins to document the knowledge and practices for leading professional development in math and science education and begins to articulate the preparation and support needed to develop these knowledge and practices. Some key challenges and needs for facilitation emerged.

First, leading discussions during PD is a challenging practice and requires knowledge, tools, and frameworks to support productive discussions that work towards
the target conceptual or pedagogical goals. Facilitators need to know when and how to push and highlight participants’ ideas, a skill that was utilized by skilled facilitators (Tekkumru-Kisa & Stein, 2017b) but found to be a struggle for novice facilitators (Hilda Borko et al., 2014; R. Elliott, Kazemi, Lesseig, Mumme, Carroll, & Kelley-Petersen, 2009; Jackson et al., 2015; Zhang et al., 2011).

PD leaders need to be skilled in the moment-to-moment decisions needed to address the learning goals. In order to do this, PD leaders need to be clear on the learning goals at both the program and activity level. Tekkumri and Stein (2017) noted the need to examine PD leaders’ moves in light of the goals in order to identify and highlight facilitator choices. Jacobs and colleagues (2017) speak to needing to understand the goals in order to analyze modifications and their impact on fidelity of enactment. Without this focus and awareness on goals, PD leaders struggled to know when and what to highlight leaving discussions superficial. A deep understanding of the content (Borko et al., 2014; Jacobs et al., 2017; Lesseig et al., 2017; Roth et al., 2017) was also identified as an important aspect of PD Leader knowledge in order to be able create learning opportunities and to lead key discussions designed to increase teacher understanding.

Additionally, an awareness of how teachers learn and viewing their learning as a progression versus filling in missing ideas was an important theme in these studies. Central to this is the ability to build and support a learning community where there is a culture of risk taking and collaborative knowledge building. Finally, support in becoming an instructional leader, a role new to many teacher leaders, was found to be important.
In order to support the ability to lead responsive discussions, make moment-to-moment decisions and modifications, be clear on the learning goals, have a deep content understanding, create a culture/community of learners, and gain skills in being an instructional leader, several aspects of PD Leader preparation were offered as effective. First, PD Leader preparation should include a direct focus on analyzing facilitation practice with video analysis highlighted as a key means to analyze this practice. The use of frameworks, many borrowed from classroom instruction, and using those frameworks as lenses for analysis of the facilitation practice was suggested. Additionally, providing opportunities to rehearse and practice aspects of facilitation and then reflect on their own facilitation was prominent. Experiencing key elements of the PD themselves as learners as well as engaging in the mathematical or science content themselves was also identified as important for preparing PD Leaders. Finally, time and structures for intentional planning and preparation is needed.

While these studies begin to highlight the needs of PD Leaders, there is still much to be learned and articulated about the specialized knowledge and skills needed for PD Leaders (Borko et al., 2014; Roth et al., 2017) and how best to support the development of such skills, particularly in science education. Both science studies discussed here examined experienced PD Leaders, leaving room to examine how to support more novice PD leaders needed for scale up of PD. And, while the math studies that have begun to examine novice leaders can inform the preparation of leaders in science, there are key differences between math and science instruction. To support the shifts in instruction called for in science education will require PD at scale to start to shift classrooms (Borko et al., 2014; Marrongelle, Sztajn, & Smith, 2013; Wilson, 2013). And, skilled PD leaders
are a pre-requisite for this scale up. Further examination and articulation of the skills and knowledge needed by these PD leaders as well as how to prepare them is needed.
CHAPTER 4

PROFESSIONAL DEVELOPMENT CONTEXT

4.1 Overview of NGSX

The Next Generation Science Exemplar (NGSX) PD program is a blended learning environment consisting of an online, web-based platform in which video-based cases, learning tasks, and tools for engaging with both cases and tasks are embedded. The system is designed to support K-12 teachers and science teacher leaders in getting introduced to the new vision of science teaching and learning (NGSS Lead States, 2013b) and take that learning back into their own classrooms. The NGSX system emphasizes the core epistemic practices of modeling, argument, and explanation, supporting participants to engage in these practices rather than learning about them (see ngsx.org). NGSX sessions are conducted with face-to-face “study groups” of science educators (typically 15-25 per cohort), using the NGSX web-based resources, and with the guidance of an expert facilitator (and most typically, two co-facilitators). NGSX consists of a set of “learning pathways” – coherent courses of learning, akin to a graduate seminar, multi-day summer institute, or extended day PD workshop. Teachers engage in the “Introduction to Three-Dimensional Learning: Argumentation, Explanation, and Modeling the Behavior of Matter” PATHWAY (Teacher Pathway), a 45-hour course of study. Additionally,

3 This NGSX Pathway has since been revised and is now called “Becoming a Next Gen Science Teacher.” There are also pathways for instructional leaders (Principals Learn About, Network, and Support 3-Dimensional Science Learning), a pathway following the initial introductory pathway (Taking it Back to Your Classroom), and two pathways that involve virtual study groups (Building Capacity for Next Gen Science Teaching and Learning While Teaching).
Teacher Leaders engage in the Facilitator Pathway (Facilitator Pathway), a 24-hour course of study, concurrently.

The design principles that guided the design of the Pathways are shown in Figure 4 and align with the characteristics of effective professional learning (Wilson et al., 2015) and were summarized by Reiser and colleagues (2017) in their review of the implementation of these two Pathways in one state.

<table>
<thead>
<tr>
<th>Design Principle</th>
<th>How The Principle is Realized in NGSX System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Situate teacher learning in tasks requiring sensemaking of classroom cases</td>
<td>Analytical tasks applied to video cases that follow classroom episodes of students engaged in science practices</td>
</tr>
<tr>
<td>2. Focus on the high leverage practices of argumentation, explanation, and modeling</td>
<td>Teachers analyze cases involving argumentation around explanatory models</td>
</tr>
<tr>
<td>3. Organize teacher study groups working to apply reforms to their own practice</td>
<td>PD tasks support teachers in incorporating science practices in their own classrooms</td>
</tr>
<tr>
<td>4. Combine focus on science, student thinking, and pedagogy</td>
<td>PD tasks interweave multiple perspectives, engaging teachers in science, analyzing student thinking, and analyzing pedagogical strategies</td>
</tr>
<tr>
<td>5. Develop peer facilitators’ capacity in knowledge-building facilitation</td>
<td>Support pedagogical content knowledge for facilitation of study groups (The Facilitator Pathway)</td>
</tr>
</tbody>
</table>

Figure 4: Summary of Design Principles for NGSX (Reiser et al., 2017)

Reiser et al. (2017) presented results from a state who prepared Teacher Leaders to implement the NGSX Teacher Pathway with their Teacher colleagues. Pre- and post-surveys of 241 teachers were analyzed to inform how the PD impacted their content knowledge, confidence and beliefs, and pedagogical content knowledge to support students in engaging with science and engineering practices to develop and use science ideas to make sense of phenomena (National Research Council, 2011). They found teachers increased their content knowledge about the nature of matter, felt more prepared
to implement the new standards in their classrooms, shifted beliefs about teaching and learning away from more traditional instruction (e.g. shifted away from pre-teaching vocabulary), and shifted their understanding about the use of modeling in the classroom. This study focused on the impact of the PD on teachers’ knowledge and beliefs where Teacher Leaders were facilitating the PD. It did not focus on implementation of that PD or the knowledge and skills of the facilitators, leaving a gap for studying how to develop skilled facilitators.

4.2 Teacher Pathway

The 45-hour introductory teacher pathway (Teacher Pathway) includes seven units which range in length from seven to four hours and support teacher learning about modeling, argumentation and explanation in the context of disciplinary core ideas about the nature of matter. The units include engaging in content via experiencing and explaining puzzling phenomena, examining classroom cases, and studying pedagogical strategies. Appendix A provides a summary of the focus of each unit. Because this study will analyze discussions from sections of the PD where teachers are engaged with science content as adult learners, I will provide some context here for that content and the “Air Puppies” model that is used in order to help the reader understand the transcript excerpts provided in the Results chapter.

Teachers in the Teacher Pathway develop and revise explanatory models for multiple phenomena related to the behavior and nature of matter, and specifically about
air pressure. For example, Teachers begin by trying to explain why a 2-liter bottle collapses when a small amount of boiling water is added and then the bottle is immediately capped. After constructing initial explanatory models, the teachers are provided with a tool for thinking about the behavior of air molecules called the “Air Puppies Model”. This model provides a set of elements and rules for how air molecules behave when they interact with objects. The model includes two “rooms” where air molecules move freely (called air puppies because they just “bumble” about like newborn puppies – they have no intentions, don’t stick to each other, and thus can’t pull but only push on things) and a “wall on wheels” (W.O.W.) that separates the two rooms. One important model characteristic of the W.O.W. is that it is as if on frictionless rollerskates and can move if pushed on by the air particles. Teachers map these elements of the model on to real world phenomena. For example, with the 2-Liter bottle, one room is inside the bottle and the other room is outside the bottle. The sides of the 2-Liter bottle is the W.O.W. because it can move if there are more frequent hits of air molecules (“air puppies”) in one “room” compared to the other. Teachers use and revise this model throughout the first three units of the Teacher Pathway to explain increasingly complex phenomena. See Appendix G for further description of the Air Puppies model and the phenomena that are the focus of each discussion.

A central design tenet of NGSX is that the same shifts in discourse required in the classroom to support students’ “figuring out” and engagement in the core science practices are required in knowledge-building PD for adult learners. NGSX believes that

4 Teachers will be capitalized when talking about the teachers who were involved in the PD and the focus of this study.
in order to apprentice students into key disciplinary practices, teachers need to build a classroom culture of public reasoning – primarily through discourse (talk and writing) where thinking becomes visible and public (Michaels & O’Connor, 2015; O’Connor & Michaels, 1996). Therefore, in the Teacher Pathway, NGSX intentionally links discourse and science practices together to create a discourse intensive, knowledge building process where participants engage in the science practices as well as APT as authentic (not pretend or imagined) learners of science. First, teachers engage in whole group discussions about complex phenomena where the APT moves are used and modeled by the Facilitators. Next, they engage in a five-hour unit centered around tools to support building a classroom culture that supports public reasoning. This includes analyzing classroom video, learning about the Goals of APT and the talk moves that support them, and an assignment to practice and reflect on a discussion in their own classrooms. Specific classroom tools such as the ‘Talk Moves Checklist’ which lists these goals and moves are utilized throughout the unit. Figure 5 shows a step in the NGSX Unit on Productive Talk. The menu bar on the left shows the steps in the unit. Teachers watch videos, discuss in small and whole group, and post responses on the website.
Figure 5: A step in an NGSX unit Supporting Teachers in Understanding Productive Talk (in Unit 4)

4.3 Facilitator Pathway

Additionally, Teacher Leaders complete the Facilitator Pathway, a 24-hour course of study, concurrently, that is, interspersed within the Teacher Pathway – see Figure 6 below – though it is sometimes done after the Teacher Pathway. The Facilitator Pathway prepares leaders to lead their own study group and directly addresses how Teacher Leaders can develop a culture of public reasoning and how to enact APT with their teacher participants. After completing both Pathways, Teacher Leaders then enact the
Teacher Pathway with teachers back at their home site or district in what is called a “study group”. Teacher Leaders complete the Teacher Pathway and Facilitator Pathway in groups that I will refer to as Leadership Development Academies (LDAs). Figure 6 shows the sequence of Units and Chapters for the LDA.

Figure 6: Sequence of Teacher Pathway Units and Facilitator Pathway Chapters for Teacher Leaders in NGSX Leadership Development Academies (LDA).

The Facilitator Pathway is designed around a “Knowledge Building Framework” (KBF) that focuses on how to support teacher participants in engaging in productive knowledge building including a focus on group culture building strategies to “establish and sustain study group norms on respect, risk-taking, equity, and collaboration, in which knowledge- building can happen for everyone, regardless of grade-level, science background or prior knowledge of the Framework and NGSS” (p. 285) as well as pedagogical content knowledge for Facilitators (PCK-F) (Reiser et al., 2017). To support facilitators in reflecting on their own practice, video cases of study groups in action were
selected to build understanding of aspects of the KBF Framework, to problematize aspects of facilitation, and to focus on key steps and “hinge ideas” in the Teacher Pathway. As Moon and Michaels (2016) note, these videos were intentionally selected to motivate critical thinking and evaluation of facilitator practice by looking at real issues with real study groups, not in “perfected examples that communicate the one ‘best practice’”. Included in this set of videos were “Director’s Commentaries” where, after the Teacher Leaders had analyzed the video themselves, the Lead Facilitators would reflect on their moment to moment decisions of the discussion clip to provoke further analysis and application to the practice of facilitation. Such an approach makes the discussions more transparent and provides models for Teacher Leaders to implement in their own PD sessions and can provide opportunities to notice facilitation skills and resources in action (Lesseig et al., 2017).

In addition to the focus on productive talk in the Teacher Pathway, the Facilitator Pathway includes an entire four-hour unit on supporting productive talk as a facilitator, returning to the same tools and utilizing video of facilitation, including a specific focus on leading consensus discussions which are the type of discussion analyzed in this study. Figure 7 shows a page from Chapter 3 of the Facilitator Pathway focused on supporting these discussions.
Further information about these discussions will be provided in the Methodology chapter.

With the context and specific approach to the PD program examined in this study described, I will shift to the methods used to analyze the data from these LDA sessions.

Figure 7: A step in an NGSX Facilitator Pathway Chapter Supporting Teacher Leaders in Analyzing Facilitation Practice (Chapter 3)
CHAPTER 5

METHODOLOGY

5.1 Overview

This qualitative study examined the characteristics of APT that Lead Facilitators and Teacher Leaders enacted during NGSX science PD. Focusing on how Teacher Leaders experienced PD emphasizing APT and how they then enacted that PD as facilitators for their teacher colleagues can inform how to prepare PD Leaders to support the knowledge and enactment of new discourse practices.

Employing a qualitative design, data were collected through videotaping of key whole-group consensus discussions (more details below) around the PD program’s focal science concepts as well as face-to-face individual interviews with Teacher Leaders and Lead Facilitators. I identified patterns or themes relating to discourse tools and strategies used, how they compare between Lead Facilitators and Teacher Leaders, and what each said about why they made the moves they did. Figure 8 illustrates the data sources for RQ1 and RQ2. RQ3 was answered by analyzing the findings from RQ1 and RQ2.
Figure 8: Data sources for RQ1 and RQ2

The rationale for the research approach and the research design including the setting and participants, gaining entry and informed consent, data collection, data analysis, and issues of trustworthiness are explained in the following sections.

5.2 Rationale for Research Design

Qualitative research seeks to make meaning out of complex, dynamic, real world situations (Rossman & Rallis, 2012). As mentioned, orchestrating talk that supports collaborative sensemaking, whether in a classroom or PD setting is complex, unscripted, and, influenced by many factors including the content, the participants, the context (setting) and the shared history of the group. Given this complexity, a qualitative research approach that values complexity by focusing on “individuals and interactions” and seeks to “describe and interpret rather than measure and predict” (Rossman & Rallis,
is most appropriate to find answers to my research questions. Based on the gaps in the literature around supporting PD Leaders to enact professional learning centered around productive academic talk, an analytic descriptive case study (Rossman & Rallis, 2012) was used that sought to describe, analyze, and interpret, and allowed for in-depth examination of specific instances of a complex issue in order to understand a larger phenomenon (Rossman & Rallis, 2012). Yin (1994) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context…” (p. 13). Rossman and Rallis (2012) describe case studies as descriptive as they depict events within context. This case study is descriptive because it sought to describe what the study participants were doing and thinking as they led whole group consensus discussions in a science PD setting.

Additionally, in this study, there was a close examination and description of this particular case of professional learning and the discourse tools and strategies that the Teacher Pathway foregrounds and presents for teachers to use. Additionally, a rich description of how the Teacher Leaders are prepared through the Facilitator Pathway added to this and helped address the gap in the literature around preparing PD Leaders.

The context dependency of case studies make them “an especially good design for practical problems – for questions, situations, or puzzling occurrences arising from everyday practice.” (Merriam, 1998, p.11, as cited in Rossman & Rallis, 2012). Here, the data were collected within the real-life context of the PD and the practice of leading whole group discussions. Because case studies rely on multiple data sources and detailed descriptions, they result in “thick descriptions” (Geertz, 1973) which can lead the reader to determine the applicability of the findings to other settings. The rich descriptions of
this study’s single case will enhance our understanding of PD centered around APT and how to support PD Leaders in promoting it for other teachers. However, Rallis and Rossman (2012) remind us that case studies are context-dependent, focusing on specific qualities and characteristics of the case which limits generalizability. By providing sufficient description of the research process (see below) and rich description of what I learn, users of my study can determine if the results are applicable in a similar setting.

5.3 Setting and Participants

In order to answer RQ1 (discourse tools and strategies used by Lead Facilitators) I examined two NGSX Leadership Development Academies (LDAs). LDA1 took place between January 2015 and June 2016 and included 18 Teacher Leaders. LDA2 took place between July 2016 and December 2017 and included 21 Teacher Leaders. Lead Facilitators for these groups included two science PD providers who have been supporting K-12 science teachers through statewide PD and graduate programs for many years. Leader 1 (the researcher) has middle and high school teaching experience, a Master’s degree in science education, and had been leading PD for over 15 years. Leader 2 (Deanna) has middle and high school teaching experience, a Master’s degree in science education and had been leading PD for over seven years. Both leaders served on the design team of the NGSX PD program, piloting and helping revise the Teacher Pathway as well as helping design the Facilitator Pathway. I will address my researcher positionality and role in a later section.

In order to answer RQ2, I examined two of the Generation 2 groups from LDA1. Teacher Leaders attended the LDA as a team that consisted of two or more Teacher
Leaders or other educational leaders from a school or district. Of the seven teams that attended LDA1, three facilitated study groups back at their home sites. Of these three sites, two were selected for analysis based on having a complete corpus of data and consent from all teacher participants in the Generation 2 study groups. These two groups were not selected based on any presumed characteristics of quality.

Detailed demographic information of the two groups is provided in Table 2. Bayedge School District is a large, urban district serving over 4,000 students and is the most racially diverse district in the State with 34.8% students from non-White households. Though Bayedge School District serves PreK-12th grade students, all the Teacher Leaders who had signed up for the PD had elementary teaching experience, were female, and as required by the LDA program, experienced teachers with two of the Teacher Leaders serving in teacher coaching positions. Nationally, the average Study Group size is 12-30; with 24 Teachers Bayedge was on the upper end for cohort size.

The second site, Lakecastle, is also a large district serving both rural and urban towns but has little racial diversity (91% White/Caucasian). Teacher Leaders at this site were also all female and experienced teachers. However, Lakecastle Teacher Leaders had both middle and elementary school teaching experience. The Lakecastle Study Group had 15 Teachers with no high school teachers represented in this cohort of Teacher participants.

Bayedge and all other names used for sites, Teacher Leaders, and Teachers are pseudonyms.
Table 2: Demographics of Participating Sites, Teacher Leaders, and Study Groups

<table>
<thead>
<tr>
<th>Site Code and Pseudonym</th>
<th>Site Description and Demographics</th>
<th>Teacher Leaders</th>
<th>Teacher Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Bayedge School District</td>
<td>Large urban PreK-12 school district (4,000 students) with racial make-up of White 65.2%, African American 14.1%, Asian 11.5%, Hispanic or Latino of Any Race 3.6%, American Indian or Alaskan Native 0.1%, Two or More Races 5.4%. Free and Reduced Lunch rate 61.9%</td>
<td>Chris - White Female. District Level Science Coach with 20 + years of elementary teaching experience.</td>
<td>24 Teachers and other educators. 4 males, 20 females. 7 grades K-2 teachers; 6 grades 3-5 teachers; 6 grades 6-8 teachers; 2 High School teachers; 1 district level math coach; 2 community education partners.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jill - White female. 20 plus years elementary teaching experience.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ann - African American female. 10+ years elementary teaching experience.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cindy - White female. School based STEM Coach. 10+ years teaching experience.</td>
<td></td>
</tr>
<tr>
<td>B. Lakecastle Supervisory Union</td>
<td>Large supervisory union (4000 students) consists of 6 schools and 1 school district. Racial makeup is 91% white/Caucasian, 9% as African-American, Asian, or Hispanic. Free and Reduced Lunch rate 7%.</td>
<td>Sarah - White Female. District Level Science Coach with 15 + years of middle school teaching experience</td>
<td>15 Teachers. All Female. 6 Grades K-2 teachers; 4 Grades 3-5 teachers; 3 grades 6-8 teachers; 2 special education or ELL teachers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cady - White female. 10 + years elementary/middle school teaching experience</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rhonda - White female. 10 + years elementary/middle school teaching experience</td>
<td></td>
</tr>
</tbody>
</table>
5.4 Gaining entry and informed consent

Informed consent to participate in the study was secured from the Lead Facilitator, Teacher Leaders, and Teachers in the study groups as part of the larger NGSX research project using Northwestern University’s IRB approved consent forms. An IRB Authorization Agreement (IAA) was completed between Northwestern University and UMass Amherst. As part of the communication between NGSX and participants prior to joining a NGSX study group, an electronic survey describing the broad purpose of the study, the risks, benefits, and ways the privacy of the participants would be protected was sent to each participant via e-mail. This was done so that those who wished to complete the pre-survey could complete the survey before attending the first face-to-face session of the study group. After reading about the study, participants were then asked to indicate if they would like to be part of the study or not. Participants could opt in or out of any aspect of the research study (e.g., survey, interviews, video/audio). A copy of the consent form was sent after submitting their responses. On the first day of the groups face-to-face meeting, the participants were provided with a verbal description of the study and given time to ask any questions they had about the study. Additional hard copy consent forms were available, and participants were reminded that they could opt in or out of the study at any time. The informed consent for this study (see Appendix A) stated generally that the “The purpose of this study is to better understand how teachers, coaches, and administrators learn about the implications of the Framework and NGSS for classroom
teaching. The findings will help inform the design of more effective professional development programs.”

As a long-time professional development provider in Vermont, I had prior professional relationships with all but one of the Teacher Leaders in the study as well as many of the other Teacher Leaders in the LDA groups. All of the Teacher Leaders in LDA1 and LDA2 groups consented to be part of the study. At Bayedge all but two participants gave permission for analysis of audio or video of their NGSX sessions. The content of non-consenting Teacher turns was struck through in the text and not included in the analysis. At Lakecastle all but one Teacher gave permission for analysis of audio or video of their NGSX sessions. This Teacher did not complete the study group and attended only on day 1.

5.5. Data Collection

5.5.1 Focal Discussions

As discussed earlier, in NGSX one talk format that is both important and challenging to facilitate is a whole-group discussion. It has been identified as a high leverage discussion type because, to the extent that it employs the tools and strategies of productive talk, it motivates engagement in the science practices of modeling, argument, and explanation. There are five whole-group consensus discussions in NGSX. Of these, I examined three as my primary data sources because they reflect varying levels of complexity regarding the phenomenon being discussed. The same whole-group consensus discussions that are facilitated by the Lead Facilitators were also facilitated by the Teacher Leaders. As mentioned in Chapter 2, understanding the nature of productive
talk and its use in discussions is challenging because much of the interaction during a discussion depends on the context including the content domain, focus for the discussion, and previous work on the topic. Focusing on the same whole-group discussions for both the Lead Facilitators and Teacher Leaders provided a unique opportunity to compare talk within the same context including the content, the activities that led up to the discussion, the discussion prompt, and the goal of the discussion. This allowed for the uncovering of patterns within discussions and across Facilitators (Note: when referring to both the Lead Facilitators’ and Teacher Leaders’ actions, I will use the term Facilitators to cover both role groups). Table 3 describes the three focal discussions for this study.

Table 3: Focal Discussions for this study

<table>
<thead>
<tr>
<th>Discussion</th>
<th>Location in the NGSX Pathway</th>
<th>Description of Phenomenon and activities that precede the discussion.</th>
<th>Discussion Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottle on the Table</td>
<td>Unit 1, Step 7</td>
<td>Participants have been introduced to a model for understanding air pressure called the “Air Puppies Model” through video simulations and discussion. This is their first attempt to apply this model to explain a phenomenon.</td>
<td>Consider a plastic bottle, with the cap on, sitting on a table. Why doesn’t the bottle collapse if the air is pushing with a force of 14.7 pounds on every square inch of the bottle?</td>
</tr>
<tr>
<td>Biggest Sucker</td>
<td>Unit 1, steps 10 and 11</td>
<td>Participants are asked to drink from a straw using two different bottles: one has a small hole in the stopper while the other has no hole in the stopper. Participants observe that it is much easier to drink out of the bottle with the hole in the stopper.</td>
<td>Why can we drink easily out of the bottle with a hole in the stopper but not out of the one with no hole in the stopper?</td>
</tr>
</tbody>
</table>
apply the Air Puppies Model to create explanations for this phenomenon in small groups on chart paper before coming to the consensus discussion.

| Soap Bubble | Unit 2, step 7 | Participants dip the mouth of a 2-liter bottle into a soap solution so that the mouth of the bottle has a soap film covering the opening. They then place the bottom of the bottle in a bucket of hot water and observe that the bubble increases in size. When they place the bottle in cold water, the bubble shrinks down into the bottle. Participants apply the Air Puppies Model to create explanations for this phenomenon in small groups on chart paper before coming to the consensus discussion. Participants are also encouraged to articulate a new rule to add to the model about temperature. | Why did the soap bubble grow in the hot water and shrink in the cold water? |

The Lead Facilitators video-recorded the discussions. Rossman and Rallis (2012) note the importance of observation as a data source for qualitative research in order to examine complex social interactions and help the researcher understand the context, see patterns, and move beyond researcher or participant perceptions.
5.5.2 Interviews

Interviews of both the Lead Facilitators and a sample of the Teacher Leaders were conducted using video-stimulated recall to understand why they made the moves they did and what might have contributed to their use of the identified discourse tools. During the interviews, segments of the discussion were played, and the Facilitators were asked to reflect on the moves that they made. For the interviews, I selected the Teacher Leaders who were primary leaders of the focal discussions resulting in a total of four Teacher Leader interviews. Note, Teacher Leaders worked with their Co-Teacher Leader to decide how to share the responsibilities of leading the discussions (e.g. assigned themselves to be either the lead on a focal discussion responsible for guiding the discussion or a co-facilitator who might offer comments, ask for clarification, or scribe).

Before watching portions of the discussion (video-stimulated recall), both Teacher Leaders and Lead Facilitators were asked what they recalled about the goals of the discussion and what they might recall about the discussion in general. Then, various segments of the discussion were viewed together. Segments might include a time when the Teacher Leader or Lead Facilitator made a particular move (e.g. an APT talk move) or an exchange between participants but no facilitator move. Facilitators were asked to comment on the segments. Prompts included “can you tell me what you were thinking about in that segment?”, “what do you remember about this segment of the discussion?”, “Why did you decide to make that move there?”, and “How did you know to make that move?”. All interview prompts are included in Appendix C. Facilitators were also encouraged to stop the video at any point and comment on what they noticed or were thinking. Each interview was video recorded and then fully transcribed. Since I was the
second Lead Facilitator, for the discussions that I lead, I used a similar protocol: paused the video and reflected on the same questions that I asked all interviewees.

5.5.3 Field Notes

I also recorded field notes while attending the NGSX study group sessions at Bayedge and Lakecastle recording anything notable that occurred outside of the scope of the video cameras or required further explanation. For Bayedge, field notes are available for all four days the study group met. For Lakecastle field notes are available for days one and three that the study group met, but were not recorded on day 2. Field notes included times and notes for each activity in the Teacher Pathway, Teacher Leader comments, observations and thoughts regarding the focal consensus discussions, and notes on conversations I had with the Teacher Leaders during a break or before or after the sessions.

5.5.4 Video Transcripts

Videos of the key whole-group consensus discussions were fully transcribed for coding using Inqscribe, a transcription software program, and include timestamp, speaker, and content of the turn. Transcripts were exported to Excel with each new row indicating a new speaker and turn. Transcripts included pauses, repeats, ums, uhs, and notable physical movements (e.g., Paul looking at Sam or pointing to Sara) in order to provide as much context for each turn at talk as possible. For example, wait time by both the person facilitating the discussion and by participants (e.g. mid-utterance) was indicated in the transcript by indicating the length of the pause in seconds in parentheses for any pause longer than 3 seconds in order to provide context to know how to code a
particular turn at talk. For example, a facilitator asking “does anyone agree or disagree with what Sarah said?” but then immediately keeps talking or moves on to something else is different than posing that same question and then waiting five seconds. Additionally, because these are model-based discussions where participants are trying to explain phenomena (such as drinking through a straw), are using a model (the “Air Puppies” Model), and bring their posters of their representations to the discussion, they often gesture to help support what they are saying. These gestures including using their hands to show how the water moves or to point to a particular aspect of a poster were included in the transcripts to help in interpreting the moves of the Lead Facilitators, Teacher Leaders, and participants. The rules for transcription that were used can be found in Appendix D An example segment of transcript from Bayedge, Bottle on the Table is shown in Table 4:

**Table 4: Example Transcript**

<table>
<thead>
<tr>
<th>Timestamp</th>
<th>Speaker</th>
<th>Content</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[00:12:08.19]</td>
<td>Teacher Leader</td>
<td>What’re you saying the wall on wheels is?</td>
<td></td>
</tr>
<tr>
<td>[00:12:11.22]</td>
<td>Shawna</td>
<td>The container- the.. plastic- (gestures to show the sides of the bottle)</td>
<td>(xxx)_Describes gesture</td>
</tr>
<tr>
<td>[00:12:14.24]</td>
<td>Lola</td>
<td>Maybe the wall on wheels is also like the other objects in room 2. (...)</td>
<td>(...)=Unintelligible</td>
</tr>
<tr>
<td>[00:12:21.10]</td>
<td>Teacher Leader</td>
<td>Is- can you explain more about that? What do you mean by that?</td>
<td></td>
</tr>
<tr>
<td>[00:12:24.22]</td>
<td>Lola</td>
<td>Um.. thinking about there being more air puppies on the outside than on the inside, why isn't it crushing the bottle because they're also pushing on other walls on wheels in the space.</td>
<td>.. = Brief break in timing</td>
</tr>
<tr>
<td>[00:12:39.26]</td>
<td>Teacher Leader</td>
<td>(looking at the group) So do you agree? Do you think there could be other walls on wheels in the space?</td>
<td>Describes who speaker is talking to</td>
</tr>
<tr>
<td>[00:12:44.26]</td>
<td>A Few</td>
<td>Yeah. (nodding)</td>
<td></td>
</tr>
</tbody>
</table>
During preparation of the transcripts, the videos were watched multiple times and research memos written to capture initial noticing, patterns, and questions that arose while watching the videos and cleaning up the transcripts.

Additional formatting of these transcripts was needed to run the Classroom Discourse Analyzer (CDA) program that produces visualizations of the interaction patterns between the Facilitators and Teachers (Chen, Clarke, and Resnick, 2015). The transcripts were set up to show a session number (e.g. Bottle on the Table for LDA was assigned session #1), turn, speaker, and content. The program is designed so that the Facilitator is indicated with a T (for teacher since the program is designed for classrooms). Here is an example of the same segment from Bayedge Bottle on the Table prepared for running in CDA:

<table>
<thead>
<tr>
<th>Session</th>
<th>Turn</th>
<th>Speaker</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>10</td>
<td>T</td>
<td>What're you saying the wall on wheels is? The container- the.. plastic- (gestures-to-show-the-side-of-the-bottle)</td>
</tr>
<tr>
<td>7</td>
<td>11</td>
<td>Shawna</td>
<td>Maybe the wall on wheels is also like the other objects in room 2. (...)</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>Lola</td>
<td>Is- can you explain more about that? What do you mean by that? Um.. thinking about there being more air puppies on the outside than on the inside, why isn't it crushing the bottle because they're also pushing on other walls on wheels in the space. (looking-at-the-group) So do you agree? Do you think there could be other walls on wheels in the space?</td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td>T</td>
<td>Yeah. (nodding)</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
<td>A Few</td>
<td></td>
</tr>
</tbody>
</table>

Part of the output of the CDA program is word counts. Because gestures and other descriptions were included and would be counted as words spoken, dashes were added so
that whatever text was in parentheses with dashes was only counted as one word. For example, (gestures-to-show-the-side-of-the-bottle) would be counted as one word instead of eight. A full description of the CDA program and how it was used will be described in the Data Analysis section.

In order to compare coding across discussions each transcript started with the Facilitator turn presenting the focus question for the discussion. Initial turns such as reviewing the norms for discussions or recapping the activity were not coded. The duration of each discussion is listed in table 5.

**Table 5: Duration (in minutes) of Each Discussion by Study Group**

<table>
<thead>
<tr>
<th></th>
<th>Duration in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LDA 1</td>
</tr>
<tr>
<td>Bottle on the Table</td>
<td>19:21</td>
</tr>
<tr>
<td>Biggest Sucker</td>
<td>25:25</td>
</tr>
</tbody>
</table>

Because my research questions target how the Facilitators orchestrate whole-group discussions in science, the primary unit of analysis was the moves they made facilitating the discussion with participant turns that preceded or followed the Facilitator’s turns. A move is defined as a specific statement and/or question that a Facilitator utilizes during the discussion. Additionally, a lack of making a statement via wait time is also considered a move. Analyzing these Facilitator moves helps demonstrate what strategies the Facilitators are utilizing. A secondary unit of analysis was the participant response to the Facilitator move. This analysis provided information
about whether the Facilitator move resulted in the intended Teacher response (e.g., Do they contribute a response? Is it related to the Facilitator move? Do they direct their utterance at another participant or at the Facilitator? Become silent?) and how this related to the goals of APT that will be used as a framework.

5.6 Data Analysis

Table 6 provides a summary of the data sources and analysis that was used for each research question. Each analysis and the rationale for why that analysis is useful in answering the question is provided below.

Table 6: Summary of Data Sources and Analysis for RQ1 and 2

<table>
<thead>
<tr>
<th>Question</th>
<th>Data Source</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. What talk patterns are evident in the ways Participants* interact with the Facilitators** and each other?</td>
<td>• Transcripts of whole group consensus discussions</td>
<td>• CDA coding and analysis of turn taking patterns</td>
</tr>
<tr>
<td>b). What academically productive talk moves do Lead Facilitators and Teacher Leaders use? What rationale do they provide?</td>
<td>• Transcripts of whole group consensus discussions • Interviews with facilitators</td>
<td>• Coding for APT Moves • Qualitative analysis of patterns of discourse to identify themes around how the moves are used to support Participant engagement and idea development. • Analysis of interview responses to refine, challenge, confirm and disconfirm themes.</td>
</tr>
<tr>
<td>c.) What are Participants doing in terms of reasoning and co-construction of ideas?</td>
<td>• Transcripts of whole group consensus discussions</td>
<td>• Coding participant turns for Reasoning/Explanation • Coding participant turns for Co-Construction moves.</td>
</tr>
</tbody>
</table>
Teacher Leaders are participants during the LDA discussions, and the Teachers are participants in the Bayedge and Lakecastle discussions.

** The term Facilitators will be used then when referring to both the Lead Facilitator and Teacher Leaders’ actions.

### 5.6.1 Analysis for RQ1a and 2a

In order to answer RQ1a and 2a (What talk patterns are evident in the ways Participants interact with the Facilitators and each other?) the Classroom Discourse Analyzer (CDA) was used to help visualize the turn taking patterns or “turn depth” (explained below) of Participants and Facilitators. These patterns show how much and to what depth the facilitator is interacting with participants and if, and if so, to what depth participants are talking with each other. “Peak Graphs” visualize three kinds of turn taking patterns: (1) Teacher to single different student, (2) teacher to a single student (the same student as before), and (3) student-to-student interactions (see Figure 9). The first is a typical Initiation-Response-Evaluation (IRE) or IRF sequence such as:

\[ F-P_1-F-P_2-F-P_3-F-P_4-F-P_5 \]

Such a sequence shows a single turn per participant and could indicate interactions that where the Facilitator is asking closed questions with little room for Participants to elaborate or others to respond to that person. The second kind of turn taking patterns might look like the following:

\[ F-P_1-F-P_1-F-P_1-F-P_2-F-P_2-F-P_1-F \]

In this example, the facilitator interacts with the same participant multiple times. Such multiple turns in a row provide room for reasoning in the form of asking for elaboration, posing clarifying questions, and asking for evidence. Of course, another situation would be one where not only the Facilitator asks for elaboration or evidence but also the
Participants do, an indication of a shift in the ownership of the sensemaking to the Participants which provides them an opportunity to co-construct ideas without relying on the Facilitator.

F-P1-P2-P1-P3-F

Chen, Clarke, and Resnick’s (2015) CDA program generates visualizations of teachers’ and students’ turns and number of words through bubbles. In these “bubble graphs” the size of the bubbles indicates the number of words in a turn. In both bubble and peak graphs the y-axis shows the discussion participants and the x-axis the turns at talk.

Figure 9 shows an example output from one of the discussions.

Figure 9: Sample CDA Peak Graph

During this discussion, the facilitator used many “F-P1-F-P1” patterns (green areas). For example, between turns 3 and 9 (7 consecutive turns highlighted with Box 1) the facilitator talked with the same participant before going to another participant. During these turns the facilitator might have helped the participant clarify or expand his or her
own thinking. I consider this to be an indicator of “turn depth” (as the same speaker has several turns in a row – a deep turn – to explicate his or her idea). Later, between turns 29 and 38 (blue areas highlighted with Box 2) we see a pattern of participant-to-participant interaction in the form of F-P1-P2-P3-P4-P5-P6-P3-P6. The bubble graphs show the number and range of participants involved and the length of their turn; the bigger the bubble, the more words were spoken and the longer a participant was involved. For example, during the turns 29-39 (highlighted with Box 3) participants’ contributions were typically long (except for turn 37). The different colors of the bubbles show different participants.

For the analysis, I used the peak graphs to characterize the general pattern of facilitator and participant interaction and then used the transcripts to annotate the moves the facilitator made that preceded a series of participant-to-participant turns as well as facilitator to same participant turns (showing turn depth). I used the bubble graph to help identify places where participants were taking longer turns. I also annotated the concepts that were being discussed in each section of the discussion. Figure 10 shows an example of a CDA visualization and my annotations (in beginning the analysis) using the peak graphs.
Figure 10: Rough Analysis Using CDA Peak Graphs

These annotated Peak Graphs were then analyzed to identify patterns that emerged within and between the key discussions which was helpful in both characterizing what was happening in terms of term depth but also in identifying recurring patterns in how the Facilitators used APT Moves.

5.6.2 Analysis for RQ1b and 2b

In order to answer RQ1b and 2b (What Academically Productive Talk moves do Lead Facilitators and Teacher Leaders use? What rationale do they provide?) transcripts of the previously identified whole group consensus discussions (see Tables 3 & 6) were
coded for APT Moves and then analyzed (both qualitatively and quantitatively) for patterns for how the APT Moves were used. Additionally, the interview responses were analyzed for themes relating to what Facilitators say about why they made certain moves; thus, provided a rationale for the Facilitators’ moves. Since APT moves were a focus of the PD I wanted to see what moves were modeled by the Lead Facilitators and what moves the Teacher Leaders were using when they led their own discussions. The patterning and moves Facilitators make can be used to characterize the dialogicality of the discussion.

5.6.2.1 Coding Facilitator Turns for APT

Creswell describes coding as “the process of analyzing qualitative text data by taking them apart to see what they yield before putting the data back together in a meaningful way” (Creswell, 2015, p. 156). Qualitative coding can be thought of on a continuum from pre-set codes (a priori) to emergent or inductive codes that emerge from the data (Elliott, 2018). Elliott characterizes coding as a decision-making process where, “the decisions must be made in the context of a particular piece of research” (p. 2850) based on the research questions and the research design. She goes on to say that, “a design which tests theory against empirical data requires preset codes” (p. 2855). Using a set of a priori codes based on the literature can be helpful in beginning to make sense of large amounts of qualitative data. However, Cresswell (2015) recommends being open to emergent codes during the analysis in order to avoid narrowing the analysis, and Elliott notes that the “most pragmatic researchers will typically use both in the course of a single research project.” (p. 2855) In fact, the very act of coding which involves repeated and
careful reflection on the data builds a deep familiarity with the data that can lead to more discoveries (Elliott, 2018; Miles, Huberman, & Saldaña, 2014). Therefore, in order to answer RQ1b and RQ2b about the specific APT moves that were used in the PD (What APT moves do the Lead Facilitators and Teacher Leaders use?) transcripts were coded with a priori codes based on the four goals of APT and developed as part of the TERC Inquiry and Talk Science Projects (Michaels & O’Connor, 2012; TERC, n.d., adapted from Anderson, O’Connor, & Chapin’s, 2011 work) and which were utilized in my previous comprehensive exam study examining classroom talk. (See Appendix E for the full coding manual). The transcripts were coded using Dedoose, a qualitative data analysis software program. Goal 1 includes Share, Expand, and Clarify Moves; Goal 2 includes Listen Moves; Goal 3 includes Dig Deeper / Press for Reasoning or Evidence Moves; and Goal 4 includes Think With Others Moves. These codes were refined by working through many turns and comparing with my Discourse Coding Group. Based on this, examples and non-examples were added to the codebook. The Discourse Coding Group is made up of an author of APT and Principal Investigator for the NGSX Project, a NGSX post-doc with expertise in science and math discourse, and a Project Assistant. Additionally, researchers that are part of NGSX or those who study classroom discourse also occasionally joined the group. We worked together to develop and refine codes, to read research and to prepare conference presentations.

Early analysis of the transcripts revealed the need for an additional code, which I labeled Goal 5 – Consensus/Synthesis Moves that includes soliciting consensus with and without a summary, inviting a summary, or providing a summary. After I had identified the need for a new code to capture some of the moves that Facilitators were making,
another coder from the Discourse Coding Group and worked through multiple examples in order to develop the description and examples for these new codes.

An interrater reliability analysis using the Kappa statistic was performed to determine consistency among coders for assigning APT codes for Goals 1-5. The interrater reliability for the coders was found to be Kappa=0.84 (p<0.001), indicating outstanding agreement (Landis & Koch, 1977). All transcripts were then recoded with the updated codebook for the five APT Goals. Table 7 shows the Goals 1-5 codes and their sub-codes with examples from the transcripts.
## Table 7: APT Codes and Examples from Transcripts

<table>
<thead>
<tr>
<th>CODE</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GOAL 1: SHARE, EXPAND, AND CLARIFY MOVES</strong></td>
<td></td>
</tr>
<tr>
<td>SAY MORE</td>
<td>Okay. Can you say a little more about that? What do you mean by concentration?</td>
</tr>
<tr>
<td>REVOICE</td>
<td>So are you saying that the amount of space these take up depends on the room that they're in or the house that they're in?</td>
</tr>
<tr>
<td>THINK TIME</td>
<td>Okay. And this might be a moment where you maybe want to try to say it to the person next to you first.</td>
</tr>
<tr>
<td><strong>GOAL 2: LISTEN MOVES</strong></td>
<td></td>
</tr>
<tr>
<td>RESTATE</td>
<td>Can someone restate what she just said?</td>
</tr>
<tr>
<td><strong>GOAL 3: PRESS FOR REASONING OR EVIDENCE/DIG DEEPER MOVES</strong></td>
<td></td>
</tr>
<tr>
<td>WHY</td>
<td>Why? What-what makes that one still be able to drink out of it?</td>
</tr>
<tr>
<td>CHALLENGE</td>
<td>Well did the room decrease on its own though?</td>
</tr>
<tr>
<td>PRESS</td>
<td>So is this true for the closed system also?</td>
</tr>
<tr>
<td><strong>GOAL 4: THINK WITH OTHERS MOVES</strong></td>
<td></td>
</tr>
<tr>
<td>ADD ON</td>
<td>Does anybody want to add on to that idea?</td>
</tr>
<tr>
<td></td>
<td>So you used to word air pressure. Who can explain what she means by air pressure?</td>
</tr>
<tr>
<td>WHO EXP</td>
<td>“What do we think that means? What do you think Amalia means when she says it causes physical breakdown?”</td>
</tr>
<tr>
<td>AGREE/DISAGREE</td>
<td>Do you agree with that? Why?</td>
</tr>
<tr>
<td><strong>GOAL 5: SYNTHESIS/CONSENSUS MOVES</strong></td>
<td></td>
</tr>
<tr>
<td>SOLICIT CONSENSUS</td>
<td>Does everybody agree with that?</td>
</tr>
<tr>
<td>SOLICIT CONSENSUS WITH SUMMARY</td>
<td>So but this idea that the puppies are moving faster when that heat energy is added, is that what people-is that a ru-is that part of a rule that we wanna add?</td>
</tr>
<tr>
<td>INVITE SUMMARY</td>
<td>So to summarize, can one person just summarize why that bottle's not collapsing before we go to break?</td>
</tr>
<tr>
<td>PROVIDE SUMMARY</td>
<td>So we've got two situations here where when you make that room bigger, things spread out. And then you have less frequent hits- we have that up here, right? And we have it again here.</td>
</tr>
</tbody>
</table>
Coding was done at the turn level. Each time a new participant spoke or “took the floor” that was counted as a new turn. Their entire utterance was counted as the same turn until a new participant spoke. A turn was only coded when it contained a move that fit the description of one of the defined moves, which means that there could be turns which were not coded. For example, in this segment from Lakecastle Bottle on the Table, turns 9 and 11 were not coded because those turns did not contain an APT move (a third-turn follow up move defined as an APT).

8 Kate: Right, and so that- that's what I was thinking was then if that wall moved, based on the density- or in this case I actually drew a little grid, like okay so they all fit in the same amount of space, on either side and if you move the wall, the space is the same so there would fewer (or-more) puppies to-

9 Teacher Leader: So Richard called that-

10 Female 1: the wall on wheels?

11 Teacher Leader: The wall on wheels. the W.O.W. the, yeah, the Wall on Wheels. So we can use that language if we want to talk about the wall on wheels. So what is the wall on wheels do you think?

Within the coding categories, if more than one codable unit appeared in a turn, it was coded more than once. For example, if a turn had both a Goal 5 and Goal 1 move, then both would be noted. But, if the same move was simply repeated within a turn, it was coded only once. That is, if a Facilitator repeated the same move with the same content within one turn (for example, asking for the participant to say more – “Can you say more? Tell us a bit more?”), it was coded only once. If the Facilitator repeated the move with a different content in that turn (for example, expressed agreement with two different Teachers who had different ideas), then it was coded more than once. If a Facilitator repeated the move with the same content in a new turn, it was coded as a new
move. The excerpt in Table 8 from LDA1, Bottle on the Table shows a sample section of coded transcript:

**Table 8: Example of coded transcript**

<table>
<thead>
<tr>
<th>Chris</th>
<th>It seems like temperature is a new rule that has to be added.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Facilitator</td>
<td>Okay and does any- so it seems like in every poster I- I'm seeing move faster and harder, and more frequency. Does everybody have all three of those elements?</td>
</tr>
<tr>
<td>Sarah</td>
<td>No. We just said move faster from more heat</td>
</tr>
<tr>
<td>Lead Facilitator</td>
<td>Okay-</td>
</tr>
<tr>
<td>Sarah</td>
<td>because we think that the Air Puppy model takes care of all the other stuff.</td>
</tr>
<tr>
<td>Lead Facilitator</td>
<td>Say- say more about that-</td>
</tr>
<tr>
<td>Sarah</td>
<td>We already knew that. We already knew that the faster they move, the more they hit each other and- from- from what I thought, from what my understanding was- that we already knew that, so all that we had to say was that increased temperature means increased movement. And the rest was-</td>
</tr>
<tr>
<td>Lead Facilitator</td>
<td>Would you guys- would you agree with that, that our starter kit rule already addresses the idea of, if you're moving faster, you're hitting with more force? ...Maybe we can pull it up again- (chatter)</td>
</tr>
<tr>
<td>Sarah</td>
<td>Maybe not, maybe I never checked that. but, I think that's what we were saying</td>
</tr>
<tr>
<td>Lead Facilitator</td>
<td>Is it important to talk about the force in this- to explain this thing that's happening?</td>
</tr>
<tr>
<td>Chris</td>
<td>The bumbling and the hits?</td>
</tr>
<tr>
<td>Lead Facilitator</td>
<td>Yes say- say more about why- why is it important to have the- that that it's hitting um faster and therefore harder? Why is that an important part of- why- what we saw here?</td>
</tr>
</tbody>
</table>
The codes were used to provide frequency counts per Talk Move and Goal. Similar to many studies analyzing dialogic discourse (e.g. Lefstein, Snell, & Israeli, 2015; Vrikki, Wheatley, Howe, Hennessy, & Mercer, 2019) a frequency rate per hour was calculated for the codes for each discussion in order to be able to compare across different length discussions. This was also necessary because a turn could have more than one code applied to it. Frequency was calculated by dividing 60 min by the time of discussion in minutes and then multiplying that by the number of moves to get moves/hour. For example, a discussion that was 13 minutes long with 9 Goal 1 moves would result in a frequency count of 41 Goal 1 moves/hour. Additionally, word counts for facilitator and participant turns were calculated and used to compare the average length of facilitator turns to participant turns. This measure can give a crude indication (a proxy) of the nature of the contributions and who is positioned as having ideas to contribute.

5.6.2.2 Qualitative Analysis of Transcripts and Interviews

Frequency counts of APT moves and participation rates only provide a partial story of the use of these moves. Correnti and colleagues (2015) in their work of developing tools that measure the extent to which “students are provided with high-quality opportunities to learn in the course of classroom discussions” (p. 306) argue for looking at patterns of discourse moves: “…collections of moves are greater than the sum of their parts because they describe how students are positioned to think during discussions” (p. 309). Their construct of moves that position students towards each other and towards the content is in line with Zhang and colleagues (2011) who argue that
productive discourse involves both participant engagement and idea development. Following these suggestions, the transcripts of each discussion were analyzed qualitatively (open coding) to identify how the moves were being used to support Teacher engagement and interaction as well as idea development towards the target.

An initial immersion in the data (Rossman & Rallis, 2012) was achieved by carefully reading all transcripts of the interviews and video-taped discussions and noting emerging themes and illustrative examples from the data to support the early analysis. During this phase, the research questions were revisited to keep the analysis focused. This was followed by open coding to develop “concepts” that can then be compared and examined for how they are related (Charmaz, 2006; Strauss & Corbin, 1998). Strauss and Corbin (1998) explain that in order to be able to name these concepts the text must be “opened up” by really examining the ideas through breaking down the data into smaller parts. The general approach is to first conceptualize the data by naming phenomena in order to later be able to group similar items under a common heading (category). Charmaz (2006) states that open coding, “means categorizing segments of data with a short name that simultaneously summarizes and accounts for each piece of data” (p. 43). Open coding in this study involved several readings of the entire data set, naming concepts. These codes were then compiled onto one list and common codes and ideas grouped to identify sub-themes within the overarching themes of engagement and idea development. To challenge and refine these sub-themes, I looked for confirming and disconfirming evidence across the interviews and transcripts. During this refinement process, the sub-themes were subjected to skepticism and to conceptual and empirical testing using multiple data sources through asking questions such as: Does it make
conceptual sense? Do I see it elsewhere in the data? Are there counterexamples? Is there disconfirming evidence? (Miles, Huberman, & Saldana, 2013)

5.6.3 Analysis for RQ1c and 2c

A goal of dialogic teaching is to get participants to think with others in order to co-construct meaning. RQ1c and 2c focus on examining the ways in which participants are interacting that indicate co-construction and how the Facilitator moves are related to what the participants are doing. Two levels of coding were completed (shown in Table 8). Teacher turns were coded for indicators of co-construction of ideas (agree, disagree, ask for clarification, etc.). They were also coded for depth of response and whether their response included reasoning or explanation. Characterizing what the participants are doing is in service of characterizing whether the Participants are actively involved in sensemaking with each other and what the facilitators are doing to support the co-construction of ideas. Each analysis and the rationale for their use is described below.

5.6.3.1 Coding Participant Turns for Co-Construction

First, codes developed as part of the TERC Inquiry and Talk Science Projects (Michaels & O’Connor, 2012; TERC, n.d.) were utilized as a starting point for coding. These codes identify markers or indicators of co-construction of ideas (e.g. agree, disagree, ask for clarification, etc.). First analysis of transcripts showed participants clarifying their own idea in response to a request for clarification; a move that wasn’t part of the pre-determined moves. I labeled these moves as “Clarify Own”. Additionally, some codes were collapsed; for example, the code ‘Challenge’ was combined with ‘Ask
for Clarification’, and ‘Agree’ and ‘Disagree’ were combined to one code of ‘Agree/Disagree’.

These codes were refined by working together with another coder from the Discourse Coding Group and examples and non-examples were added to the codebook. An interrater reliability analysis using the Kappa statistic was performed to determine consistency among coders. Two transcripts from the LDA sites and two transcripts from the Teacher Leader sites were selected for coding to get a representative sample and the first 25 turns of each were coded for Participant turns that included co-construction (1) or no co-construction (0). The interrater reliability for the coders showed substantial agreement (Landis & Koch, 1977) with Kappa=0.65 (p<0.001). Then all transcripts were recoded with the new codebook. Table 9 shows the Participant Co-Construction codes and their sub-codes with examples from the transcripts.

**Table 9: Participant Co-Construction Codes**

<table>
<thead>
<tr>
<th>Code</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGREE/ DISAGREE</td>
<td>I agree with this um the collisions. I'm not sure I agree with the (spacing).</td>
</tr>
<tr>
<td>ASK FOR CLARIFICATION</td>
<td>Can you try and say more (...) like if.. um.. things were different like that we could end up squishing not just the sides of the bottle but also the bottom to the top, is that kinda what you're getting at?</td>
</tr>
<tr>
<td>RESTATE OR CLARIFY OTHER</td>
<td>What I hear Laura struggling with is something that I think is worth exploring a little, which is how is it if there are so many more air puppies outside.. this bottle, that it's not more pressure outside?</td>
</tr>
</tbody>
</table>
And to piggy back on that I'm also thinking ratios. So there'd have to be (...) of a space to molecules ratio-

Right when I- when I drew it as analogous, I drew it floating in the center because the forces are all equal. So it was- there was no top or bottom in-in my drawing.

Coding followed the same approach described above for coding Facilitator turns (e.g. coded at turn level, only coded turns if it had a co-construction move, etc.). The excerpt in Table 10 from Lakecastle, Bottle on the Table shows a sample section of coded transcript:

Table 10: Sample transcript coded for co-construction

<table>
<thead>
<tr>
<th>Turn</th>
<th>Speaker</th>
<th>Text</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>Kate</td>
<td>I want to go back to what Meredith said but I don't really understand (but) um, mostly, I don't understand if your thinking is different that this or not. Can you explain again?</td>
<td>Ask for clarification</td>
</tr>
<tr>
<td>48</td>
<td>Meredith</td>
<td>you want me to explain again? So, I was just thinking of it as this is an object, just like any other object in this room like that chair, that's not moving, and that the air particles around it are all even and moving at the same speed and bumping into that and not allowing that to change.</td>
<td>Clarify own</td>
</tr>
<tr>
<td>49</td>
<td>Kate</td>
<td>So where do you think the wall on wheels is?</td>
<td>Ask for clarification</td>
</tr>
<tr>
<td>50</td>
<td>Meredith</td>
<td>I think that's the wall on wheels.</td>
<td>Clarify own</td>
</tr>
<tr>
<td>51</td>
<td>T</td>
<td>Which? Can you be more specific about what that is?</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Meredith</td>
<td>The bottle (points)</td>
<td>Clarify own</td>
</tr>
<tr>
<td>53</td>
<td>Patty</td>
<td>So you think the whole bottle hasn't moved over there, over here because- (many- Oh!-Okay-nodding). Where I'm thinking the inside has to be the</td>
<td>Restate or clarify other</td>
</tr>
</tbody>
</table>
same or the whole thing would get smushed in together.

| 54 | Betsy | I think the difference between a bottle and like a chair, is that the bottle has space inside it where there- where we can assume that there's air. So, because air can't get out of that bottle right now, because it's sealed, just like in the air puppies model, the puppies couldn't move from one section to another. The air in the room can't get out of the bottle, the air in the bottle can't get into the room. So that's why the structure of the bottle, including the cap is the wall on wheels. | Add on |
| 55 | T | So they're effectively separated? |
| 56 | Betsy | Yes. | Clarify own |

5.6.3.2 Coding Participant Turns for Depth of Response.

Examining both the length and substance of participant responses can be used to characterize the talk that is happening in relation to what the Facilitator is doing. Since a focus of APT is helping participants reason or make meaning through the talk, a coding scheme based on the coding scheme from Pimental and McNeill’s (2013) study on classroom discourse in secondary classrooms was used. Similar to this study, Pimental and McNeill (2013) were interested in how teachers support science talk where students are actively involved in the sensemaking. Their coding scheme looked at student contributions, and in particular the depth of response and whether their response included reasoning or explanation. Their original coding scheme is included in Table 11 below.
Following an iterative analysis of the transcripts (Miles & Huberman, 1994) using this coding scheme, the codes were refined by working through many turns and comparing with a member of my Discourse Coding Research Group; examples and non-examples were added to the codebook (see Appendix G). Because all responses are part of the co-construction of ideas, the revised codebook eliminated Code 0. In order to indicate that the codes are for Participant turns (versus the Facilitators), they are labeled P1-P3. Table 12 shows the codes, their definitions and examples from the transcripts.

**Table 12: Participant Reasoning or Depth of Response Codes**

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3</td>
<td>The contribution includes a complete thought which resembles a sentence and includes an explanation of his/her thinking OR explains someone else’s reasoning, model, or representation.</td>
<td>Um, I assume kind of the-the frequency of collisions was the same on the inside and outside, or both rooms, even if the like actual number of air puppies wasn't the same, so kinda distributed evenly.</td>
</tr>
</tbody>
</table>
Often includes linguistic markers like “because”, “so”, “if,” or “that’s why”, or “that” that indicate the presence of reasoning.

So, if you imagine a three dimensional box, the bottle was not on the top or the bottom the bottle was in the center. It was suspended.

<table>
<thead>
<tr>
<th>P2</th>
<th>The contribution includes a complete thought which resembles a sentence but no explanation of his/her thinking is included.</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>When I- when I drew it in my notebook, I drew it... floating. I drew the bottle in the center of...the air puppies box.</td>
</tr>
<tr>
<td>P2</td>
<td>There's more air puppies in space than there are in this bottle.</td>
</tr>
</tbody>
</table>

The contribution consists of a word or phrase only.  

Heavier walls.  

Yeah.  

The container- the... plastic

Coding was done at the turn level with each Participant turn getting a P1, P2 or P3. Only one P1-P3 code could be applied to each turn. The excerpt below from LDA2, Soap Bubble shows a sample section of coded transcript.

**Table 13: Sample transcript coded for P1-P3**

<table>
<thead>
<tr>
<th>76</th>
<th>Facil</th>
<th>They're slower when they cool down. Now the discussion that wa-that I heard a lot at the tables was okay so if they're moving faster are they hitting harder or more frequently or both? So we can talk about that for a minute but, what did-what-what were your discussions there?</th>
</tr>
</thead>
<tbody>
<tr>
<td>77</td>
<td>M.L.</td>
<td>I think both.</td>
</tr>
<tr>
<td>78</td>
<td>Jen</td>
<td>Both.</td>
</tr>
</tbody>
</table>
5.6.4 Analysis for RQ3

Finally, for RQ 3 (*How does the facilitation of these whole-group consensus discussions by the Lead Facilitators compare to the Teacher Leaders’ enactment of the same discussions?*) I examined how the facilitation of the same discussions compared between the Lead Facilitators and the Teacher Leaders. The analysis of data for each research question described above provided outputs (e.g. APT counts, interaction patterns) that were compared between sites (Lead Facilitator sites and Teacher Leader sites) and how Teacher Leader moves compared to the LDA sites.

5.7 Trustworthiness of Data

Lincoln and Guba (1985) identify four ways to help establish trustworthiness in qualitative studies: credibility (confidence in the truth of the findings), transferability (applicability in other settings), dependability (findings are consistent and could be repeated), and confirmability (findings emerge from the data and not personal bias) (D. Cohen & Crabtree, 2006; Lincoln & Guba, 1985; Shenton, 2004). Credibility can be
established with such techniques as prolonged engagement, triangulation, peer debriefing, and member checking (D. Cohen & Crabtree, 2006; Lincoln & Guba, 1985; Rossman & Rallis, 2012; Shenton, 2004). In this study, I worked to establish credibility and dependability by utilizing debriefing sessions with my Discourse Coding Research Group in order to select and refine codes, analyze subsets of the discussions using the codes and other measures, and share initial findings. Additionally, the codes were refined iteratively (Glaser & Strauss, 2009) through a process of individually coding the same transcript, comparing coding results with a member of the group, talking through and resolving disagreements in coding, and adding new codes to capture other elements observed not already in the Talk Moves Codebook (Appendix E) or codes that needed revision. Additionally, I ensured dependability through an interrater reliability analysis using the Kappa statistic to determine consistency among coders, which revealed substantial to outstanding agreement (Landis & Koch, 1977).

Member checks, that support credibility and confirmability involved sharing initial results and preliminary interpretations with the other Lead Facilitator and the Teacher Leaders. Their reaction and any possible interpretations or reasons for emergent data were used in refining themes from the qualitative analysis of the transcripts. These member checks helped limit researcher bias.

Triangulation in qualitative data is used to “ensure that an account is rich, robust, comprehensive and well-developed” (D. Cohen & Crabtree, 2006) and to help “ensure that you have not studied only a fraction of the complexity you seek to understand” (Rossman & Rallis, 2012, p. 65). The different data sources (videotaped discussions, interviews, observation notes), different foci of data analysis (examining the discussions
from different angles such as APT moves, interaction patterns, and nature of Participant contributions), Facilitators’ perceptions of why they made certain moves, and looking at multiple discussions across groups provided a rich understanding of what leading these discussions entails, and how the discussions compared between Lead Facilitators and Teacher Leaders; thus providing a more complete picture of the phenomenon.

Finally, as one of the Lead Facilitators for the PD I needed to be careful to acknowledge and reflect upon my role and position as researcher and how this might have impacted my observations. My involvement with the development of the Facilitator Pathway and my experience with APT and leading whole group discussions could have clouded (or shaped) my observations. Additionally, since I was analyzing discussions that were led by me, I needed to utilize methods to manage this dual role. I sought to manage this by using member checks with other researchers in the Discourse Coding Research Group and with the Teacher Leaders, and regular analytical memos while doing the analysis to track any moments of how I was feeling about this dual role (researcher and Lead Facilitator).

Beyond the challenges posed by my dual role, there was a risk of participant reactivity or observer effect where the participant’s behavior may have changed due to the presence of the researcher or of a video camera. I sought to minimize this through language used to explain the research project as well as working to develop co-membership (Rossman & Rallis, 2012). The informed consent for this study stressed that participants were not being evaluated and stated generally, that video would be collected to “understand how teachers, coaches, and administrators perceive the ideas in NGSS and the challenges in bringing NGSS into classrooms. The findings will help inform the
design of more effective professional development programs”. By being transparent about the purpose and emphasizing that the observations were non-evaluative, I hoped to establish a more comfortable experience when present. As one of the PD leaders I spent a considerable amount of time with the Teacher Leaders during the NGSX Teacher and Facilitator Pathways. Additionally, I was also charged with providing support for the Teacher Leaders as they implemented their study groups. This included meetings ahead of time to help them plan, being available via phone and e-mail, and being present to answer questions and support them on-site when they facilitated their groups. This support, our shared interest of improving science instruction, and the lack of an evaluative role may have helped build co-membership where the researcher and the participants find a common ground as well as reciprocity where there is some level of mutual benefit for all parties (Rossman & Rallis, 2012). This reciprocity which includes sharing the results of this study and sharing tools and strategies that inform their own practice may have helped reduce the potential “unequal power relationship” (Rossman & Rallis, 2012) often found between the researcher which may have helped minimize the participant reactivity.
CHAPTER 6
RESULTS: LEAD FACILITATORS

In this chapter I will share the results for Research Question 1 (What are the characteristics of talk when Lead Facilitators enact whole-group consensus discussions with Teacher Leaders during science PD?). I examined two cohorts of Leadership Development Academies (I will refer to these as LDA1 and LDA2). During these LDAs, the Teacher Leaders engaged in the NGSX Teacher Pathway and the Facilitator Pathway led by the Lead Facilitators.

I will begin with an examination of the interaction patterns between and among the Teacher Leaders and the Lead Facilitators (RQ1a). LDA discussions were marked by multiple Teacher Leader turns, both in quantity and in the number of different Teacher Leaders involved. There were many Teacher Leader to Teacher Leader interactions across all discussions as well as frequent segments where the Lead Facilitator would stay with the same Teacher Leader for several turns before opening up the discussion. I will provide examples of these interaction patterns using the CDA Peak Graphs.

I will then share the results around what APT moves Lead Facilitators use, how they use them, and the rationale they provide (RQ2a). APT moves were used extensively in all discussions and I will share results for which APT moves were being used, including the new category of Goal 5 moves identified in the emergent analysis of these LDA groups. Since frequency counts of APT moves only provide a partial story of the use of APT moves, I will share the themes that emerged from the qualitative analysis around supporting Teacher Leader engagement and idea development.
This will be followed by the results of what the Teacher Leaders are doing in terms of reasoning and co-construction of ideas (RQ3a). Teacher Leaders (as part of the LDAs, where they were Participants) made many attempts at co-constructing ideas with their peers across all three discussions and their turns often included reasoning or explanation. Rationale for the Lead Facilitators’ moves provided in the interviews will be included throughout to add nuance to my findings of the patterns that emerged.

6.1 Interaction patterns

The number of Lead Facilitator and Teacher Leader turns and words per turn can give a crude measurement of the nature of the contributions and who is positioned as having ideas to contribute. Figures 12 shows the results for mean number of turns.

![Mean Number of Turns at LDA Sites](image)

**Figure 11: Mean Number of Turns for Teacher Leaders and Lead**

The number of Teacher Leader turns (average of 91) far outweighed the number of Lead Facilitator turns (average of 46) for all three discussions. This points to Teacher Leaders being positioned to contribute. However, only in the Bottle on the Table
discussion did Teacher Leaders have longer turns (37 words) on average than the Lead Facilitators (27 words). Particularly for the Biggest Sucker discussion, the Lead Facilitator turns, while much less frequent, were longer on average (33 words) than Teacher Leader turns (20 words). A closer examination of the substance of those turns is needed to understand the nature of those contributions and is included in the following sections.

Another low inference measure of Teacher Leader interaction is the number of Teacher Leaders who contributed in a particular discussion. Getting as many Teachers involved in the discussion as possible is important since a goal of these discussions is for all Teachers to develop understanding and co-construct ideas. Figure 12 shows the percentage of Teacher Leaders who took at least one turn for each of the discussions.

![Figure 12: Percentage of Teacher Leaders Who Took at Least One Turn for Each Discussion](image)
These discussions were marked by high participation rates with over 80% of Teacher Leaders contributing to all but one discussion.

Another way to examine the interactions between Lead Facilitator and Teacher Leader and Teacher Leader to Teacher Leader interaction is to look at the turn taking patterns or “turn depth”. This low inference measure may show how much the Lead Facilitator is interacting with Teacher Leaders and getting them to dig deeper with their ideas as well as how she is supporting them in interacting with each other. One way to visualize the sequence of a discussion is by looking at the pattern of Lead Facilitator and Teacher Leader turns. I used the Classroom Discourse Analyzer (CDA) (Chen, Clarke, & Resnick, 2015) to visualize the sequence of a discussion by looking at the pattern of Lead Facilitator and Teacher Leader turns. In particular, I analyzed the CDA “Peak Graphs” that help visualize three kinds of turn taking patterns: 1) Lead Facilitator to single different Teacher Leader (orange), 2) Lead Facilitator to a single Teacher Leader (green), and 3) Teacher Leader to Teacher Leader interactions (blue). The bubbles represent the speaker (size of bubble shows length of turn) and align with the peak graph. Figure 13 provides guidance for how to read a CDA peak graph.
Teacher Leader to continue evaluative continue” move such as “okay” or “mmhmm” which made space for the discussed below with examples to illustrate the patterns. Facilitator and different Teacher Leaders in a row was seldom used. Each will be Leader interactions. The m Additionally, the discussions were characterized by extensive Teacher Leader to Teacher Leader interactions. The more traditional sequence of back and forth between Lead Facilitator and different Teacher Leaders in a row was seldom used. Each will be discussed below with examples to illustrate the patterns.

6.1.1. Working with the same Teacher Leader.

In each discussion, the Lead Facilitators used moves to stick with the same Teacher Leader for more than one turn. In some cases the Lead Facilitator used a “non-evaluative continue” move such as “okay” or “mmhmm” which made space for the Teacher Leader to continue but did not evaluate the idea. Additionally, the Lead

Figure 13: Sample CDA Peak Graph with Guidance for Each Element

Analysis of the peak graphs revealed that the Lead Facilitators stuck with the same Teacher Leader for multiple turns to clarify or dig deeper into their ideas. Additionally, the discussions were characterized by extensive Teacher Leader to Teacher Leader interactions. The more traditional sequence of back and forth between Lead Facilitator and different Teacher Leaders in a row was seldom used. Each will be discussed below with examples to illustrate the patterns.
Facilitators used APT moves such as “say more” or revoicing moves during these exchanges. These exchanges where the Lead Facilitator stays with a Teacher Leader can be seen in green on the peak graphs. For example, in LDA 2 Bottle on the Table, we see two segments where the Lead Facilitator stayed with the same Teacher Leader to uncover their thinking.

![Peak Graph Showing Lead Facilitator to Same Teacher Leader Turn, LDA 2 Bottle on the Table](image)

Similarly, in Biggest Sucker, Cohort 2 we see multiple exchanges with the same person for two or three turns.

![Peak Graph showing Lead Facilitator to same Teacher Leader, LDA 2 Biggest Sucker](image)

Staying with the same Teacher Leader allows the Teacher Leader to take a longer, connected, multi-part turn. I refer to this as “turn depth” and it can mark places where the Lead Facilitator is pressing for reasoning in the form of asking for elaboration, posing clarifying questions, and asking for evidence. In almost all cases, the Lead Facilitators
would open the discussion up for others to respond to the idea that was just uncovered for others to respond to.

6.1.2 Teacher Leader to Teacher Leader interaction.

One goal of these discussions was Teacher Leaders talking to each other during the co-construction of ideas. Moments of turn depth described above were often followed by long Teacher Leader to Teacher Leader exchanges with little or no Lead Facilitator interjection. This can be seen in the blue for the peak graphs shown both above and below. For example, returning to the LDA 2 Bottle on the Table, we see multiple exchanges in blue that indicate Teacher Leaders engaging with each other:

![Figure 16: Peak Graph showing Teacher Leader to Teacher Leader exchanges, LDA 2 Bottle on Table](image_url)

For example, between turns 29 and 37 (blue areas) we see a pattern of Teacher Leader to Teacher Leader interaction (annotated with TL4-TL5-TL6, etc.) where eight different Teacher Leaders spoke. Their turns were long as indicated by the large bubble size;

115
Teacher Leaders directly referenced others’ ideas and, after a Teacher Leader voiced confusion, offered multiple different ways to think about the phenomenon. There were talking directly to each other without the Lead Facilitator being involved. Another typical example is Biggest Sucker, Cohort 1 where we see multiple sections of blue that mark these interactions.

Figure 17: Peak Graph Showing Teacher Leader to Teacher Leader Exchanges, LDA 1 Biggest Sucker

All of the discussions showed many such episodes where Teacher Leaders spoke to each other without the Lead Facilitator interjecting. This is in contrast to a more typical IRE exchange where the discussion goes back and forth between the Lead Facilitator and Teacher Leader.

6.1.3 Lead Facilitator and different Teacher Leaders.

Exchanges between the Lead Facilitator and different Teacher Leaders in the form of LF-TL1-LF-TL2 marked by orange in the peak graphs could indicate places with a more traditional IRE exchange. These segments were limited as you can see in the above examples. Orange sections often involved the Lead Facilitator working with the group to capture on paper what they had just discussed and agreed upon. An example of such an exchange is shown below; between lines 93-102 in the LDA 1 Biggest Sucker:
This back and forth exchange can also be seen in LDA 2 Biggest Sucker between turns 106-121 (see Figure 15), when trying to synthesize and capture what the group agreed upon.

Figure 18: Peak Graph Showing Lead Facilitator to different Teacher Leader Exchanges, LDA 2 Biggest Sucker

While this segment did feature the Lead Facilitator speaking after each Teacher Leader, this exchange involved multiple APT moves including Goal 1 revoicing moves as well as
Goal 5 synthesis moves and, was focused on synthesizing the ideas the group was in consensus about. It did not include IRE exchanges where the Lead Facilitator was posing a known answer question and then phishing for the “right” answer.

In summary, the Lead Facilitator discussions were marked by multiple Teacher Leader turns, both in quantity and in the number of different Teacher Leaders involved. The Lead Facilitators frequently stuck with the same Teacher Leader for two or more turns in order to dig deeper into their thinking often followed by long Teacher Leader to Teacher Leader exchanges (often where the ideas that were developed through turn depth were taken up by the group). All discussions involved multiple Teacher Leader to Teacher Leader exchanges where the Teacher Leaders were working with each other’s ideas without Lead Facilitator intervention, providing opportunities for Teacher Leaders to co-construct ideas together with the Lead Facilitator acting as a guide. In the following sections I describe what moves the Lead Facilitators used to support these patterns of interaction.

6.2 Academically Productive Talk Moves

Lead Facilitators used APT moves at an average rate of 83 APT move/hour across cohorts and discussions. The Biggest Sucker discussion had the highest rate of APT Moves (average of 122 moves/hour) with a marked difference in rate compared to the other discussions, particularly for Lead Facilitator Cohort 2. The total APT moves expressed as a rate/hour for each of the three discussions are shown in Figure 20.
Figure 19: Lead Facilitator’s Use of APT Moves

Because a turn could have more than one code, including more than one APT code, rates were used in order to be able to compare across discussions and Lead Facilitators. Additionally, a look at what percentage of turns included an APT move is also helpful in characterizing the use of these moves. Figure 21 shows the percentage of Lead Facilitator turns that include at least one APT Move.
Figure 20: Percentage of Lead Facilitator Turns Containing At Least One APT Move Across Discussions

APT moves were used in 50%-80% of Lead Facilitator turns with the fewest used in the Soap Bubble discussion. One explanation for this decrease in use of APT moves is the fact that it is the third whole group consensus discussion that happens two days into professional development where Teacher Leaders have had a chance to practice these discussions and develop a group culture and might, therefore, be more readily working with and digging into ideas on their own. A closer examination of what is happening as we progress through the discussions as well as what other moves the Lead Facilitator is making (besides APT moves) will be discussed in a later section.
6.2.1 APT Moves by Goal

An examination of which APT moves were being used is helpful in broadly characterizing the use of APT moves in the discussions. A breakdown of average moves per APT goal across the discussions and cohorts for the Lead Facilitators is shown in Figure 21.

![Lead Facilitators Use of APT Moves by Goal](image_url)

**Figure 21: Average APT Moves by Goal for Lead Facilitators**

Lead Facilitators used many Goal 1, Goal 3, Goal 4, and Goal 5 moves across discussions. Goal 2 moves (supporting participants to listen closely to each other) were less commonly used. There were some marked differences in the use of Goal 5 and Goal 1 moves in the biggest sucker discussions which is consistent with the finding that there were more APT moves used overall in that discussion. I will show results for each of the Goals with examples to illustrate their use.
• **Goal 1 Moves.** Moves to help Teacher Leaders go public with their ideas (Goal 1) were used in all discussions. Revoicing (54%) and Say More (40%) moves were the most frequently used Goal 1 moves and varied by LDA with LDA1 using more say more moves and LDA2 using more revoicing moves. Patterns of how these moves were used regarding what preceded or followed and what happened as a result will be discussed in the next section.

• **Goal 2 Moves.** Goal 2 Moves centered around helping Teacher Leaders listen to each other by asking for someone in the group to restate what someone else said were used minimally in both LDA groups (3 Goal 2 moves/hour or 4% of total APT moves used). These moves were found in four out of six discussions and were used after a long or complex Teacher Leader turn or after a long series of Teacher Leader to Teacher Leader turns. For example, in Lead Facilitators Cohort 2 during the Biggest Sucker discussion we see the following exchange:

  **Patty:** So on the bottom of the wa- th-the air puppies.. are- because the..- some of the air puppies at the top are being released into your mouth, into that room, so they're be- there's les- there's less collision happening on top cause the room is bigger. And there's more collision happening at the bottom, and so- and in the other room, and so it's pushing that wall up.

  **Lead Facilitator:** What do people think of that idea? Can somebody else restate it? What-what's she saying about this room changing- room- are you talking about room.. B?

  **Patty:** I'm talking about, yeah, yes.

  **Louise:** So I think what she's saying is that room B is getting bigger by you.. adding your mouth, your lungs, to that room so that room B is bigger so the puppies- same number of puppies but much more space to bumble around in, are gonna have fewer hits against the wall-
Additionally, restate moves were used following a long Teacher Leader to Teacher Leader exchange. For example, during the LDA 1 Soap Bubble the restate move was used after a 20-turn exchange that involved 10 different speakers.

- **Goal 3 Moves.** Moves to help Teacher Leaders dig deeper (Goal 3) were consistently used across discussions for LDA 1 and used most with the Biggest Sucker for LDA2. Press moves that asked Teacher Leaders to dig deeper into their own reasoning, explanations, and models were the most used Goal 3 move (51%). For example, in LDA 2 Bottle on the Table, Deanna presses for more reasoning around the wall on wheels.

  **Janice:** I think it does represent the wall but I think it's different from the wall- (this wall) because it's not.. perfectly- it's not frictionless, it's more stiff and has um.. uh more resistance to that pressure, I think.

  **Lead Facilitator:** But what quality of the bottle, of that is enabling you to think that it is the wall on wheels in the first place? Even if it is different than that?

Challenge moves that offer or ask for a counter example or challenge an idea (e.g. “So is there elasticity in this bubble, though?” Soap Bubble, LDA1) were also used, particularly in the Biggest Sucker discussion for LDA2.

- **Goal 4 Moves.** Moves to help Teacher Leaders reason with others (Goal 4) were used across lessons but most consistently with the Bottle on the Table Discussion that happens early in the PD. Of the Goal 4 moves used, the majority (79%) were add-on moves that invited participation from others to join in and respond to someone else’s idea with the remaining 21% of Goal 4 moves soliciting agreement or disagreement.

- **Goal 5 Moves.** A new category of moves and their associated goal of helping Teacher Leaders synthesize the ideas being discussed and come to consensus
emerged from the data analysis and were named Goal 5 moves. Based on their frequency these moves seem to play an important role in the discussions, particularly the Biggest Sucker discussion. Goal 5 moves included moves to either solicit or summarize what the group is in agreement on (or not). Over 70% of Goal 5 moves used by Lead Facilitators across cohorts were moves to solicit consensus and half of those included the Lead Facilitator synthesizing some or all of what is agreed upon or where there is disagreement and then soliciting consensus. For example, during LDA 2 Soap Bubble, the Lead Facilitator summarized the idea being discussed and then asked if the group was in consensus regarding this idea as a new rule about how air molecules behave.

Formulas? Sort of-so taking that and putting it in a different kind of representation. So but this idea that the puppies are moving faster when that heat energy is added, is that what people-is that a ru-is that part of a rule that we wanna add?

Goal 5 moves that offered or invited a summary for what was agreed upon made up close to 30% of the moves. For example, during Bottle on the Table, cohort 2 the Lead Facilitator invited the Teacher Leaders to summarize what has been agreed upon:

So.. what- um, at this point I think we ought to wrap up and we would love to have someone sort of try to articulate..- just summarize for us why it is that the bottle is not crushing with all this outside air pushing on it. And Renee's gonna type it up for us.

This is in contrast to moves where the Lead Facilitator summarized where the group was at that point in the discussion as in this example during the LDA 2 Biggest Sucker:
So it sounds like.. we have a fair amount of agreement about what's going on here. We still have some- or we're raising some more questions about the role of gravity in here, the role of the weight of the water. We keep coming back to the material of the container, right, like can you have more pressure on the outside just because of the rigidity of the material that doesn't collapse, right? So even though we're saying that there's sort of equal hits on either side because nothing's moving, maybe there could be a difference, and still (have) no movement. Those are some questions we still have.

These Goal 5 moves will be discussed further in the themes regarding how these goal 5 moves are used.

- **Other Lead Facilitator moves.** In addition to APT moves, teacher turns were coded for wait time, defined as pauses that are 3 seconds or longer. For the Lead Facilitators, wait time ranging from 3-10 seconds and occurred before, during, and after Teacher Leader turns was utilized in all discussions. An example of wait time is the exchange below from LDA2 Bottle on the Table. After two Teacher Leaders shared ideas the Lead Facilitator used wait time to allow other voices to participate in the discussion.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 15: Sample Transcript, Other Lead Facilitator Moves</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mary</td>
<td>I'll start. I-I see the bottle as um inside the bottle could be room A, and the walls.. of the bottle is the sliding.. wall on wheels, and then the outside would be room B.</td>
</tr>
<tr>
<td>5</td>
<td>Lead Facilitator</td>
<td>The outside.. say a little more about the outside, you mean the outside air around-</td>
</tr>
<tr>
<td>6</td>
<td>Mary</td>
<td>The air outside it, and-and not out there, not here, but just directly around what-what's able to hit it.</td>
</tr>
<tr>
<td>7</td>
<td>Lead Facilitator</td>
<td>Okay.</td>
</tr>
<tr>
<td>8</td>
<td>Mary</td>
<td>And bounce off.. the wall. So I would..do you want me to continue? or leave it at that-</td>
</tr>
<tr>
<td>9</td>
<td>Lead Facilitator</td>
<td>Um yeah hold on one sec. Does- is anybody have a different idea about where room A, room B, and the wall are?</td>
</tr>
</tbody>
</table>
Jasmine: I was wondering if room B could just be this box that we're sitting in, this room. (Because the doors are closed).

Lead Facilitator: (4 second pause) (...) are we comfortable with that? We'll call this room A- well whichever (...). One room is this whole room, and the other room we'll say is inside the bottle, okay? And the wall was what?

In reflecting on this segment Deanna discussed the importance of wait time, even though it can feel uncomfortable in the moment:

Because if I were to jump in really quickly, [snaps] then it shuts down the, the learning for everybody else there. They have to think hard about whether they do or don't agree. Once you ask the question you gotta give them time to think about that.

Wait time was also used within Teacher Leader to Teacher Leader exchanges such as in the segment in LDA 2 Soap Bubble

<table>
<thead>
<tr>
<th>Turn</th>
<th>Speaker</th>
<th>Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>Jesse</td>
<td>It makes me wonder how significant that is knowing that air puppies are so-so little (Audrey: right)</td>
</tr>
<tr>
<td>100</td>
<td>Cindy</td>
<td>That's what I've been thinking about.</td>
</tr>
<tr>
<td>101</td>
<td>Lead Facilitator</td>
<td>Is it significant in this phenomenon?</td>
</tr>
<tr>
<td>102</td>
<td>Audrey</td>
<td>Yes. [4.5-second pause]</td>
</tr>
<tr>
<td>103</td>
<td>Tara</td>
<td>Something I think about though is, we're also talking about like on average, when you look at the simulation there's--there's molecules that are moving super fast, and there's always that super super slow molecule so it--(others: mmh) so it's all about an average number of hits and an average speed or possibly one or the other-</td>
</tr>
<tr>
<td>104</td>
<td>Lead Facilitator</td>
<td>So we're saying on average it's hitting harder and more frequently</td>
</tr>
</tbody>
</table>

In this case, the wait time used in turn 102 allowed someone other than the Lead Facilitator to respond, making space for Tara to take a rather lengthy turn that was focused on the target science ideas.
In summary, Lead Facilitators used APT moves at a high rate across the discussions with a high rate of Goals 1, 3, 4, and 5 moves. However, these frequency counts of APT moves only provide a partial story of the use of these moves and do not reveal the context of their use nor how those moves might have been related to Teacher Leader responses. I therefore analyzed the transcripts and the use of these talk moves qualitatively looking for any patterns in their use and how they support Teacher Leader engagement and idea development.

6.2.2 Patterns in how the APT Moves were used

The goal of these discussions is conceptual growth where meaning is co-constructed. This involves supporting broad participant engagement both with each other and with scientific concepts, practices, and crosscutting concepts. Two main themes emerged regarding how APT and other moves are being used to support collaborative knowledge building around target concepts:

1. supporting engagement and broad participation
2. maintaining focus and direction.

Findings from the qualitative analysis showed that Lead Facilitators intentionally used APT moves to support Teacher Leader engagement with target concepts by “setting the table” (described below) and opening up the discussion to others. They supported idea development by maintaining focus and direction around key ideas through a series of episodes involving clarifying and digging deeper into ideas, opening the discussion to others, and helping to synthesize or focus the discussion back towards focal ideas.
6.2.2.1 Theme 1: Using moves to support Teacher Leader engagement and participation.

A recurrent pattern in the discussions led by Lead Facilitators involved multiple segments that used moves to open up the discussion by soliciting multiple ideas, multiple voices, and/or depth of an idea followed by moves. These segments were often followed by the use of moves that will be discussed in Theme 2 that help the group focus on, converge on, and/or come to consensus on ideas. Within theme 1 there were two patterns in the ways that moves were used: digging deeper into ideas in order to “set the table” for others to work with the ideas and using moves to open up the discussion.

Table 17: Theme 1 Sub-Themes and Description for How APT Moves Were Used.

<table>
<thead>
<tr>
<th>Theme 1: Using moves to support Teacher Leader Engagement</th>
<th></th>
</tr>
</thead>
</table>
| “Setting the table”- digging deeper before opening up    | ● Goal 1, 2, 3 Moves  
|                                                          | ● Stick with the same Teacher Leader for several turns  
|                                                          | ● Led to multiple turns of Teacher Leader to Teacher Leader exchanges |
| Using Moves to open up the discussion to other Teacher Leaders and ideas | ● Goals 2, 4, and wait time  
|                                                          | ● Made space for alternative ideas.  
|                                                          | ● Followed moves that “set the table” |

6.2.2.1.1 Setting the table.

Lead Facilitators used Goal 1, Goal 2, and Goal 3 moves to help clarify or dig deeper into an idea before opening it up to the group. In this way, these moves helped surface or clarify an idea so that others could work with it, thereby “setting the table” for productive discussion. Often this happened during a multiple turn exchange with the same Teacher Leader. For example, during LDA 1 Soap Bubble, the Lead Facilitator stuck with
the same Teacher Leader, Sarah, for four turns using non-evaluative continue, say more, and challenge moves to uncover ideas about what is happening when air particles heat up. Once those ideas were uncovered the Lead Facilitator opened it up for another Teacher Leader to say more about that idea (turn 14 below).

**Table 18: Sample Transcript, Setting the Table**

<table>
<thead>
<tr>
<th>Turn</th>
<th>Participant</th>
<th>Statement</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Chris</td>
<td>It seems like temperature is a new rule that has to be added.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Lead Facilitator</td>
<td>Okay and does any- so it seems like in every poster I- I'm seeing move faster and harder, and more frequency. Does everybody have all three of those elements?</td>
<td>Goal 5</td>
</tr>
<tr>
<td>5</td>
<td>Sarah</td>
<td>No. We just said move faster from more heat</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Lead Facilitator</td>
<td>Okay- Non-evaluative continue</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sarah</td>
<td>because we think that the Air Puppy model takes care of all the other stuff.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Lead Facilitator</td>
<td>Say- say more about that- Goal 1-say more</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Sarah</td>
<td>We already knew that. We already knew that the faster they move, the more they hit each other and- from- from what I thought, from what my understanding was- that we already knew that, so all that we had to say was that increased temperature means increased movement. And the rest was-</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Lead Facilitator</td>
<td>Would you guys- would you agree with that, that our starter kit rule already addresses the idea of, if you're moving faster, you're hitting with more force? ..Maybe we can pull it up again- (chatter) Goal 4-agree/disagree</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>Maybe not, maybe I never checked that. but, I think that's what we were saying</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Lead Facilitator</td>
<td>Is it important to talk about the force in this- to explain this thing that's happening? Goal 3-challenge</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Chris</td>
<td>The bumbling and the hits?</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Lead Facilitator</td>
<td>Yes say- say more about why- why is it important to have the- that that it's hitting um faster and therefore harder? Why is that an important part of- why- what we saw here? Goal 1-say more</td>
<td></td>
</tr>
</tbody>
</table>
The exchange that followed this segment involved 11 different Teacher Leaders speaking for over 20 turns before the Lead Facilitator spoke again (using a Goal 2-’who can restate’ move). During this exchange, Teacher Leaders agreed and disagreed with each other, asked for clarification, posed questions to challenge ideas, and provided analogies and examples from the real world with a specific focus on whether the air particles are pushing with more force when they heat up. This set of moves of serves to “set the table” by helping to clarify ideas first before opening it for the group to work with. This was a common pattern across discussions. Figure 16 shows this pattern in the CDA peak graphs from the LDA1 Soap Bubble discussion just discussed.

![Figure 16: Annotated CDA peak graph for LDA1 Soap Bubble](image)

In this case, in addition to sticking with the same Teacher Leader for several turns to clarify an idea (turns 3-14), at the end of this long exchange, the Lead Facilitator solicited others to help clarify ideas by using a Goal 2, restate move in turn 14. This set-up led to a long Teacher Leader to Teacher Leader exchange discussing the idea that was uncovered prior.
In another example during LDA 2 Soap Bubble, Teacher Leaders were discussing why the bubble eventually stops growing when the bottle is placed in the hot water. The Lead Facilitator started by asking the group to restate an idea that a Teacher Leader shared. The Lead Facilitator then checked back with the original speaker and then revoiced the idea in two different turns:

**Table 19: Sample Transcript, Setting the Table 2**

<table>
<thead>
<tr>
<th></th>
<th>Lead Facilitator</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>So are people clear on what we're-discussing right now? The-idea that's on the table right now can anybody clarify for us?</td>
<td>Goal 2-restate</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>Tara</td>
<td>I-I-I can try</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Lead Facilitator</td>
<td>Okay, go</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>Tara</td>
<td>I think we're discussing, like does this represent motion? or does this repre-represent the, end of the motion?</td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>Lead Facilitator</td>
<td>Is that?--</td>
<td>Check back with original speaker to see if that is what she meant</td>
</tr>
<tr>
<td>63</td>
<td>Jamie</td>
<td>Right.</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Lead Facilitator</td>
<td>and I think you're saying that it represents, as that bubble's getting bigger, what's really making that bubble bigger? (few talking)</td>
<td>Goal 1-revoice</td>
</tr>
<tr>
<td>65</td>
<td>Jamie</td>
<td>What's making it bigger-that's right</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>Lead Facilitator</td>
<td>Sort of the [end point]-the end point and then what that would look like and you're saying that there'll be this [gesturing]-by the end point where [it's] just sitting there and not getting any bigger that there would be this balance in terms (Female: right) in terms of hits inside and out.</td>
<td>Goal 1-revoice</td>
</tr>
</tbody>
</table>

While the Teacher Leaders are contributing the ideas, the Lead Facilitator moves serve to clarify those ideas so that others in the group can understand and work with them. In this
case, the use of the restate move first opened up a space for those in the group to clarify the ideas followed by revoicing moves that serve to further clarify and highlight the ideas being discussed. In summary, these Goal 1, 2, and 3 moves were used to help explicate an idea so that others in the group could work with it.

6.2.2.1.2 Using Moves to open up the discussion to other Teacher Leaders and ideas.

Lead Facilitators used Goal 1, Goal 2 and Goal 4 moves as well as non-evaluative continue moves and wait time (a Goal 1 move) in order to open up the discussion around the ideas that were just uncovered and to invite others to join the discussion. For example, in LDA 2 Bottle on the Table, the Lead Facilitator first used Goal 1 and non-evaluative continue moves to get the same person to contribute before using a Goal 4 move to invite new ideas into the interaction. In this way, the Lead Facilitator makes space for alternative ideas.

Table 20: Sample Transcript, Opening Up 1

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Mary</td>
<td>I'll start. I-I see the bottle as um inside the bottle could be room A, and the walls.. of the bottle is the sliding.. wall on wheels, and then the outside would be room B.</td>
</tr>
<tr>
<td>5</td>
<td>Lead Facilitator</td>
<td>The outside.. say a little more about the outside, you mean the outside air around-</td>
</tr>
<tr>
<td>6</td>
<td>Mary</td>
<td>The air outside it, and-and not out there, not here, but just directly around what- what's able to hit it.</td>
</tr>
<tr>
<td>7</td>
<td>Lead Facilitator</td>
<td>Okay.</td>
</tr>
<tr>
<td>8</td>
<td>Mary</td>
<td>And bounce off.. the wall. So I would..do you want me to continue? or leave it at that-</td>
</tr>
<tr>
<td>9</td>
<td>Lead Facilitator</td>
<td>Um yeah hold on one sec. Does- is anybody have a different idea about where room A, room B, and the wall are?</td>
</tr>
</tbody>
</table>

132
The discussion continues with the Lead Facilitator continuing to use Goal 5 synthesis and consensus moves as well as wait time and Goal 4 moves designed to invite participation. What results is a 17-turn exchange that involves seven different Teacher Leaders contributing different ideas around the central intellectual task of mapping the elements of the model onto phenomenon.

Table 21: Sample Transcript, Result of Opening Up

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Jasmine</td>
<td>I was wondering if room B could just be this box that we're sitting in, this room. (Because the doors are closed).</td>
</tr>
<tr>
<td>11</td>
<td>Lead Facilitator</td>
<td>(4 second pause) (...) are we comfortable with that? We'll call this room A- well whichever (...). One room is this whole room, and the other room we'll say is inside the bottle, okay? And the wall was what?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Mary</td>
<td>The actual bottle.</td>
</tr>
<tr>
<td>13</td>
<td>Lead Facilitator</td>
<td>Okay. Does everybody believe her- agree that the wall on wheels is-is the bottle itself?</td>
</tr>
<tr>
<td>14</td>
<td>Hilary</td>
<td>I had a thought that when the.. cap is opened, I mean before the cap was put on, the wall might've been different in order to be the same amount of air molecules.. inside as there were outside. So at some point the cap was put on, and I'm assuming that it wasn't- it wasn't (...) so I'm assuming that the air was just- the cap was put on but somehow when the cap was not there air molecules was able to flow through that opening.</td>
</tr>
<tr>
<td>15</td>
<td>Lead Facilitator</td>
<td>Okay.</td>
</tr>
<tr>
<td>16</td>
<td>Hilary</td>
<td>So at some point that might've been a slightly different place (where) that wall (is).. on wheels.</td>
</tr>
<tr>
<td>17</td>
<td>Lead Facilitator</td>
<td>What do you think of that?</td>
</tr>
<tr>
<td>----</td>
<td>------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>18</td>
<td>Tom</td>
<td>So what I'm hearing, Hilary, is that if the cap is open, there's like a hole in the wall, and air molecules can move from room A, room B, and vice versa? But when you put the cap on now you- now you've like.. sealed- you've made two rooms,</td>
</tr>
<tr>
<td>19</td>
<td>Hilary</td>
<td>you've made... yeah.</td>
</tr>
<tr>
<td>20</td>
<td>Lead Facilitator</td>
<td>(5-sec-pause) Okay, so who would like to continue this story? It's a- because we have agreement on rooms, and the wall itself, are there- well let's check again. Anybody think that the wall is something- potentially something else? I like that you shared that idea of opening (...).</td>
</tr>
<tr>
<td>21</td>
<td>Janice</td>
<td>I think it does represent the wall but I think it's different from the wall- (this wall) because it's not.. perfectly- it's not frictionless, it's more stiff and has um.. uh more resistance to that pressure, I think.</td>
</tr>
<tr>
<td>22</td>
<td>Lead Facilitator</td>
<td>But what quality of the bottle, of that is enabling you to think that it is the wall on wheels in the first place? Even if it is different than that?</td>
</tr>
<tr>
<td>23</td>
<td>Cindy</td>
<td>Because there's no exchange of molecules from the inside of that bottle to the outside because the cap is on, so.. even though it- you know it's a different material, per se, there's still puppies on one side and puppies on the other.</td>
</tr>
<tr>
<td>24</td>
<td>Jamie</td>
<td>And yet the wall is flexible.</td>
</tr>
<tr>
<td>25</td>
<td>Cindy</td>
<td>Exactly.</td>
</tr>
</tbody>
</table>
In reflecting on this segment, Deanna noted how one of her goals is to bring others into the discussion:

Um, one thing that stands out is I just keep, I keep trying to pull everybody or pull other people and say, you know, so, what do you think of that, and asking for a lot of confirmation of others, that they agree with- with...that's always a goal for me especially early on, that, you want- because if you've got one person who ends up talking to you constantly and other people are not, they can tune out and it's no longer a consensus discussion it's no longer a sha- shared, um, sense making if it's only a couple people doing it back and forth with me.

She goes on to discuss her in-the-moment decisions and the tension between making space for Teacher Leaders to make sense together and helping Teacher Leaders dig deeper into their own reasoning:

Yeah it is a c- a constant tension, you wanna involve as many people as possible and make sure everybody's with the conversation and making sense, collaboratively, but sometimes you need to ask a question to help people dig deeper, and I'm not sure that I did that as well as I could have there.

Another example of this pattern (Lead Facilitator discussing with a Teacher Leader and then trying to invite others to join the discussion) can be seen during the LDA 2 Biggest Sucker discussion. The Lead Facilitator worked to clarify two Teacher Leaders’ ideas using a revoicing move before inviting others to respond using a restate move.
The use of Goal 2 and Goal 4 moves opened the discussion to other Teacher Leaders, providing opportunities for the co-construction of ideas, a key goal of these discussions.

In summary, the Lead Facilitators used Goal 1, 2, and 3 Moves, often sticking with the same Teacher Leader for several turns, to help clarify and invite elaboration in order to “set the table” for others to work with those ideas. The use of these moves
signals to the group that their ideas are important and worth discussing. This was often followed by the use of wait time as well as Goal 2 and Goal 4 moves that worked to open up the discussion, inviting different ideas and Teacher Leaders into the discussion, which is an important aspect of these discussions where co-construction of meaning is the goal.

6.2.2.2 Theme 2: Maintaining focus and direction.

Another theme revealed in the analysis of the transcripts was the use of APT and other moves to maintain focus and direction around target concepts and explanations in the discussion (see Table 2). The sub-themes of clear segments of the discussion, focused attention around ideas to discuss, and synthesis and consensus moves to maintain direction and come to consensus will be discussed with examples from the transcripts.

**Table 22: Theme 2 Sub-Themes and Description for How APT Moves Were Used**

<table>
<thead>
<tr>
<th>Theme 2: Maintaining focus and direction</th>
</tr>
</thead>
</table>
| **Clear segments of the discussion.** | • Launch  
  • Focused segments around key content-Goals 1-5  
  • Closure-Goal 5 |
| **Focused attention around ideas to discuss** | • Goals 1, 2, 4  
  • Using moves and artifacts to direct attention to key ideas  
  • Naming the ‘that’ |
| **Moves to maintain direction, support convergence, and come to consensus** | • Goals 1 and 2 moves to help group converge on ideas discussed  
  • Goal 5 moves for synthesis and consensus  
  • Summarizing or synthesizing followed by clear, focused direction |
6.2.2.2.1 Clear segments of the discussion.

The Lead Facilitators helped maintain direction with a clear launch, focused segments around key content, and closure.

Launch. Discussions were launched with the Lead Facilitator highlighting the goal of the discussion with specific attention to the phenomenon being discussed, reinforcing discussion norms, and providing a clear direction for where to start, as in this example from LDA 1 Bottle on the Table. Note that this is a single turn formatted to indicate the different segments of the turn.

<table>
<thead>
<tr>
<th>Table 23: Sample Launch 1, Lead Facilitators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Facilitator</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
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<td></td>
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</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

In some cases, the Lead Facilitator would state the phenomena and question being discussed as in the LDA 2 Bottle on the Table:
139

<table>
<thead>
<tr>
<th></th>
<th>Lead Facilitator</th>
<th>All right, so who would like- well actually let's- to get us back in the mode, turn to the person next to you and talk to them about what did you identify as room A, what did you identify as room B, and what was going on with the behavior of the air puppies in this sit- in this phenomenon, why the bottle doesn't collapse, okay? So turn to the person next to you and talk about this.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Everyone</td>
<td>(talking)</td>
</tr>
<tr>
<td>3</td>
<td>Lead Facilitator</td>
<td>Okay, let's come back together. (...). So let's remember the question, the question is we have this empty bottle, nothing really happening with the bottle, it's just sitting there. Why is it that the bottle's not collapsing? That's our question that we're working on. Remember uh that as we talk kinda push you to stick to the air puppies model rules, you are welcome to talk about these as air molecules, you don't always have to call them puppies, you don't have to feel like you have to call them puppies, but stick with the model okay? Stick with the idea of room A and room B and that wall.. being (...) slidable and you know flexible. So, okay, who would like to get us started? Anybody.</td>
</tr>
</tbody>
</table>

In this case the Lead Facilitator focused the group on the specific phenomenon and the model that they were asked to apply prior to a brief turn and talk and then again before opening up the discussion to the whole group. This provided two opportunities to focus the group on the phenomenon at hand. In other cases, the Lead Facilitator solicited the focus of the discussion from the Teacher Leaders. Regardless of whether the Lead Facilitator provided or solicited the phenomenon and focus of the discussion, this was always part of the launch across discussions.
Additionally, the launch of each discussion included reminders regarding norms of the discussion as seen in Bottle on the Table, cohort 1:

...we're trying to build understanding together and we need to hear everybody's confusions and (hear) everybody's questions and everybody's thoughts, and.. so i- it's not- it's all of our responsibilities to jump in (...) clarify things as needed.

Finally, the launches of the discussion included a clear directive for where to start. (e.g. “So let's start with um areas of agreement, um, what did you notice um in terms of mapping our elements? What was the wall on wheels?”). Here the Lead Facilitator is providing direction around an important aspect of the discussion; mapping the elements of the model to the real world phenomenon. This specific prompting can also be seen in Soap Bubble, Cohort 2:

Alright, um. Fantastic work! So we're gonna ch- this is a consensus discussion, so we're gonna see if we can come to consensus on our explanation and on whether or not we have a rule and what that rule is, add it to our starter kit- oh it's not there any more- our starter of rules about um air behavior, okay? So why don't we start with what did you notice about maybe a common rule that people seem to add? Are we in agreement about the rule that we need to add?

Instead of a general opening that might have led to Teacher Leaders talking about what they noticed in their investigation or an even more general invitation such as “what do you think?”, the Lead Facilitator provided a clear and specific direction (about agreement on a new rule) for the discussion. This rule about how air molecules behave is the target conceptual goal of the discussion.

The launch with a clear focus on the phenomenon question, reminder of community discussion norms, and a clear directive for where to start was a central structure in all of the discussions and helped set up the work of the group around the focal science ideas.
Focused segments around key content. Lead Facilitators used moves to focus the discussion around target concepts or aspects of the model, make space for Teacher Leaders to discuss those ideas, help synthesize that segment and then refocus on another target idea. For example, the Bottle on the Table discussions both included a segment focused on mapping the air puppies model onto the real world phenomenon and then a synthesis and relaunch that asks Teacher Leaders to use those model elements to explain why the bottle is not collapsing. Within each segment, the Lead Facilitator used moves to invite Teacher Leader to Teacher Leader interaction as well as moves to help them dig deeper. Figure 23 illustrates this for the Bottle on the Table, Cohort 1 by annotating the CDA peak graph.

**Figure 23: Annotated CDA Peak Graph for LDA 1 Bottle on the Table**

This discussion started with a launch that indicated the direction for the start of the discussion,
When we saw the air puppies model, and we saw this notion of there being a wall on wheels, and rooms, can somebody... jump in and talk to me- talk with all of us, what do you think is the wall on wheels in this situation?

Segment 1 then included a 64 turn exchange that involved two areas of focus centered around a key goal of the discussion, mapping the elements of the model to the real world phenomenon. The first focused on one element of the model, the “wall on wheels”. The Lead Facilitator used multiple goal 4 moves and wait time and engaged five different Teacher Leaders. She then posed the question, “So does that correspond with the rooms? Did anybody figure out what the rooms were in this situation?”, thereby refocusing on another element of the model, “the rooms”. During this portion the Lead Facilitator used Goal 1 revoicing and say more moves as well as moves that provided a direction for the discussion as in this exchange:

**Table 25: Focused Segments, Lead Facilitator**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>29</td>
<td>Stacy</td>
<td>So-so-so instead of being on a plane.. between four rigid walls, now we have a circular wall.. that can move. There's no outside walls, just-just the moving- just the wall on wheels. (agreement from others)</td>
</tr>
<tr>
<td>30</td>
<td>Lead Facilitator</td>
<td>Except that's-that's building onto what you're saying, Stacy, 'cause you're saying...(looks at Sharon) are you talking about the wall on wheels or the rooms? Goal 1 and Goal 3</td>
</tr>
<tr>
<td>31</td>
<td>Stacy</td>
<td>So-so I'm not sure there is a room anymore I guess.</td>
</tr>
<tr>
<td>32</td>
<td>Lead Facilitator</td>
<td>Which-which may have been- did that thought to you come after she started-</td>
</tr>
<tr>
<td>33</td>
<td>Stacy</td>
<td>Yes. Absolutely</td>
</tr>
</tbody>
</table>
After opening up a direction for the discussion, the Lead Facilitator used Goal 4, Goal 1, and Goal 2 moves to support Teacher Leaders working through ideas centered on what the “rooms” are in this phenomenon. This resulted in multiple Teacher Leader to Teacher Leader exchanges that included long exchanges where Teacher Leaders were challenging each other, voicing confusion, and connecting to others’ ideas.

After this exchange, in turn 65, the Lead Facilitator synthesized what the group seemed to be saying in terms of mapping the elements of the model and relaunched, focusing the group on now applying the model to explain the phenomenon.

Lead Facilitator: Okay, all right. So what I hear (laughter)- no I think this is incredibly rich and excellent discussion. Um.. we had some questions- we-we still I think have some questions about what is the wall on wheels, um and now what I hear a lot of people saying is the flexible.. part is the wall on wheels, that's the part that is able to move. So we asked- I-I had asked a q-question about what the elements- I think at this point what I'd like to do is move onto the-the bigger question they asked, which is.. why is that bottle not collapsing right now? It's got the cap on, it's sitting there. Can we apply the-the air pup- this notion of air puppies, okay. Thinking of the wall on wheels as this bottle that cannot-cannot collapse, okay. So.. wh- ho- tell me why you think it's not collapsing.. right now, with 14.7 square inches.

Segment 2 then included a 59-turn exchange that involved two areas of focus. First the discussion started with a discussion about the role of temperature. The goal of the discussion is to apply the air puppies model and understand that it is the concentration of air molecules hitting the inside and outside the bottle, not the sheer number of air molecules, that explains why the bottle does not expand nor collapse. Therefore, the Lead Facilitator made space for the temperature discussion that was raised by a Teacher Leader.
by using a Goal 4 (add on) move and wait time but then redirected to the focal idea after 14 turns. This honored the Teacher Leaders’ ideas, but provided direction towards the target concepts of the discussion. In my reflection on this segment I noted the tension between making space for Teacher Leader ideas and maintaining direction:

It is a hard balance to keep the group focused on the discussion topic, in this case explaining the bottle on the table phenomenon while still allowing for them to connect to experiences and ideas that are relevant to them. However, without some work to either redirect or ask how the alternative ideas relate to the phenomenon at hand, the discussion can become unfocused and can lose effectiveness in making progress on ideas. It is not unusual to bring up other phenomena with hot water. I had anticipated this and chose to redirect back to this phenomenon in order to make progress on that in the time we had.

Segment 2 ended with the Lead Facilitator soliciting a summary of what the group agrees on from the Teacher Leaders.

This pattern of clear segments of the discussion focused on key concepts and goals of the discussion can be seen in both Biggest Sucker and Soap Bubble discussions. Figures 24 and 25 are annotated CDA Peak graphs for the LDA 1Biggest Sucker and LDA2 Soap Bubble.
Figure 24: Annotated CDA Peak Graph Showing Segments for LDA 1 Biggest Sucker

Segment 1: Discussing a new rule for how temperature affects air molecules.

Focus on elements of the model
Refocus on explanation for why the bubble grew or shrunk.
Goal 4, Goal 1

Refocus on if the air molecules are hitting harder or more frequently, or both
Goal 2, Goal 5, Goal 3, Goal 1

Participant shares specific example of cleaning tank on form

Refocus on using the rule to explain why the tanker collapsed
Goal 1, Goal 5

Synthesize and relaunch

Segment 2: Apply the new rule for temperature to the original phenomena of the tanker collapsing

Idea of elasticity of the soap bubble
Goal 1, Goal 5

Figure 25: Annotated CDA Peak Graph Showing Segments for LDA 2 Soap Bubble

The Lead Facilitator used APT moves, the small group posters, wait time, and redirects to allow space for Teacher Leaders to work with the ideas in each segment. In that way, the Lead Facilitators maintained focus and direction of the discussion around the target conceptual ideas.

Closure. Finally, the Lead Facilitators helped maintain direction and focus by synthesizing at key points in the discussion. For example, in the above examples, the Lead Facilitators often synthesized where the group seemed to be at that point in the discussion before relaunching into a new area of discussion. For example, in turn 109 of the LDA 2 Soap Bubble, the Lead Facilitator states:

So-let's take this now and talk um, a little bit about how this helps us with the bottle on the table-uh with the collapsing bottle and the-and the oil cleaner. How does this new rule about the puppies moving faster when they get heated and slower when they cool down help us?
Here she summarizes the new rule they just discussed (molecules move faster when heated and slower when cool) and asks the group to now focus on the explanation. In that way, she is providing some closure to that part of the discussion before moving on.

Often the synthesis used Goal 5 moves where the Lead Facilitator would ask for agreement from the group before continuing as in LDA1 Biggest Sucker:

(4-second-pause) So it sounds like we're pretty - we're feeling pretty good about our rooms now, especially if we add in that you - that there has to be something that you do, um, to make that room - that-that the mouth has to be included. There's something you have to do, um.. in this room, wherever you're calling number 2, to make the room bigger. Is that correct? Yes? Okay. Um, so-so we can map our elements pretty well, and asi- and we've already sort of eeked into the explanation now in words, and so let's hear some people talk a little bit about.. the explanations that you see up here on the posters and-and where the-where we're in agreement or where we might still have some gaps.

This synthesis move has the same goal of bringing closure to one segment before redirecting to the next ideas. Closure at the end of discussions varied. In some cases, the Lead Facilitator would ask for someone in the group to summarize where they thought the group was as in LDA 2 Bottle on the Table:

All right, Renee's over there with her little beeper telling me we have to wrap up (laughter). So to summarize, can one person just summarize why that bottle's not collapsing before we go to break? That's your incentive, by the way. (laughter)

In other cases, the Lead Facilitator would summarize where the group was in agreement and what questions the group still has. Deanna reflected on this segment and why she asked for a summary:

Because if you just end and you leave, you haven't helped everybody synthesize what they're thinking about, as a group. That marks it, as being, okay this is what we leave, understanding. And this is where we'll leave off for next time and we'll dig in a little further.
She goes on to talk about the importance of this summary for supporting future sensemaking:

...a summary's a really important, I mean I did it when I taught kids too you gotta do that. I help- people- it's part of how you- how you thread the (needle) to the next activity is to wrap up this one and here's what we learned and then you're ready to move on to the next thing.

Not every discussion ended with the Lead Facilitator seeking or providing synthesis of the discussion. However, in those cases, the Lead Facilitator synthesized and captured the ideas on chart paper as they moved through the discussion. Deanna discussed how and why she synthesizes the ideas of the group along the way:

Well if in the middle of a conversation, there have been a lot of ideas put out there, sometimes you have to pause and do this kind of okay like let's talk about where we're at right now. What do- what do we all agree right now, before you move on and continue to dig deeper. You sort of- you just have to- if there's too much in the air, you'd sort of sense that and decide it's time to summarize and pull those things together...

In this way, the Lead Facilitator is helping to bring closure to ideas as they move through the discussion.

6.2.2.2 Focused attention around ideas to discuss.

In addition to bounding segments of the discussion discussed above, as the Lead Facilitators used APT moves they often were very specific in naming or revoicing the ideas that they wanted Teacher Leaders to attend to, a move that I will explain as “naming the that”. Throughout the discussions, the Lead Facilitators used this move to highlight key conceptual ideas important to the target conceptual understanding. For example, in LDA 1 Biggest Sucker, Teacher Leaders discussed what the rooms were in
the phenomenon. The Lead Facilitator picked up on a Teacher Leader’s idea and asked the group to discuss it.

**Table 26: Sample Transcript, Focused Attention**

<p>| | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>Lead Facilitator</td>
<td>And then the other room is?</td>
</tr>
<tr>
<td>35</td>
<td>Cindy</td>
<td>The straw. Inside the straw.</td>
</tr>
<tr>
<td>36</td>
<td>Jane</td>
<td>Well it seemed like some people in our group thought the mouth too.</td>
</tr>
<tr>
<td>37</td>
<td>Lead Facilitator</td>
<td>Yeah, so someone talk a little bit- anybody who represented it that way with a mouth or lips or something over it, tell me about that as being part of the room.</td>
</tr>
</tbody>
</table>

In drinking through a straw, the idea that the mouth is part of one of the rooms is important for Teacher Leaders to understand in order to understand that a change in volume (e.g. by making the space in your mouth bigger) can lead to a pressure difference. In this case, the Lead Facilitator named the specific idea she wanted the group to work with versus a more general, “can someone tell me about that”. This practice of naming the specific “that” for Teacher Leaders to restate, agree/disagree with, or to add on to was seen consistently throughout the Lead Facilitators’ discussions. This strategy helped maintain focus and direction around important conceptual ideas.

Additionally, the Lead Facilitators would refer to or ask Teacher Leaders to utilize the models that they had created in small groups and brought to the consensus discussions as seen in this Lead Facilitator turn:

So can somebody show that on one of these maps (points to their models and sits back down) ’Cause I- it's-it- I don't know that it's clear to everybody. Maybe on the box one, the um- Colleen your group’s. Can you explain.. this movement-
open system, look at the open system right now.

Throughout these examples we see the Lead Facilitators elevating ideas that are target science concepts for the discussion. This requires listening carefully to what the Teacher Leaders are saying and then using those ideas to provide a direction for the discussion. Both Deanna and I reflected on the need to really listen carefully:

So much that you are listening for/to that sometimes you don’t hear everything. Have to listen so closely and intently all the time and make decisions about what to lift up, press on, or have others work with. *Renee reflection on a segment where I revoiced an idea but got it wrong.*

Um, I listen incredibly carefully, I try not to be distracted by other people sitting and you know playing with pens [Renee:Right] (maybe) you're moving or you know focused looking at the person that's speaking and.. actually that's it. - *Deanna interview*

Additionally, understanding the conceptual goals of the discussion and using those to help support the moment-to-moment decisions is essential. Deanna spoke to this and her purposeful use of moves with the goal in mind:

It's very purposeful, yeah, like if you're- if you're planning to sit down and lead a discussion, it doesn't just happen, you have to think ahead of time what is my goal for Teacher Leaders at the end of the discussion, [Renee:Mm-hmm] and- give yourself some time to think about how you're gonna get them there. [Renee:Right.] Even though you don't know what's going to happen, some of the questions you can ask, some of the things that- will remind yourself what moves you can do to help, in a variety of situations when people have [indistinct], so, that's the only way to- that I've- been able to- take in and get better at using talk moves, is by practicing them and by planning, a- keep- before I go into discussions, [Renee:Yeah] (making a plan) [Renee:Yep.] so. Knowing your key ideas, you wanna get to. Hinge ideas.

In reflecting on a segment where I asked the group to use their small group posters to show their thinking, I note my rationale for this move:

even though we had it in writing what is happening, it is such an important idea that I wanted to make sure everyone understood it so I asked someone to use one
of the posters and show us what they meant when they said it gets pushed up because more hits on one side than the other.

Lead Facilitators also spoke about elevating ideas based on what they are seeing Teacher Leaders struggle with. I mention in my reflection on the LDA 1 Biggest Sucker:

I press on if there were any questions about the water….I know from walking around that there is debate about if it is all of the water or just the top of the water. Trying to open up some discussion around this so that if there is still uncertainty it can surface. Understanding that it is all of the water and that both sides of the wall are being pushed on is helpful in understanding what is happening.

This purposeful use of moves to focus and guide the discussion around target conceptual ideas based on both the goal of the discussion and the ideas that Teacher Leaders are struggling with was a theme discussed by both Lead Facilitators.

6.2.2.2.3 Moves to maintain direction, support convergence, and come to consensus.

After opening up the discussion for others to agree, disagree, or add new ideas, (Theme 1) the Lead Facilitators used Goal 5 synthesizing moves, Goal 2 restate moves, and/or Goal 1 revoicing moves to help the group converge on ideas that were just discussed. These moves often followed Teacher Leader to Teacher Leader exchanges. The Lead Facilitator either asked for someone to restate (Goal 2) what was just discussed or to revoice the idea (Goal 1). For example, in LDA 2 Biggest Sucker, a Teacher Leader made a statement regarding what is leading to more pressure and the Lead Facilitator opened up that idea in this exchange:

**Table 27: Sample Transcript, Maintaining Direction 1**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Melodie</td>
<td>So that's making more.. pressure on the wall, on our WoW.</td>
</tr>
<tr>
<td>51</td>
<td>Lead</td>
<td>What do people think?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goal 4</td>
</tr>
</tbody>
</table>
This leads to a 12-turn exchange between six different Teacher Leaders including turns that were long and complex. The Lead Facilitator then used a Goal 2 restate move to make sure that all Teacher Leaders understood what was being discussed, thereby involving the Teacher Leaders in helping focus the discussion to help the group converge on ideas:

**Table 28: Sample Transcript, Maintaining Direction 2**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>Female 1</td>
<td>Yes.</td>
</tr>
<tr>
<td>53</td>
<td>Jamie</td>
<td>More pressure than.. room?</td>
</tr>
<tr>
<td>54</td>
<td>Melodie</td>
<td>In room A, there's more pressure on our WoW-</td>
</tr>
<tr>
<td>55</td>
<td>Lead Facilitator</td>
<td>Compared to?</td>
</tr>
<tr>
<td>56</td>
<td>Melodie</td>
<td>More hits because there's more bumbling compared to room B.</td>
</tr>
<tr>
<td>57</td>
<td>Cindy</td>
<td>I-I-I guess my question is if we increase the room in room A, that gives us more room in room B, why do we assume that there's going to be more space in B than A? Like I-I-I mean we're just- we increased both areas but.. at some point there's gotta be some sort of equilibrium. We can't keep sucking forever, we have to somehow say oh I probably have to swallow whatever- we hit a point but we can't do anything more.</td>
</tr>
</tbody>
</table>
Another pattern emerged in which the Lead Facilitators first made space for divergent ideas (Goal 4 and wait time) and then used Goal 1 revoicing moves to focus the discussion. The following exchange from LDA 2 Biggest Sucker is an example of this pattern:

Table 29: Sample Transcript, Maintaining Direction 3
<table>
<thead>
<tr>
<th>99</th>
<th>T</th>
<th>What do people think of that? Do you understand what she's saying? (some heads moving to say not really) (4 second pause) If you're not sure you gotta ask her.</th>
<th>Goal 4 wait time</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Marc</td>
<td>(I) think, i-if I'm understanding is.. there's less of a- as the room gets bigger- room A gets bigger-</td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>Hope</td>
<td>As room A gets bigger, is that what you're saying? So room A is the space above the.. water, okay.</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>Marc</td>
<td>Yeah, so as (some wat)- in the closed system as some water was pushed up the straw and room A gets bigger, (looks at Joan) um.. the puppies in room A collide less often with the wall, so there's not as strong as a push.. unless you could cr- unless you could continue to expand room B?</td>
<td></td>
</tr>
<tr>
<td>103</td>
<td>Janice</td>
<td>Yeah cause it's a difference.. in frequency between the two rooms (the)-the-</td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>Marc</td>
<td>And sort of (...) lessening?</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>Janice</td>
<td>Exactly, yeah.</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>T</td>
<td>So are you saying in this case, once this moves out a little bit, then you're actually getting the frequency of hits here equal to the frequency of hits here because you've made this room a little bit bigger? (Marc and Janice nodding)</td>
<td>Goal 1 Revoice</td>
</tr>
</tbody>
</table>

Here, we see the Lead Facilitator opening up the discussion for others to respond in line 99, which led to a Teacher Leader to Teacher Leader exchange, followed by a revoicing
move. In my reflection on this revoicing move in my role as one of the Lead Facilitators, I noted:

Revoicing here is important so that all are clear on the idea we are trying to work with. If you just ask for agreement or even just ‘say more’, especially if the turn is long and there is a lot in there, you sometimes run the risk of the Teacher Leader not knowing which part to say more about. The revoice here was intended to be like, “ok, here’s the idea on the table” now keep going with that idea.

This revoicing move served to clarify and re-broadcast the idea out to the group thereby helping focus the discussion. Goal 1 moves like these along with Goal 5 synthesizing moves and Goal 2 restate moves were used to first open up the discussion and then bring it in to converge on ideas that were just discussed.

Goal 5 moves were used often by Lead Facilitators to help maintain focus and direction of the discussion and to support the group in coming to consensus. Goal 5 moves included moves to solicit or summarize what the group is in agreement on (or not). These moves provided direction and focus for the discussion with the Lead Facilitators using APT moves in between to help Teacher Leaders go public, listen, dig deeper and work with each other’s ideas. For example, in LDA2 Biggest Sucker, we see this exchange that starts and ends with Goal 5 moves.

Table 30: Sample Transcript, Maintaining Direction 4
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td><strong>Lead Facilitator</strong></td>
<td>So right, ‘cause these are just sitting here on the table, nothing’s happening right? So in order to be able to do anything with them, you gotta put your mouth on it. So we're saying that room B is the air in the straw, and.. in this sort of mouth situation (happening up here). (drawing) I don't know if anyone's mouth looks like that but. (sits-back-down) All right, so those seem to be quite a bit of improvement on those elements. Now we gotta put the pieces together and see if we can come up with sort of the explanation for what's going on. So.. somebody just get it started here, how do we- how is it that we can drink out of that one with the door open?</td>
</tr>
<tr>
<td>35</td>
<td>Cindy</td>
<td>The molecules are free to move into the room.. as where um- and so it- therefore it can help push.. the.. wall.. and um.. move the wall of water up the straw.</td>
</tr>
<tr>
<td>36</td>
<td>Patty</td>
<td>Right so there's more hits when-when you're expanding that room, more hits are happening below to help you move that wall, to help the wall move.</td>
</tr>
<tr>
<td>37</td>
<td><strong>Lead Facilitator</strong></td>
<td>So I'm actually hearing two things, I'm hearing that.. somehow that- those airs- the air's pushing on the water and then making the water go up the straw (Cindy nods). But then you added something (points-to-Patty) that she hadn't said yet.</td>
</tr>
<tr>
<td>38</td>
<td>Patty</td>
<td>So on the bottom of the wa- th-the air puppies.. are- because the..- some of the air puppies at the top are being released into your mouth, into that room, so they're be- there's less collision happening on top cause the room is bigger. And there's more collision happening at the bottom, and so- and in the other room, and so it's pushing that wall up.</td>
</tr>
</tbody>
</table>
This type of segment where the Lead Facilitator makes room for Teacher Leaders to work with ideas but bounds the discussion by both providing direction for an area to discuss and pauses to capture what has been agreed upon was typical in all discussions.

Soliciting and trying to capture the words of the Teacher Leaders after they have discussed an idea was seen in all discussions such as in LDA2 Biggest Sucker,

Okay, so how-how can I say that? Um so room B is bigger, (reading) when you put your mouth over and pull your tongue back, so the same number of puppies have more room to bumble, so there are fewer hits on the wall in room B. And now, help me out here.

Lead Facilitators would often summarize the ideas that were agreed upon and then ask for agreement or solicit modifications as in this example from LDA1 Biggest Sucker:
Table 31: Sample Transcript, Maintaining Direction 5

| 150 | Lead Facilitator | Right, so if you made this room bigger and they've got a lower concentration, there's fewer hits on this side of the wall, which means the other side of the wall can push. Remember when we made that room bigger? So the other side of the wall can push, happens to be the other side of the wall is-is our- what I'm calling room A, right? So then room A pushes down that water, which pushes it up the straw into your mouth, okay? Um-

| 151 | Cady | It's not about an increase as much as it is about the decrease in the other room.

| 152 | Julie | Yeah.

| 153 | Lead Facilitator | So-so what're we-what're we gonna do with this statement? This decreases the number of hits in room B. Is that accurate?

In this way, the Lead Facilitator is capturing the ideas and moving the discussion forward while at the same time honoring and soliciting the Teacher Leaders’ ideas. Here we also see the Lead Facilitator “naming the that” to discuss, in this case what decreases the number of air molecule hits. Deanna discussed the challenge of helping the group come to consensus while still providing the space for the Teacher Leaders to do the “heavy lifting”:

Um, it's challenging to- to, [pause] leave, [pause] to leave the work of coming to consensus, to the group. Without, taking it over and deciding, like, basically without doing too much of the, sensemaking yourself... to bring it to the, consensus. To figure out what we do and don't understand, to just- to ask the questions that get them to be the ones that, or- to consensus. And see what they agree on and what they don't agree on.
Goal 5 moves were almost always accompanied with a prompt for where to go next as in LDA1 Biggest Sucker:

(4-second-pause) So it sounds like we're pretty- we're feeling pretty good about our rooms now, especially if we add in that you- that there has to be something that you do, um, to make that room- that-that the mouth has to be included. There's something you have to do, um.. in this room, wherever you're calling number 2, to make the room bigger. Is that correct? Yes? Okay. Um, so-so we can map our elements pretty well, and asi- and we've already sort of eeked into the explanation now in words, and so let's hear some people talk a little bit about.. the explanations that you see up here on the posters and-and where the-where we're in agreement or where we might still have some gaps.

In summary, Lead Facilitators used moves to maintain focus and direction around target concepts. The discussions were organized into clear segments with the Lead Facilitators using Goal 1, 2, and 5 moves to help synthesize segments of the discussion. Lead Facilitators used Goals 1, 2, and 4 APT moves to focus attention around the target concepts and explanations in the discussion, redirecting and elevating Teacher Leader ideas for others to work with. Goal 5 synthesis and consensus moves played a central role in the discussions, and the move of summarizing or synthesizing at key points of the discussion followed by a clear, focused direction for where to go next further supported this theme of maintaining focus and direction.

**6.3 Nature of the Teacher Leader Turns: Reasoning and Co-Construction**

In dialogic teaching the Lead Facilitator’s questions and moves work to encourage multiple Teacher Leader ideas and extended turns that include reasoning. Therefore, another way to characterize the dialogicality of the discussion is to examine the substance of Teacher Leader turns. In this section I will present results regarding the length and substance of Teacher Leader turns in terms of depth of their response and
whether their response included reasoning or explanation. I will then share results around how Teacher Leaders are interacting with each other using indicators of co-construction of ideas.

### 6.3.1 Depth of Teacher Leader Response: Reasoning/Explanation

A focus of APT is helping Teacher Leaders reason or make meaning through talk. An important role of the Lead Facilitator is to encourage longer and more complex responses that include an explanation of the Teacher Leaders’ thinking. As mentioned earlier, in order to characterize the depth of the Teacher Leaders’ responses, I used a coding scheme based on Pimental and McNeill’s (2013) coding scheme that identified to what extent their response included reasoning or explanation. Those turns coded as P3 included an explanation of their thinking, P2 turns included a complete thought but no explanation or reasoning, while P1 turns consisted of a word or phrase only. Figure 26 shows the results for the substance of the Teacher Leader turns shown by the percentage of turns that were coded P1-P3.
Figure 26: Substance of Teacher Leader Turns Using P1-P3 codes

Sixty-Eighty eight percent of Teacher Leader turns were rated as a P2 or P3 (red and green bars). With the exception of BS1, short P1 responses made up less than 30% of the Teacher Leader turns. These P1 turns included phrases or words such as “right” or “concentration” as well as if a turn was interrupted. The slightly higher rate of P1 turns in the Biggest Sucker discussions might be attributed to the fact that there are several segments where the Lead Facilitators are trying to capture the ideas that have been discussed on chart paper where the Teacher Leaders would repeat a word to help clarify.

For four of the six discussions (BOT 2, BS 2, SP1, and SP2), 50% of Teacher Leader turns including reasoning or explanation (P3)

A typical exchange would include a combination of P1-P3 turns where Teacher Leaders had the space to clarify or say more about an idea as in this example for LDA2 Soap Bubble:

Table 32: Sample Transcript, P1-P3 1

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>76</td>
<td>They're slower when they cool down. Now the discussion that wa-that I heard a lot at the tables was okay so if they're moving faster are they hitting harder or more frequently or both? So we can talk about that for a minute but, what did-what-what were your discussions there?</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>Mary</td>
<td>I think both.</td>
</tr>
<tr>
<td>78</td>
<td>Judy</td>
<td>Both.</td>
</tr>
<tr>
<td>79</td>
<td>Cindy</td>
<td>I-I-I'm confused as to why it would be harder we don't have an increase I mean-we have an increase of speed, we have an increase of movement but I don't know as if we actually have an increase of force.</td>
</tr>
<tr>
<td>80</td>
<td>Audrey</td>
<td>We do it's uh-inertia right, so if something's moving faster, the mass hasn't changed, it's gonna have [more] force.</td>
</tr>
<tr>
<td>-----</td>
<td>------------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td>81</td>
<td>Patty</td>
<td>It's like if you're in a car and if you're driving faster-</td>
</tr>
<tr>
<td>82</td>
<td>Cindy</td>
<td>I-I-I know I just-I just-yeah.</td>
</tr>
<tr>
<td>83</td>
<td>Tom</td>
<td>Well maybe-maybe it's more energy for sure-</td>
</tr>
<tr>
<td>84</td>
<td>Cindy</td>
<td>Absolutely.</td>
</tr>
<tr>
<td>85</td>
<td>Tom</td>
<td>Right I think that-that's easier to agree to right? Force gets a little bit funky I think in some ways.</td>
</tr>
<tr>
<td>86</td>
<td>Cindy</td>
<td>Yeah.</td>
</tr>
<tr>
<td>87</td>
<td>Tom</td>
<td>But-but energy for sure because the mass-the mass is the same but the velocity's greater so more energy more, as well as more momentum. (murmers of mmm hmm) But, that's a lot to add into this model.</td>
</tr>
<tr>
<td>88</td>
<td>Cindy</td>
<td>Yeah.</td>
</tr>
<tr>
<td>89</td>
<td>Tom</td>
<td>But I think, I think it's easy to agree that there's gonna be more [gesturing] collisions, I think with the-without stretching it too much we can say each collision that uh-- each particle has more energy as well. (murmers of mmm hmmm) [2-second pause]</td>
</tr>
<tr>
<td>90</td>
<td>Lead Facilitator</td>
<td>What do people think about that? Is the energy-are we on-are we all on the same page?</td>
</tr>
</tbody>
</table>

In this case, the Teacher Leaders were elaborating on their ideas without prompting by the Lead Facilitator. In other cases, the Lead Facilitators would push for elaboration.
For example, in LDA1 Biggest Sucker, we see the Lead Facilitator asking for elaboration on the idea of why including the space in your mouth is an important aspect of the explanation for how the pressure changes.

**Table 33: Sample Transcript, P1-P3 2**

<table>
<thead>
<tr>
<th>Turn</th>
<th>Role</th>
<th>Transcript</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>Lead Facilitator</td>
<td>So, including a mouth or lips or something, is an important part of one of the rooms.</td>
<td>Lead Facilitator</td>
</tr>
<tr>
<td>47</td>
<td>Cathy</td>
<td>'Cause it explains why water can even be pushed up the straw when it's closed. When the stopper is stopped.</td>
<td>P3</td>
</tr>
<tr>
<td>48</td>
<td>A few</td>
<td>yeah, that's right.</td>
<td>P1</td>
</tr>
<tr>
<td>49</td>
<td>Cathy</td>
<td>Otherwise it wouldn't do anything.</td>
<td>P3</td>
</tr>
<tr>
<td>50</td>
<td>Lead Facilitator</td>
<td>(to-Cathy) Say more about that, explain that more. Explain what you mean by that one.</td>
<td>Goal 1 (say more)</td>
</tr>
<tr>
<td>51</td>
<td>Cathy</td>
<td>Well if-if (your mouth)- if you don't include this part of the room...the water- the- there's noth- there's no reason why anything would change. Nothing changes in here, the-these- these little puppies are just doing their thing and these little puppies are doing their thing and nothing changes. But as soon as you, like she said, increase- and this is closed, so nothing's coming in nothing's changing, as soon as you increase the space, you change.. where- you change the space of these puppies can go into and once they do that, that explains why.. it pushes the water- the puppies push the water- why the water even goes up. You can get some of it, you can get some water, but you can't drink very much of it 'cause...there's no outside-</td>
<td>P3</td>
</tr>
</tbody>
</table>

The use of the Goal 1 move here led to the Teacher Leader elaborating and explaining her thinking in turn 51.
A closer examination of the nature of the P1 codes showed that many of the turns coded with a P1 were part of a back and forth between Teacher Leaders and the Lead Facilitator during portions of the discussion where the Lead Facilitator was working to capture on paper the pieces of the group’s explanation. For example, in the following exchange from LDA1 Biggest Sucker, there are multiple P1 and P2 turns.

**Table 34: Sample Transcript, P1-P3 3**

<table>
<thead>
<tr>
<th>Turn</th>
<th>Speaker</th>
<th>Text</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>T</td>
<td>(standing-by-a-chart-paper-with-the-2-bottles-drawn) Okay. Oh right, now the open system and the closed system. So if we start with this one over here with the open system, what has to happen-what-what happens first? Or so- what-what's the first thing that we wanna try to explain?</td>
<td>P1-P3 3</td>
</tr>
<tr>
<td>96</td>
<td>Julie</td>
<td>The creation of more space (...).</td>
<td>P2</td>
</tr>
<tr>
<td>97</td>
<td>T</td>
<td>Okay.</td>
<td>P1-P3 3</td>
</tr>
<tr>
<td>98</td>
<td>Sarah</td>
<td>You have to put your mouth on and draw the tongue back(...).</td>
<td>P2</td>
</tr>
<tr>
<td>99</td>
<td>T</td>
<td>(writing-on-the-chart-paper)...What happens when you do that?</td>
<td>P1-P3 3</td>
</tr>
<tr>
<td>100</td>
<td>Cindy</td>
<td>Create more space.</td>
<td>P1</td>
</tr>
<tr>
<td>101</td>
<td>T</td>
<td>Where?</td>
<td>P1-P3 3</td>
</tr>
<tr>
<td>102</td>
<td>Amanda</td>
<td>In room 2.</td>
<td>P1</td>
</tr>
<tr>
<td>103</td>
<td>Cindy</td>
<td>In room B.</td>
<td>P1</td>
</tr>
<tr>
<td>104</td>
<td>Sarah</td>
<td>And the puppies spread out more.</td>
<td>P2</td>
</tr>
<tr>
<td>105</td>
<td>T</td>
<td>Did I screw it up up here?</td>
<td>P1-P3 3</td>
</tr>
<tr>
<td>106</td>
<td>Cindy</td>
<td>No it's okay. (chatter)</td>
<td>P1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>T</td>
<td>Than in Room B? More space in room B?</td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>Cindy</td>
<td>Yep.</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>T</td>
<td>And then what?</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>Sarah</td>
<td>The puppies spread out more in that. The puppies from room whatever (...) bumble around more yeah.</td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Amanda</td>
<td>Have more space to bumble around and don't bump into the wall as much.</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>T</td>
<td>(writing-for-6-seconds) Okay so then more space to bumble around. Then what?</td>
<td></td>
</tr>
</tbody>
</table>

These exchanges were interspersed with sections of the discussion where the group was discussing the ideas before committing them to the public record (chart paper). This synthesis of the step by step explanation in words on chart paper was an important aspect of the Biggest Sucker discussion which might help explain the higher percentage of P1 turns in those discussions.

### 6.3.2 Depth of Teacher Leader Turns: Co-construction of ideas

An important goal of these discussions and dialogic teaching is to get Teacher Leaders to think with others in order to co-construct meaning. Teacher Leader turns were analyzed using codes that serve as markers or indicators of co-construction (e.g. agree, disagree, ask for clarification, etc.). Teacher Leaders made many attempts at co-constructing ideas with their peers across all three discussions (Bottle on the Table 98/hour; Biggest Sucker 92/hour and Soap Bubble 72/hour). There was some variation in
the number of co-construction moves between discussions across the LDAs (e.g. LDA1 Bottle on the Table and LDA2 Biggest Sucker had higher rates) but there were not big differences between groups indicating that one LDA group was not more likely to co-construct ideas more than another.

The most used co-construction moves were ‘add-on’ moves where Teacher Leaders were building on others’ ideas (31%) or ‘clarify own’ moves (29%) where Teacher Leaders provided more information or details about their own idea in response to a request for clarification. Asking for clarification (20%) and agreeing or disagreeing (14%) were seen to a lesser extent. The excerpt below from LDA1 Soap Bubble, shows a typical exchange where Teacher Leaders are adding on.

**Table 35: Sample Transcript, Co-Construction 1**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Julie</td>
<td>And what we know is that not all the puppies are gonna hit the wall on wheels, some of them never get there. So I think we kind of have to talk about force a little bit? Because you know if you think about a car going twenty miles an hour hitting something, versus a car going fifty miles an hour and hitting something, it's gonna cause- like running into a balloon or whatever it is, it's definitely gonna push it more this way with you know fifty miles an hour than twenty. (5-second-pause) I don't know.</td>
</tr>
<tr>
<td>25</td>
<td>Rhonda</td>
<td>But if there's several cars hitting and we add all that together it's still gonna be the same.</td>
</tr>
<tr>
<td>26</td>
<td>Julie</td>
<td>They're not all gonna hit the wall on wheels.</td>
</tr>
<tr>
<td>27</td>
<td>Rhonda</td>
<td>But they're more apt to if they're moving more.</td>
</tr>
</tbody>
</table>
For the ‘clarify own’ moves, Teacher Leaders might prompt each other for clarification as in this example from LDA 1 Bottle on the Table:

**Table 36: Sample Transcript, Co-Construction 2**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>43</td>
<td>Jill</td>
<td>And to change that I think you take the cap off, is that right? Is that what you’re-(talking to Bill)</td>
</tr>
<tr>
<td>44</td>
<td>Bill</td>
<td>Hold on, uh.. yeah, so if you take the cap off, they're no longer two separate rooms.</td>
</tr>
</tbody>
</table>

Additionally, Teacher Leaders may be clarifying their idea in response to a Lead Facilitator prompt. For example, in LDA2 Biggest Sucker we see the Lead Facilitator using a revoice move to clarify an idea:

**Table 37: Sample Transcript, Co-Construction 3**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>T</td>
<td>So I'm actually hearing two things, I'm hearing that.. somehow that- those airs- the air's pushing on the water and then making the water go up the straw (Cindy nods). But then you added something (points-to-Patty) that she hadn't said yet.</td>
</tr>
<tr>
<td>38</td>
<td>Patty</td>
<td>So on the bottom of the wa- th-the air puppies.. are- because the..- some of the air puppies at the top are being released into your mouth, into that room, so they're be- there's less collision happening on top cause the room is bigger. And there's more collision happening at the bottom, and so- and in the other room, and so it's pushing that wall up.</td>
</tr>
</tbody>
</table>

Clarification of Teacher Leader’s own ideas were more likely to be in response to a Lead Facilitator prompt in the Biggest Sucker discussions than in the other discussions. This
matches with the findings that the Biggest Sucker discussions had a high number of Goal 1 (supporting Teacher Leaders to clarify their ideas) and Goal 3 (helping Teacher Leaders to dig deeper into their own reasoning) moves.

In summary, across discussions Teacher Leaders used co-construction moves to work with each other’s ideas. Segments where Teacher Leaders added on to others’ ideas, asked for clarification, and agreed and disagreed without interruption by the Lead Facilitator were common, making space for Teacher Leaders to talk to each other.

6.4 Summary

The characteristics of the talk during the whole group consensus discussions led by Lead Facilitators was analyzed through the lenses of interaction patterns, use of APT moves, and substance of the Teacher Leader turns. Teacher Leaders were positioned as knowers as evidenced by the high rate of Teacher Leader turns compared to Lead Facilitator turns as well as number of different Teacher Leaders who contributed in each discussion. Teacher Leaders added on or clarified their own ideas and included reasoning and explanation both prompted and unprompted. The Lead Facilitators used moves to support the dual goals of Teacher Leader engagement and concept development by sticking with the same Teacher Leader to uncover their thinking, which was often followed by long Teacher Leader to Teacher Leader exchanges. These exchanges indicate that a group culture for sharing thinking and the space to support Teacher Leader interaction and co-construction of ideas was provided.

Lead Facilitators used APT moves in over 50% of their turns with intentional use of Goal 1-5 moves as seen in the Lead Facilitators’ interviews. APT moves were used to
help Teacher Leaders go deeper into their own thinking, elevating ideas through moves like revoicing that can signal to the group that their ideas are important and worth discussing. Additionally, the Lead Facilitators used moves to invite other voices and ideas and to support Teacher Leader to Teacher Leader interaction, a prerequisite for co-construction of ideas. Since the goal of these consensus discussions is to make progress on understanding target concepts the Lead Facilitators intentionally used moves to maintain focus and direction. They would facilitate the direction of the discussion by focusing the talk around ideas Teacher Leaders had raised, clearly articulating the ideas to be discussed. Understanding the target conceptual goals helped guide the Lead Facilitators’ moves. A challenge of these discussions as a Lead Facilitator is to honor and provide space for Teacher Leaders to discuss their ideas, responding in the moment while still making conceptual progress. Lead Facilitators used Goal 5 synthesis and consensus moves to help gather up the ideas discussed making the discussions feel productive. In the next chapters I will analyze the same discussions led by the Teacher Leaders and how they compare to those of the Lead Facilitators.
CHAPTER 7

RESULTS: BAYEDGE

In this chapter I will share the results for the Bayedge Study Group for research question 2 (What are the characteristics of talk when Teacher Leaders enact whole-group consensus discussions with Teachers during science PD?) and question 3 (How does the facilitation of these whole-group consensus discussions by the Lead Facilitators compare to the Teacher Leaders’ enactment of the same discussions?). I will begin with an examination of the interaction patterns between and among the teachers and the Teacher Leaders. I will then share the results around what APT moves Teacher Leaders used and in what ways they used them. This will be followed by the results of what the Teachers were doing in terms of reasoning and co-construction of ideas. Rationale for the Teacher Leaders’ moves provided in the interviews will be included throughout to add to the patterns that emerged.

7.1 Interaction Patterns

Similar to the LDA sites, the majority of Bayedge discussions were marked by multiple Teacher turns and Teacher to Teacher exchanges where Teachers were working with other’s ideas without Teacher Leader intervention. Additionally, though less frequently than in the LDA discussions, the Teacher Leaders stuck with the same Teacher to dig deeper into their ideas, particularly in the Biggest Sucker discussion. However, participation rates were lower in the Bayedge discussions (50-73%) compared to the LDA discussions (over 80%). Results from word and turn counts, percent of different Teachers talking, and interaction patterns for Bayedge will each be examined below.
Turn and word counts are a low inference measure that can indicate if Teachers are being positioned to contribute to the discussions. Results show that this was the case: Teachers contributed to the discussions more often (average of 86 turns) than Teacher Leaders (average of 52 turns). Additionally, Teachers turns were on average longer (23 words) than Teacher Leaders’ turns (18 words), particularly for the Soap Bubble discussion (see Figure 27 below.).

![Bayedge: Total Number of Turns](image)

**Figure 27: Number of Turns for Teacher Leaders and Teachers for Bayedge**

Another low inference measure of Teacher interaction is the number of teachers who contributed in a particular discussion. Getting as many Teachers involved in the discussion as possible is important since a goal of these discussions is for all Teachers to develop understanding and co-construct ideas. Figure 28 shows the percentage of teachers who took at least one turn for each of the discussions.
Participation rates were highest for the two longer discussions; the Biggest Sucker discussion had 73% of Teachers contributing while Soap Bubble had 64% participating. Bottle on the Table had only 50% of Teachers involved.

Interaction patterns can help give a better sense of how Teachers and Teacher Leaders are interacting during these turns. Analysis of the peak graphs (see Figure 30 for an example) revealed that the Bayedge Teacher Leaders would stick with the same teacher for multiple turns to clarify or dig deeper into their ideas. Additionally, most discussions included Teacher to Teacher interactions characterized by long exchanges between Teachers without Teacher Leaders interruption. The more traditional sequence of back and forth between Teacher Leaders and different Teachers was used least often. Each will be discussed below with examples to illustrate the patterns.
7.1.1 Turn Depth: Working with the same Teacher.

In both the Biggest Sucker and Soap Bubble discussions, the Bayedge Teacher Leaders used moves to stick with the same Teacher for more than one turn. These exchanges where the Teacher Leader stays with a Teacher can be seen in green on the peak graphs. For example, in Figure 29 (Bayedge Biggest Sucker) we see several segments where the Teacher Leader stayed with the same Teacher to uncover their thinking.

Figure 29: Peak graph showing Teacher Leader to same student turns, Bayedge: Biggest Sucker

In some cases, shown in gray in Figure 30, the Teacher Leaders used APT moves such as “say more” or revoicing during these exchanges in order to uncover the Teacher’s thinking. Other segments shown in the unshaded boxes are moments when the Teacher Leader was trying to capture the ideas on the group chart and did not involve digging deeper into their ideas. A similar pattern can be seen in the Soap Bubble discussion with four segments that involved the Teacher Leader sticking with the same Teacher to uncover their thinking. While the Teacher Leaders did work with the same Teacher the Lead Facilitators interacted with the participants in this way more often and for more turns in a row.
7.1.2 Teacher to Teacher interaction.

Bayedge discussions were marked with multiple Teacher to Teacher exchanges as seen in Figure 29 above and in the Peak Graph for the Bottle on the Table discussion in Figure 30 below.

Figure 30: Peak graph showing Teacher to Teacher interaction, Bayedge: Bottle on the Table

Figure 30 shows a typical pattern of a Teacher to Teacher interaction during the Bottle on the Table discussion where between turns 5-13 and turns 23-34 (blue areas) five different Teacher talked with each other. Their turns were long as indicated by the large bubble size where the Teachers directly referenced others’ ideas talking directly to each other and were initiated by Teacher Leader moves of revoicing and say more. Similarly,
during the Soap Bubble discussion multiple Teacher to Teacher exchanges happened often following a Goal 4 move by the Teacher Leader asking if others agree or disagree.

7.1.3 Teacher Leader and different Teachers

Exchanges between the Teacher Leader and different Teachers in the form of Teacher Leader-Teacher 1-Teacher Leader-Teacher 2 (TL-T1-TL-T2) marked by orange in the peak graphs could indicate places with a more traditional IRE exchange. These segments were limited as seen in the above examples as well as in the Soap Bubble discussion in Figure 31, below.

Figure 31: Peak graph showing Teacher Leader to different Teacher turns, Bayedge: Soap Bubble.

These exchanges were marked with the use of APT moves such as Say More (where the move was said to the group at large or someone other than the original speaker would respond), Agree/Disagree, and Press or were used when the Teacher Leader was trying to capture the group’s thoughts on chart paper. In the following sections I describe results about the type of moves the Teacher Leaders used to support these patterns of interaction.

7.2 Academically Productive Talk Moves

7.2.1 Overall APT Moves and Moves by Goal.

Teacher Leaders at Site A used APT Moves at a high rate (average of 82 APT moves/hour) with Goal 1, 4, and 5 moves making up 80% of those moves. Goal 2 and
Goal 3 moves made up 7% and 12% respectively. Lead Facilitators’ had a similar average of 83 APT moves/hour. Bayedge Teacher Leaders used APT Moves by Goal at a similar rate to those of Lead Facilitators as shown in table 12. Goal 2 moves, while used the least were used on average twice as frequently by Teacher Leaders compared to the Lead Facilitators.

Table 38: Average APT Moves by Goal for Bayedge Teacher Leaders and Lead Facilitators

<table>
<thead>
<tr>
<th>Goal 1</th>
<th>Goal 2</th>
<th>Goal 3</th>
<th>Goal 4</th>
<th>Goal 5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Leaders</td>
<td>22</td>
<td>6</td>
<td>10</td>
<td>15</td>
<td>29</td>
</tr>
<tr>
<td>Bayedge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead Facilitators</td>
<td>22</td>
<td>3</td>
<td>15</td>
<td>15</td>
<td>27</td>
</tr>
</tbody>
</table>

Because a turn could have more than one code, including more than one APT code, rates were used in order to be able to compare across discussions and facilitators. Additionally, a look at what percentage of turns included an APT move was helpful in characterizing the use of these moves. For Bayedge, APT moves were used in 65% of Teacher Leader turns for both the Bottle on the Table and Biggest Sucker discussions with the least used (38%) in the Soap Bubble discussion. Similarly, APT moves were used in 50%-80% of Lead Facilitator turns across all discussions with the least used (50%) in the Soap Bubble discussion. Additionally, Teacher Leaders used wait time extensively (both between and within Teacher turns at over 3 times the rate of Lead Facilitators), which allows space for Teachers to take or continue a turn. A breakdown of average moves per APT goal across the discussions at Bayedge is shown in Figure 32.
Figure 32: Average APT moves used per APT Goal for Bayedge.

- **Goal 1 Moves.** Moves to help Teachers go public with their ideas (Goal 1) by encouraging individuals to share, expand, and clarify their own thinking were used in all discussions. Revoicing (44%) and Say More moves (56%) were the most frequently used Goal 1 moves. Patterns of how these moves were used regarding what preceded or followed and what happened as a result will be discussed in the next section. The opposite was true for the Lead Facilitators who used revoicing moves the most (54%) followed by say more (40%) and think time (e.g. turn and talk to a partner, 6%).

- **Goal 2 Moves.** Goal 2 Moves centered around helping Teachers listen to each other by asking for someone in the group to restate what someone else said were used minimally (average of 6 Goal 2 moves/hour or 7% of total APT moves used) across discussions. This move was used most in the Biggest Sucker discussion and was used after a long series of Teacher turns or after a target concept was being discussed. For
example, after a Teacher brought up the idea that air is able to come into the bottle in the open system, an idea that is important to explaining the phenomenon, the Teacher Leader states, “Can someone else restate what Heather has stated a couple of times?” Additionally, restate moves were used following a long Teacher to Teacher exchange. For example, during the Biggest Sucker the restate move was used after a 16-turn exchange that involved eight different speakers.

- **Goal 3 Moves.** Moves to help Teachers dig deeper were used in the Biggest Sucker discussion at a rate of 16 moves/hour but only 8 moves/hour in the other two discussions for an average of 10 moves/hour. Asking Teachers to explain why was used in the Biggest Sucker but not in the other discussions. Press moves that asked Teachers to dig deeper into their own reasoning, explanations, and models were only used at rate of 5 moves/hour with challenge moves being used the least (average of 2 moves/hour). Lead Facilitators used more Goal 3 Moves with an average of 15 Goal 3 moves/hour with 19 moves/hour used in Bottle on the Table. Challenge (average of 5 moves/hour) and Press (average of 9 moves/hour) were used twice as much by Lead Facilitators compared to Teacher Leaders from Bayedge.

- **Goal 4 Moves.** Moves to help Teachers reason with others (Goal 4) were used in all discussions at an average rate of 14 Goal 4 moves/hour making up 19% of total APT moves used which is a similar rate to Lead Facilitators (average of 15 moves/hour). Of the Goal 4 Moves, the majority were add-on moves (73%) that invited participation from others to join in and respond to someone else’s idea.

- **Goal 5 Moves.** Goal 5 moves included moves to either solicit or summarize what the group is in agreement on (or not). Goal 5 moves include the facilitator offering a
summary or inviting a Teacher to summarize as well as moves to solicit consensus (“do we all agree on that?”) or solicit consensus with a summary (“can we all agree that the bottle is the wall on wheels?”). Moves to solicit consensus made up just over 80% of the Goal 5 moves with just 20% of those moves including a summary before asking for consensus. While Lead Facilitators had a similar total for soliciting consensus (72% of goal 5 moves) 32% were aimed at soliciting consensus including a summary. Moves to invite or provide a summary made up 28% of Goal 5 moves for the Lead Facilitators but only 19% of Goal 5 Moves for the Teacher Leaders. While Goal 5 moves were used overall at a similar average rate by Bayedge Teacher Leaders (29 moves/hour) as Lead Facilitators (27 moves/hour), Lead Facilitators were more likely (55% of Goal 5 moves) to provide a summary than the Teacher Leaders (29% of Goal 5 moves). A deeper analysis of how these Goal 5 moves were used at Bayedge will be further examined in the next qualitative analysis section.

- **Other Teacher Leader moves.** In addition to APT moves, teacher turns were coded for wait time, defined as pauses that are 3 seconds or longer. Teacher Leaders at Bayedge used wait time ranging from 4-19 seconds before, during, and after Teacher turns extensively throughout all of the discussions at an average rate of 36 times/hour which is more than 3 times as often as was used by Lead Facilitators (average of 10 times/hour). Wait time was used after a Teacher Leader prompt and allowed space for Teacher voices. For example, “So can someone restate what Laura and Roger are saying? (...) Can somebody restate that? (6 second pause)” seen in Bottle on the Table was common. Additionally, the Teacher Leaders used wait time within or after a Teacher turn as in this example from the Biggest Sucker:
Kristina: But to me that's the same in both cases, so I just wanna try and compare the one with this stopper to that- I'm thinking more about.. what's happening in room 2 (5-second-pause) right? So to me that kind of happens both times than.. you know, the drink from the straw.

These frequency counts of APT moves only provide a partial story of the use of these moves. In the next section I will share patterns of their use around the two qualitative themes used in the analysis of the LDA groups and how that relates to the Goals of APT.

### 7.2.2 Patterns in how the APT Moves were used

The Bayedge transcripts were analyzed for the two main themes used with Lead Facilitators regarding how APT and other moves were being used to support collaborative knowledge building around target concepts:

1. supporting engagement and broad participation
2. maintaining focus and direction.

Teacher Leaders at Bayedge used moves to dig deeper into Teacher’s thinking and to open up the discussion. They further supported idea development through Goal 1, 2, and 4 moves to make space for Teachers to discuss target concepts. However, there was minimal use of moves to maintain focus and direction around key target concepts by synthesizing or bounding segments of the discussion. These two themes with examples from the transcripts and comments from the interviews are discussed below.

### 7.2.2.1 Theme 1: Using Moves to Support Teacher Engagement and Participation

Bayedge Teacher Leaders used moves to make space for and invite participation both to work with their own and other’s ideas and with the target concepts of the discussion (e.g. understanding pressure in terms of a ratio of air molecules to space...
Table 39: Summary of Theme 1 for Bayedge

<table>
<thead>
<tr>
<th>Theme 1: Using moves to support Teacher engagement and idea development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using moves to dig deeper into Teachers thinking</td>
</tr>
<tr>
<td>● Goal 1, 2, 3 Moves</td>
</tr>
<tr>
<td>● Interviews spoke to using these moves to so that the Teachers are doing the hard work</td>
</tr>
<tr>
<td>Using Moves to open up the discussion to other Teachers and ideas</td>
</tr>
<tr>
<td>● Goals 2, 4, and wait time</td>
</tr>
<tr>
<td>● Interviews spoke to using these moves to support <em>all</em> Teachers in the sensemaking</td>
</tr>
</tbody>
</table>

7.2.2.1.1 Dig deeper into Teachers’ thinking

Bayedge Teacher Leaders used moves to make space for and invite participation.

For example, in Bottle on the Table the Teacher Leader uses a Goal 1 revoice move as well as capturing the ideas on chart paper to clarify an idea.

Table 40: Transcript, Bayedge Dig Deeper 1

<table>
<thead>
<tr>
<th>Turn</th>
<th>Participant</th>
<th>Dialogue</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Heather</td>
<td>Um, I think it’s a model of equilibrium, in terms of the number of air puppies is somewhat equivalent inside the bottle as (...) the number of air puppies outside the bottle. And the wall on wheels is the (plastic) siding, which perhaps is moving a little bit but it’s not- it’s not visible to the naked eye. (T recording what she is saying on chart paper)</td>
</tr>
<tr>
<td>5</td>
<td>T</td>
<td>(pointing-to-what-she-has-written) So you’re saying that there’s the same number of puppies on the inside of the bottle as there is on the outside of the bottle?</td>
</tr>
<tr>
<td>6</td>
<td>Heather</td>
<td>Yeah.</td>
</tr>
</tbody>
</table>

This helped others in the group be able to work with that idea as can be seen in the three turns that follow this excerpt:

Table 41: Transcript, Bayedge Dig Deeper 2

<table>
<thead>
<tr>
<th>Turn</th>
<th>Participant</th>
<th>Dialogue</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Female 1</td>
<td>They’re the same ratio.</td>
</tr>
<tr>
<td>8</td>
<td>Mark</td>
<td>Can I ask a question about that? Uh, there’s way more air puppies outside that bottle than there is inside that bottle so I want to ask a question. If there’s so many more outside than inside then maybe it should be collapsing. There’s- let’s say there’s a million inside the bottle- there must be millions of billions outside the bottle.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>9</td>
<td>Shawna</td>
<td>So, can you clarify and say there’s the same number hitting the bottle inside and outside- hitting the wall on wheels. Right? So, if you have an equal number hitting the wall on wheels outside as you do inside.</td>
</tr>
</tbody>
</table>

In this case, three other Teachers challenge the incorrect idea that it is the number of air puppies but, rather, the ratio of air puppies to space. Using a revoicing move (in turn 5) opened up the space for Teachers to address the target concept without the Teacher Leader evaluating or providing her own thoughts.

During the interview, one of the Teacher Leaders, Chris, stressed using APT moves to facilitate; so, that the Teachers are doing the hard work of sensemaking instead of the Teacher Leaders doing that work for them. The following segment is a typical example of Chris articulating her intention to support Teacher engagement:

Well I mean because the key is for me to have them do the figuring out and do the talking and then discuss it, so my goal is more just like facilitating and make sure that people are involved and that everybody understands what we're talking about so in order for me to see if that's happening I have to ask these questions and these follow up questions and ask people to expand more so everyone has a chance to say oh wait that's not what I was thinking oh wait that is what I was thinking and to come to some kind of consensus.

**7.2.2.1.2 Using Moves to open up the discussion to other Teachers and ideas.**

The Teacher Leaders at Bayedge also used Goal 2 and Goal 4 moves plus wait time to open up the discussion to other Teachers. For example, Goal 2 restate moves were used after either a long Teacher to Teacher exchange or after a Teacher introduced
an idea. For example, in Biggest Sucker there was an exchange about what Teachers mean when they say the word concentration:

**Table 42: Transcript, Bayedge Open Up 1**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>43</td>
<td>Natalie</td>
<td>(...) is concentration of air puppies and so the room is getting bigger. If you keep saying that if the number of air puppies in the room is the same and the room gets bigger, then the concentration gets smaller, and there's less of a concentration.</td>
</tr>
</tbody>
</table>
| 44 | Teacher Leader | So what did you guys find- did everyone understand concentration? Can we maybe define that? (laughter) (...)
| 45 | Natalie | -talk about concentration lemonade, you know lemonade base that has higher concentration has more flavor to it, and less concentration has less flavor. |
| 46 | Karen | So fewer puppies for the same amount of space |
| 47 | Teacher Leader | So concentration (...) being more puppies. |
| 48 | A few | In the same amount of space. |
| 49 | Teacher Leader | Okay. |
| 50 | Teacher Leader | Does- can anybody restate what they're talking about here? Does that make sense? |

While the restate move was used less often compared to other moves, each time the Teacher Leaders used it was around a target concept to make sure everyone in the group understood the ideas being discussed and the language being used to describe it. Jill, who facilitated the above segment, noted why she uses these moves:

…so that talk move, helped everybody slow down and make sense of what what's what they're talking about with concentration…Well the goal of this, this discussion was consensus right and so consensus means that everybody needs to understand, what's going on and not just the few that are speaking up, sooo to kind of, dig into this ideas a little bit more, and bring a little clarity to them is- is essential to come to consensus, that's, it's too easy to just kinda okay yeah nod your head umm but it like the co- the goal of the conversation is to- is to make sense together everybody, in consensus.
Similarly, Goal 4 add-on and agree/disagree moves were used to encourage Teacher interaction around target concepts such as in Soap Bubble when there is a lengthy discussion about whether the air molecules are hitting harder or more frequently or both when they are heated:

Table 43: Transcript, Bayedge Open Up 2

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Janet</td>
<td>So and it also might be frequency and force of the air puppies. So it might be both of those for air pressure.</td>
</tr>
<tr>
<td>28</td>
<td>Teacher Leader</td>
<td>Do you agree?</td>
</tr>
<tr>
<td>29</td>
<td>Sara</td>
<td>Is it frequency or force? I don't know.</td>
</tr>
</tbody>
</table>

The Teacher Leaders at Bayedge often used wait time in conjunction with these Goal 4 moves as in Biggest Sucker, “Does anyone want to respond to that idea? (18 second pause)”. Jill spoke to her use of wait time after watching this segment:

I've been given feedback that I'm incredibly patient with wait time…and even though I'm comfortable and confident sharing in a group and usually 'go for it’ I know sometimes I need to formulate my thoughts and so out of respect for people who aren't normally ready to jump forward [I use wait time]….I remember feeling like let's let them talk, instead of us because…just that whole idea of I'm not the expert, you guys are, I trust you can do this, I am gonna give you the time to, to make that, your own.

Here, she speaks of her use of wait time both as a way to provide Teachers with think time but also to position the Teachers as holders of ideas to contribute.

In summary, the Teacher Leaders at Bayedge used particular APT moves and wait time to help Teachers clarify their ideas and to work with others. They noted the importance of these moves in supporting their role as Teacher Leader who positions the Teachers as the ones doing the sensemaking. Additionally, their moves and rationale spoke to the collaborative nature of the discussions where the group is co-constructing.
meaning. However, while the Teacher Leaders made space for Teachers to work with their own and other’s ideas, there was less use of APT Moves to help the group converge on what is being discussed. I will address themes around maintaining focus and direction around target concepts in the next section.

7.2.2.2 Theme 2: Maintaining focus and direction

Teacher Leaders at Bayedge used a clear launch focused around the phenomenon at hand and provided opportunities for Teachers to discuss the target concepts. However, the discussions were not organized into clear segments focusing on particular concepts, and there was often no or limited closure to the discussion. Additionally, while Teachers were engaged in explaining the phenomenon using target concepts, there was limited use of moves to help synthesize or direct attention to the concepts or mechanisms being discussed. Table 44 shows the three sub-themes for maintaining focus and direction (segments of the discussion, focused attention around ideas to discuss, and synthesis and consensus moves to maintain direction) and the specific moves Teacher Leaders made.

<table>
<thead>
<tr>
<th>Table 44: Summary of Theme 2 for Bayedge</th>
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<tbody>
<tr>
<td><strong>Theme 2: Maintaining focus and direction</strong></td>
</tr>
<tr>
<td><strong>Segments of the discussion</strong></td>
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<tr>
<td><strong>Focused attention around ideas to discuss</strong></td>
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7.2.2.2.1 Segments of the discussion.

Teacher Leaders at Bayedge began the discussion with a clear launch but focused segments and closure were less evident.

**Launch.** Similar to the LDA discussions, Bayedge Teacher Leaders highlighted the goal of the discussion, focused on the phenomenon being discussed, reinforced discussion norms, and often provided a clear direction for where to start as in this example from the Biggest Sucker:

**Table 45: Transcript, Bayedge Launch**

| 1 | Teacher Leader 1 | Okay, so we are gonna enter into a consensus building discussion, and so the difference between that and when you're sitting in your small groups is we really want to share the understanding of this one model we're gonna create together, where we can all agree upon and get behind the ideas here. Using the air puppies model as.. our.. primary language, mkay? Now what's also really important to understand in this process is that we're going to really push for understanding, do we understand? Is it gonna be okay for just- you know kind of an explanation we said once? You know, we're gonna wanna really make sure that we can listen hard to one another, and then kind of take it for granted. See where we were, and see where we're going to.. try to get to together. |

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<th></th>
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<tbody>
<tr>
<td>2</td>
<td>Teacher Leader 2</td>
<td>And we have the same norms, (...), but the same norms that we agreed on last time (points to the chart) we came to a consensus discussion, same norms this time. And then one other thing I wanted to point out before T goes on is I’ve created um a map of your conversation the last time we had a consensus building-building understanding discussion. And um, I thought it was great a lot of you um, gave ideas and as you can see, I put T and T up here. Most of the comments were directed towards T. So just remember to talk to one another, um because we're a learning community so it doesn't just mean T and I.</td>
</tr>
<tr>
<td>3</td>
<td>Teacher Leader 1</td>
<td>So, don't talk to me (many-laughing). So, um, who can restate kind of the question, um, that we're trying to come to a consensus about? By using these models. (6-second-pause)</td>
</tr>
<tr>
<td>4</td>
<td>Shawna</td>
<td>Why was it easier to get water through the str-through the one that had an open top versus the one that was closed?</td>
</tr>
<tr>
<td>5</td>
<td>Teacher Leader 1</td>
<td>So we're going to keep this our focus for the discussion...(posts-a-piece-of-chart-paper-that-has-a-foucus-question-on-it) But I think before we like delve deep into that let's just talk about well what has to happen first in order to get water through a straw? (7-second-pause)</td>
</tr>
</tbody>
</table>

While the launches varied, all included a focus on the phenomenon and a mention of the goal of coming to consensus on an explanation for the phenomenon, which helped focus the work of the group. Chris mentioned how the understanding the type of discussion impacts her moves:

And that and that's like those are there're different types of meeting like if we're having a gathering idea meeting that would be totally different but we're trying to have a consensus meeting on one on two things where the rooms are and where the walls on wheels are that's what, so I have to remember that's the focus of our meeting.

**Focal segments.** Two of the discussions, Biggest Sucker and Soap Bubble, had segments that seemed to be focused around particular aspects of the explanation or
model. Bottle on the Table had no clear focal segments. For example, and similar to the LDA discussions, the Biggest Sucker discussion at Bayedge began with mapping the elements of the model to the phenomenon and then shifted to using the model to explain why we can drink out of one bottle more easily than another. However, less time (23 turns and 4 different Teachers speaking) was spent on the first segment than in either of the LDA discussions (LD1 had 75 turns and 12 different Teacher Leaders speaking and LDA 2 had 34 turns and 7 different Teacher Leaders speaking).

The Soap Bubble discussion also had two clear segments but in contrast to the LDA discussions, within those segments APT moves were not used to synthesize or bound smaller sections being discussed. The annotated peak graph for Soap Bubble of LDA2 (Figure 33) shows clear segments and sub-segments where the Teacher Leader is using moves to refocus or synthesize a series of turns. These are not seen in the annotated peak graph for Bayedge Soap Bubble discussion (Figure 34). While there was some good back and forth between Teachers as shown by the blue dotted line, and the Teachers bring up one of the target concepts (air molecules hitting harder or more frequently), the Teacher Leader does not help synthesize or revoice the ideas to help focus the discussion.
Figure 33: Annotated CDA peak graph for Soap Bubble, LDA 2 showing moves used to maintain focus around key segments

Segment 1: Discussing a new rule for how temperature affects air molecules.
Segment 2: Apply the new rule for temperature to the original phenomena of the tanker collapsing

Figure 34: Annotated CDA Peak Graph for Soap Bubble, Bayedge showing two larger segments but no moves to synthesize or focus the discussion into logical segments.

Segment 1: Sharing their model for what happened with the phenomenon.
Segment 2: Summarizing the new rule for how temperature affects air molecules

Groups sharing their model one group at a time. Opportunities to discuss ideas with each other (as seen by the blue segments) but no synthesis of ideas along the way.

Relaunch towards the new “rule”

In summary, a key difference between Bayedge and the LDA sites is the use of moves to focus or redirect segments of the discussion. In all discussions, Teachers are digging into important concepts in service of explaining the phenomenon. But without Teacher Leader moves to maintain focus on them, it can leave Teachers unsure of what progress they are making.
Closure. Bayedge Teacher Leaders often captured what the group was agreeing on a public chart but they lacked synthesis at the end of segments and sometimes at the end of the discussion. For example, in Bottle on the Table the Teacher Leader ended the discussion by saying,

“Hmm. (nodding. 6-second-pause) Anybody want to add anything?… (7-second pause) Anybody still a little confused? (6-second-pause).”

While the Teacher Leader gave room for Teachers to say more via the wait time, there is no solicitation of what the group has concluded at this point. When asked about this segment and how she thinks about bringing discussions to closure, Chris explained that if she led this discussion again, she would help the group record what they agree on so that they can revisit it later.

So it's like to me it was clear that we have an understanding so what I would do and I don't know if I did this what I do now is I would take that another sheet of paper and let's just make another model let's start the model and let's put in what we agree, so I would make you know the bottle and I would label it wall on wheels or label it room A room B same amount of pressure and just get all the things we agreed on have that down and I would say is okay is this what we all agree on, and then--

She goes on to explain why capturing these ideas is important:

Well I think it's important and I think people have to see. I think people learn differently you know and I think with a visual we can keep going back to it so we'll keep going back to that model if we wanna change anything add anything we'll keep doing it to that model so that's like our fra- our starting point our frame of reference with it.

The Teacher Leader seems to know that capturing what is agreed upon is important in order to have a model that the group agreed upon and can return to, even if she did not do that in this discussion. She also signals her understanding of incrementally building ideas
when she discusses changing and adding ideas to the model as the group continues to work with additional phenomena.

Similar to the LDA discussions, in both the Biggest Sucker and the Soap Bubble discussions the Teacher Leaders at Bayedge captured what was agreed upon either on chart paper or on the shared electronic platform asking Teachers to tell them how and what to record. Jill spoke to the use of such public records as important tools for both supporting co-construction of ideas and closure:

So what I think I always do in there, umm, we have the model drawn, it seemed like people were agreeing on what's going on, but I just wanted to press, is it complete… but yeah just make sure, give em, give em a chance not to rush it and uh…kind of bringing it all together in one place, and so as she was, capturing that, we just were checking in to make sure it wasn't her interpretation of it or just a few people's interpretation of it.

The use of such tools to help synthesize the ideas is a way to bring closure, representing the agreed upon ideas. Additionally, her mention of making sure to capture the group’s ideas and not just the Teacher Leader’s interpretation speaks again to the Teacher Leader’s support of the co-construction of ideas.

In summary, the Teacher Leaders at Bayedge helped maintain focus and direction by using a clear, phenomenon-focused launch and using public records like chart paper to capture and synthesize the ideas the Teachers shared. However, unlike in the LDA discussions, APT moves were not used as readily to synthesize or bound smaller sections being discussed which could make the discussion feel unfocused for the Teachers.

7.2.2.2 Focused attention around ideas to discuss.

The Teacher Leaders at Bayedge used APT moves to make space for Teachers to discuss target concepts. The Teacher Leaders reflected on being clear about the target
concepts and goals for a discussion and how those influenced the moves that they made. However, while the Teacher Leaders were listening for and making space for the target concepts to be discussed they were often not specific in naming or revoicing the ideas that they wanted Teachers to attend to ("naming the that"). Therefore, while Teachers were working with target concepts, the Teacher Leaders were less likely to pick up those ideas to make sure that all in the group were on the same page.

**Making space to discuss target concepts.** Throughout the discussions, the Teacher Leaders used Goal 1, Goal 2, and Goal 4 APT moves to make space for Teachers to discuss target concepts. For example, in Bottle on the Table the discussion started with the Teachers discussing why the bottle doesn’t collapse. Shawna brings up the idea of the wall on wheels and the Teacher Leader uses a Goal 1 move to get her to clarify what she means by the wall on wheels.

**Table 46: Transcript, Bayedge Making Space 1**

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>9</td>
<td>Shawna</td>
<td>So can you clarify and say there’s the same number hitting the bottle inside and outside- hitting the wall on wheels. Right? So if you have an equal number hitting the wall on wheels outside as you do inside.</td>
</tr>
<tr>
<td>10</td>
<td>T</td>
<td>What’re you saying the wall on wheels is?</td>
</tr>
</tbody>
</table>

In this case, the Teacher Leader specifically names the idea that she wants the Teachers to attend to. Since mapping the elements of the model to the phenomenon is a key goal of this discussion, this move with a specific naming of what she wants the Teachers to attend to helps focus the discussion. The discussion continues with several more APT moves used to help keep Teachers focused on the model element of the wall on wheels.
The Teacher Leader continued by using a redirect move to keep the discussion focused on the specific phenomenon the group is trying to explain:

**Table 48: Transcript, Bayedge Making Space 3**

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<thead>
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<tbody>
<tr>
<td>18</td>
<td>Roger</td>
<td>I think.. every object.. in the room.. is a wall on wheels. And that.. they're all getting pushed deeper.. (…).</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Teacher Leader</td>
<td>Does everybody agree with Roger? Does everybody understand what Roger is saying?</td>
<td>Goal 5, Goal 4</td>
</tr>
<tr>
<td>20</td>
<td>Roger</td>
<td>But the wall on wheels that we're considering right now (…) question, is this bottle (...)</td>
<td>Redirect towards focal phenomenon and target concept</td>
</tr>
<tr>
<td>21</td>
<td>Teacher Leader</td>
<td>Good. So let's bring it back to that. Let's bring it back to this bottle and the walls on wheels and what the rooms are.</td>
<td></td>
</tr>
</tbody>
</table>
discussion. Chris reflected on why she made these moves to focus on the Wall on Wheels.

That’s what I’m trying to get a consensus on. I want to make sure too everybody knows what the wall on wheels is. There was like three things in there I think I wanted people to come to consensus the wall on wheels, where it was pushing, and I think maybe the rooms, yeah the rooms. So I really wanted people to make sure they understood that before we went on to the next lesson or next activity so in order for me to do that I had to use some kind of talk moves or questioning for everybody to be involved and make sure everybody really understood that.

When asked if she uses these goals in thinking about leading the discussion, she notes how having a few targets in mind was an important idea she learned in the Teacher Leader training:

I use that all the time now. I mean like that to me when we learned that first before I even led it with this group and I remember learning it with you and I’m like ‘wow!’ that’s like such a big ah-hah moment…just to pick one or two things in the meeting so we’re not overwhelming kids either you know or the class so pick one or two things that I really want them to take from the meeting come to consensus on and just do a lot of talking and discussing around that question, so that I use that all the time.

The discussions at Bayedge provided many opportunities for Teachers to talk about these target goals of the discussion. For example, Teacher Leaders used moves that pushed Teachers to not simply use scientific vocabulary but explain what a term meant, and to make sure that all Teachers understood the term. Examples from both Biggest Sucker and Soap Bubble highlight such moves:

- So what did you guys find- did everyone understand concentration? Can we maybe define that? (laughter) (...) (Biggest Sucker, turn 44)
- So you used to word air pressure. Who can explain what she means by air pressure? (Soap bubble, turn 24)

In this way, the Teacher Leaders are helping the group dig more deeply into their reasoning around target concepts and not allowing ideas to be “black boxed” by using
vocabulary without explaining the meaning. Jill spoke to this as she reflected on these two segments:

…so I guess I wanted to check in, with the group, what is air pressure maybe we hadn't been using that word a lot or we were, I don't remember, but she made a generalization umm, which causes umm, which causes relatively more a- air pressure inside pushing it, so her explanation is kind of dependent on that word. So I guess I was looking for…okay are we, are in an agreement in understanding what language she's using in that explanation?

Pushing Teachers to explicate their thinking about the mechanism behind phenomena using language that all agree on and conceptually understand is an important instructional shift that is emphasized in the NGSX Teacher and facilitator pathways that the Teachers Leaders participated in.

In summary, the Teacher Leaders used the goals of the discussion to influence the moves they made to make space for Teachers to discuss target concepts. However, they were less likely to name or revoice the ideas they wanted Teachers to attend to.

**Limited use of moves to name or focus the talk around target concepts.**

While the Teacher Leaders did use some Goal 1, Goal 2, and Goal 4 APT moves to restate or name the ideas Teachers were offering, they made moves that opened up the discussion more generally (e.g. anyone want to add on to that?) versus specifically “naming the that” to be discussed. This was particularly visible in the Biggest Sucker discussion. For example:
In turn 51, Steph offers a very long and complex explanation that includes ideas about how changing the volume changes the pressure as well as the idea that the air is pushing the water up the straw (not being pulled or sucked). Without some help naming the idea articulated in that long turn, Teachers may have difficulty knowing how to respond. We see evidence of this in turn 53 when, after an 18 second pause, the Teacher Leader took another turn redirecting the group to summarize on the chart paper what happens with the phenomenon.
Occasionally, some target concepts did not get picked up and instead the Teacher Leader refocused the discussion around other ideas. For example, in the Bottle on the Table we see this exchange:

**Table 50: Transcript, Bayedge Refocus**

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<tbody>
<tr>
<td>31</td>
<td>Natalie</td>
<td>So if you took the volume of air inside the bottle, and you found that exact same volume of space outside the bottle, you counted the molecules or the puppies, there’d be the same number of puppies inside the bottle as in that exact same amount of space outside the puppies- I mean outside the bottle, right (7-second-pause) And that connects back to what Michelle was saying, that the number of times the bottle’s getting hit is about the same-</td>
</tr>
<tr>
<td>32</td>
<td>Roger</td>
<td>To make it a little more exact we have to say on an average it’d be the same amount of puppy hits. We took here, here (…) (gesturing)</td>
</tr>
<tr>
<td>33</td>
<td>Mark</td>
<td>To me that sounds like density, talking about volume- number of things (...). Talking about numbers is confusing ‘cause there’s a misconception there’s a lot more air out here than there is inside the bottle.</td>
</tr>
<tr>
<td>34</td>
<td>T</td>
<td>So I think- I think we’re using a lot of terms (that) maybe.. people aren't understanding like the volume and the mass I heard, density so- Maybe if we can take it back, and maybe if we can talk and re-direct and see- maybe if we can first come to consensus on where the wall on wheels is and what are the two rooms we’re talking about. Anybody wanna (…)</td>
</tr>
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</table>

When reflecting on this segment, Chris explains why she didn’t pick up on the target concept (pressure as ratio) and instead redirected the discussion: Because the Bottle on the Table was the first discussion, she wanted to make sure that everyone in the group is clear on the basic idea of mapping the elements of the model:

Because I mean this again talks about the different levels in that circle, we throw out terms and we throw out vocabulary just like we do on the younger grades too but not everybody has a clear understanding of what they mean so it's like okay so let's go back to the basics first so we can explain what volume is what mass is but we have to go back and to the very beginning basic understanding of where the rooms are where the wall on wheels where the wall on wheels is and then go
deeper into that first but I still think we're in the beginning stages… I don't want to discourage them trying to use some of the vocabulary but I wanted to bring it back to where we are and then later we will get deeper into that also.

While it might appear that not picking up on pressure as a ratio is a missed opportunity, Chris has a clear rationale for staying focused on one or two key goals and making sure the entire group understands those elements of the model first since they are a key stepping stone for future discussions:

Table 51: Transcript, Bayedge Interview

<p>| | |</p>
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<tbody>
<tr>
<td>Chris</td>
<td>Well that goes to having enough time to do these meetings which you know I- I notice by being in some teachers' classrooms like they rush it so even you can have that model but they still don't understand it so if you don't spend that time really talking about it asking questions pulling things out from other students not everyone's gonna understand it, which amazes me that since I've done it with you that when I have my meeting and just focus on one or two things I can get an understanding just about a hundred percent of my kids.</td>
</tr>
<tr>
<td>Interviewer</td>
<td>Because you spend more time on that those one or two ideas and instead of talking about everything?</td>
</tr>
<tr>
<td>Chris</td>
<td>And not overloading and really letting them come to an understanding, so when they have an understanding on those initial ideas they're gonna have a starting point for when we add to it.</td>
</tr>
</tbody>
</table>

7.2.2.2.3 Moves to maintain direction

Goal 5 moves include moves to solicit or summarize what the group is in agreement on (or not). For Bayedge the majority of Goal 5 moves used by the Teacher Leaders were moves to solicit consensus (65%) with only a small percentage (16%) involving the Teacher Leader synthesizing some or all of what is agreed upon or where there is disagreement and then soliciting consensus. For example, general solicitation comments like, “do you all agree” or “So, are there any places of hesitation or discontent that we have? or frustration?” “I think- do we agree on this one? Does this model fit with
"what you think?" were used most. This is in contrast to a turn, like the following example that summarizes the ideas and solicits consensus (“So should we have them separate? Does everyone like them separate? (reads-from-the-computer-where-scribing) Because you increase the temperature, explain what the air puppies do, and then…”).

Goal 5 moves that offered or invited a summary for what the group agreed on were very limited (13%) and were only used to summarize individual ideas. For example, in Biggest Sucker the Teacher Leaders would summarize what the group had just agreed on, reading from what was just recorded on the chart paper as in this example:

(reading) When we create space with our mouths, puppies have room to move up the straw because- wait what'd you say, Heather?

Moves that would help the group summarize the overall take-aways of the discussion or a section of the discussion were lacking in the Bayedge discussions. Instead of soliciting or providing a summary the Teacher Leaders would ask if there was anything else someone would like to add (“So with the- is there still some confusion or questions that people might have... about how--why the bottle is not being crushed?”). Without synthesizing the ideas being discussed along the way, the discussion can feel unfocused and leave Teachers unsure about what the group actually agreed upon at various points in the discussion.

In summary, the Teacher Leaders at Bayedge used APT moves to make space for Teachers to discuss target concepts. The goal of the discussion (e.g. to come to consensus) and the target concepts guided which moves they made as they worked towards these target concepts, even if that meant not picking up ideas that the Teachers were raising in the moment. Thus, the Teacher Leaders made principled decisions about
which ideas to discuss. However, they were less likely to use Goal 5 moves or “naming the that” to synthesize or bound smaller sections being discussed. Therefore, while the Teacher Leaders had the target goals and concepts laid out in the workshop materials in mind and were listening for Teachers to discuss them, the Teachers may have been less clear on the focus of the discussion and what progress was being made.

7.3 Nature of the Teacher Turns: Reasoning and Co-Construction

Another way to characterize the dialogicality of the discussion is to examine the substance of Teacher turns. Teacher turns at Bayedge included reasoning as well as multiple turns that included co-construction of ideas between Teachers.

In this section I will present results regarding the length and substance of Teacher turns in terms of depth of their response and whether their response included reasoning or explanation. I will then share results around how Teachers are interacting with each other using indicators of the co-construction of ideas.

7.3.1 Depth of Teacher Response: Reasoning/Explanation

Productive discussions involve Teachers deepening their understanding by making meaning through talk. During these discussions the Teacher Leader worked to encourage Teachers to share their reasoning including longer and more complex responses. Figure 35 shows the substance of the Teacher turns (reasoning or explanation) using the P1-P3 codes. Turns coded with P3 included an explanation of their thinking, P2 turns included a complete thought but no explanation or reasoning, and P1 turns consisted only of a word or phrase.
Over 76\% of Teacher turns were coded as a P2 or P3 (grey and orange bars) with almost half of Teacher turns including reasoning or explanation (P3). Short P1 responses made up less than 20\% of the Teacher turns. The Teacher Leaders would push for elaboration using Goal 1 and Goal 4 APT moves as well as wait time to encourage Teachers to say more or to respond to others ideas. A typical example of a high number of Goal 1 moves is the exchange below during the Bottle on the Table discussion:

**Table 52: Transcript, Bayedge P1-P3**

<table>
<thead>
<tr>
<th></th>
<th>Teacher Leader</th>
<th></th>
<th>Goal 1- Revoice</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Teacher Leader</td>
<td></td>
<td>Goal 1- Revoice</td>
</tr>
<tr>
<td>6</td>
<td>Heather</td>
<td></td>
<td>P1</td>
</tr>
<tr>
<td>7</td>
<td>Female 1</td>
<td></td>
<td>P2</td>
</tr>
<tr>
<td>8</td>
<td>Mark</td>
<td></td>
<td>P3</td>
</tr>
<tr>
<td>Turn</td>
<td>Participant</td>
<td>Dialogue</td>
<td>Goal/Action</td>
</tr>
<tr>
<td>------</td>
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<td>-------------</td>
</tr>
<tr>
<td>9</td>
<td>Shawna</td>
<td>there’s a million inside the bottle—there must be millions of billions outside the bottle.</td>
<td>P3</td>
</tr>
<tr>
<td>10</td>
<td>Teacher Leader</td>
<td>So can you clarify and say there’s the same number hitting the bottle inside and outside—hitting the wall on wheels. Right? So if you have an equal number hitting the wall on wheels outside as you do inside.</td>
<td>Goal 1-Say More</td>
</tr>
<tr>
<td>11</td>
<td>Shawna</td>
<td>What’re you saying the wall on wheels is?</td>
<td>Goal 1-Say More</td>
</tr>
<tr>
<td>12</td>
<td>Kate</td>
<td>The container— the.. plastic- (gestures to show the sides of the bottle)</td>
<td>P1</td>
</tr>
<tr>
<td>13</td>
<td>Kate</td>
<td>Maybe the wall on wheels is also like the other objects in room 2. (...)</td>
<td>P2</td>
</tr>
<tr>
<td>14</td>
<td>Teacher Leader</td>
<td>Is- can you explain more about that? (What do you mean by that?)</td>
<td>Goal 1-Say More</td>
</tr>
<tr>
<td>15</td>
<td>Teacher Leader</td>
<td>Um.. thinking about there being more air puppies on the outside than on the inside, why isn’t it crushing the bottle because they’re also pushing on other walls on wheels in the space.</td>
<td>P3</td>
</tr>
<tr>
<td>16</td>
<td>A few</td>
<td>(looking at the group) So do you agree? Do you think there could be other walls on wheels in the space?</td>
<td>Goal 4-Agree/Disagree</td>
</tr>
<tr>
<td>17</td>
<td>Teacher Leader</td>
<td>So expand on that, tell me (what do you think they are?)</td>
<td>Goal 1-Say More</td>
</tr>
</tbody>
</table>

In this exchange we see both space being made for Teachers to respond as shown by the turns 6-9 with no Teacher Leader interjection as well as the Teacher Leader pushing for elaboration (turns 10, 13, 15, 17).

### 7.3.2 Depth of Teacher Turns: Co-construction of ideas

An important goal of these discussions and dialogic teaching is to get participants to think with others where the participants and the facilitator work together to co-
construct meaning. An examination of how Teachers at Bayedge were working together to co-construct meaning revealed high rates of co-construction for the Bottle on the Table (111 co-construction moves/hour) and Soap Bubble (89 co-construction moves/hour) discussions and fewer turns coded as co-construction for the Biggest Sucker (56 co-construction moves/hour). Though the Biggest Sucker discussion shows segments where Teachers worked with other’s ideas, the discussion was also marked by segments where the Teacher Leader was trying to capture the ideas on chart paper leaving little Teacher co-construction during those segments. With the exception of the Biggest Sucker, the rates of co-construing in Bayedge were similar to the rates of the LDA sites (Bottle on the Table 98/hour; Biggest Sucker 92/hour and Soap Bubble 72/hour).

The majority of co-construction moves were ‘add-on’ moves (27%) followed by moves showing Teachers building on others’ ideas coded as ‘clarify own’ moves (25%) – Teachers provide more information about their own idea in response to a request for clarification (24%). Figure 36 shows the breakdown of Teacher co-construction moves as a percentage of the total co-construction moves.
In summary, Teachers used co-construction moves to work with each other’s ideas across discussions at similar rates as the LDA discussions. Segments where Teachers added on to others’ ideas, asked for clarification, and clarified their own ideas without interruption by the Teacher Leader were common indicating that the Teacher Leaders provided space for Teachers to talk to each other. Since one of the goals of these discussions is to allow for the co-construction of ideas between participants, providing opportunities these opportunities for participants to work together is important.

7.4 Summary of Research Question 2 and 3: Bayedge

This chapter focused on research question 2 (What are the characteristics of talk when Teacher Leaders enact whole-group consensus discussions with Teachers during science PD?) and question 3 (How does the facilitation of whole-group consensus discussions by
Lead Facilitators compare to the Teacher Leaders’ enactment of the same discussions?)

Similar to the LDA sites, Teacher Leaders at Bayedge used APT moves at a high rate across discussions and most frequently with Goal 1, 4, and 5 moves as well as wait time. They used these APT moves and wait time to help Teachers clarify their ideas and to work with their peers. A deeper look at the discussions showed that, like the LDA sites, Teacher turns were longer and more frequent than Teacher Leader turns, and included explanation and reasoning. Additionally, Teacher interaction during Bayedge discussions showed multiple Teachers, working with other’s ideas without Teacher Leader intervention (high rate of co-construction moves between Teachers). Though the participation rates were lower in the Bayedge discussions (50-73% Teachers) compared to the LDA discussions (over 80% of Teachers). Bayedge Teacher Leaders noted the importance of the co-construction moves in order to facilitate Teachers’ own sensemaking as well as the group’ co-constructing of meaning.

However, while the Teacher Leaders made space for Teachers to work with their own and others ideas, they did not use the moves in the same way as the Teacher Leaders to help the group converge on what is being discussed. Unlike the Lead Facilitators during the LDA discussions, Bayedge Teacher Leaders did not use APT moves as readily to synthesize or bound smaller sections of the discussions or to provide closure, often making the discussion feel unfocused. Though, Teacher Leaders helped maintain some focus and direction by using a clear, phenomenon-focused launch and public records like chart paper to capture and synthesize the ideas the Teachers shared.

The Teacher Leaders discussed that experiencing the phenomena and discussions themselves as learners was important in helping them lead the discussions:
Well I think the most helpful was me experiencing it with the student hat and the teacher hat...’cause first you made us [do it] which was intimidating...but um that was huge for me ‘cause I had to experience it as a student first and then put on my facilitator hat saying okay so how would I do this in my class and then the fact that you made us lead a discussion after this... -Chris.

The opportunity to experience it, lead it, experience, lead it like, I when you were leading the discussions two weeks ago, I was learning again cause I hadn't been a participant in a while - Jill, Site A

Both Bayedge Teacher Leaders also discussed how understanding the content themselves was both needed to lead the discussions and a challenge for them. For example, Jill noted:

Yeah and it, it was intimidating because of, umm they're high school teachers middle school teachers that focused on this, I had never taken a physics class in my life...ummm I had never taken uhh upper level chemistry, you know like I just, lacked the content knowledge. But I felt so good about my facilitation training and I trusted the NGSX process and the tools, so I had, I held on to the tools extra tight to overcompensate. -Jill

Teacher Leaders stated that their moves were guided by the goal of the discussion, even if that meant not picking up other target concepts that the Teachers were discussing in the moment. They made principled decisions about the ideas to discuss and how to reach their goals. However, they were less likely to use moves to name or focus the talk around these target concepts, which in turn made the focus of the discussion sometimes less clear or oriented the Teachers about what progress was being made towards the target concepts.

In the next chapter I will analyze the same discussions led by the Teacher Leaders at Lakecastle and how those compare to those led by the Lead Facilitators.
CHAPTER 8

RESULTS: LAKECASTLE

In this chapter I will share the results for Lakecastle for research question 2 (What are the characteristics of talk when Teacher Leaders enact whole-group consensus discussions with Teachers during science PD?) and question 3 (How does the facilitation of these whole-group consensus discussions by the Lead Facilitators compare to the Teacher Leaders’ enactment of the same discussions?). I will begin with an examination of the interaction patterns between and among Teachers and the Teacher Leaders. I will then share the results around what APT moves Teacher Leaders use and in what ways they use them. This will be followed by the results of what the Teachers are doing in terms of reasoning and co-construction of ideas. Rationale for the Teacher Leaders’ moves provided in the interviews will be included throughout to support the patterns that emerged.

8.1 Interaction Patterns

Similar to the LDA sites, Lakecastle discussions had high participation rates characterized by multiple Teacher turns and Teacher to Teacher exchanges where the Teachers were working with other’s ideas without Teacher Leader intervention. The Teacher Leaders at Lakecastle also stayed with the same Teacher for more than one turn to clarify or challenge their ideas. Participation rates were lower for Soap Bubble (53%) but similar for Bottle on the Table (74%) and Biggest Sucker (94%) compared to the
LDA discussions (over 80%). Results from word and turn counts, percent of different Teachers talking, and interaction patterns for Bayedge will each be examined below.

The low inference measures of Teacher Leader turns and word counts can indicate how Teachers are being positioned to contribute to the discussions. Teachers took more turns for Bottle on the Table (98 turns) and Biggest Sucker (108 turns) than Teacher Leaders (72 turns and 79 turns). For Soap Bubble the Teachers Leaders had more turns (62) than the Teachers (52). Teacher turns were longer or a similar length (16-29 words/turn) compared to the Teacher Leader turns (17-21 words/turn). In general, Teachers contributed often and with long turns.

Another low inference measure of Teacher interaction is the number of teachers who contributed in a particular discussion. Since a goal of these discussions is for all Teachers to develop understanding and co-construct ideas, then getting as many Teachers involved in the discussion as possible is important. Figure 37 shows the percentage of Teachers who took at least one turn for each of the discussions. The Bottle on the Table and Biggest Sucker discussions had high rates of participation (74%-94%) while just over half contributed to the Soap Bubble discussion. All of the discussions were of similar duration between 18-20 minutes.
Interaction patterns can help give a better sense of how Teachers and Teacher Leaders are interacting during these turns. Analysis of the peak graphs revealed that Lakecastle discussions included multiple Teacher to Teacher interactions characterized by long exchanges between Teachers without Teacher Leader interruption across discussions. Additionally, the Lakecastle Teacher Leaders would stick with the same Teacher for more than one turn to clarify or dig deeper into their ideas. The more traditional sequence of back and forth between Teacher Leader and different Teachers in a row was seen least often. Each will be discussed below with examples to illustrate the patterns.

8.1.1 Working with the same Teacher.

Lakecastle interaction patterns showed some segments where the Teacher Leaders stuck with the same Teacher for more than one turn shown in green on the CDA peak graphs. This was particularly true for the Soap Bubble discussion shown in figure 38.
Figure 38: Peak graph showing Teacher Leader to same student turns, Lakecastle:

Soap Bubble

Here, the Teacher Leaders used APT moves to help clarify and uncover the Teacher’s thinking. In Bottle on the Table there were segments where the Teacher Leaders stayed with the same Teacher for 2, 3, and 5 turns, using moves to ask for elaboration and pose clarifying questions. Sticking with the same Teacher to clarify and dig deeper was seen less often with the Biggest Sucker discussion.

8.1.2 Teacher-to-Teacher interaction.

Lakecastle discussions were marked with multiple Teacher to Teacher exchanges across all discussions. This can be seen in the blue segments in Figure 38 above and also in this annotated example from Bottle on the Table shown in Figure 39 below.
In most cases, these interactions involved Teachers working with each other’s ideas, posing questions, clarifying, and agreeing or disagreeing. For example, the 14-turn example shown in Figure 39 between turns 99-112 show six different Teachers working with other’s ideas.

**Table 53: Transcript, Lakecastle Teacher Interaction**

<table>
<thead>
<tr>
<th></th>
<th>Teacher</th>
<th>Leader</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>Teacher</td>
<td>Leader</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hilary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>Hilary</td>
<td>Leader</td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>Leader</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Um, so because this air puppy cannot move nearly as much as this air puppy can, it will hit the bottle a lot more than this air puppy will hit the bottle. But there's a lot more air puppies out here to hit the bottle than there are in here to hit the bottle, so these guys have to hit the bottle a lot more than these guys do, but these guys have a bigger team.

Hm.
<table>
<thead>
<tr>
<th>Turn</th>
<th>Speaker</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>Kate</td>
<td>I found it really helpful to make a grid. Like I had to sort of, prove it to myself. When he did the four and eight, I had to make little squares- like okay so four- four puppies, four squares, eight puppies, eight squares. So if I wanted to put four more puppies on the eight side I'd need four more squares of space. So they were like, invisible squares, it was just that this space, to keep it balanced.</td>
</tr>
<tr>
<td>103</td>
<td>Naomi</td>
<td>And some of these air puppies out here in the room are never going to hit that bottle.</td>
</tr>
<tr>
<td>104</td>
<td>Many</td>
<td>Right, yeah.</td>
</tr>
<tr>
<td>105</td>
<td>Jenna</td>
<td>That's what I was just thinking too (looking at Naomi)</td>
</tr>
<tr>
<td>106</td>
<td>Naomi</td>
<td>There's tons of them here that are never going to hit that bottle. Whereas the guys inside are all going to have a much greater- you'd think even with the randomness, much more of an opportunity (to hit the bottle).</td>
</tr>
<tr>
<td>107</td>
<td>Karen</td>
<td>I have a general question for Hilary. I'm just trying to make sure I understand what you are saying. You're saying inside the particles have to hit more? than the outside because the outside has the bigger team. So I just want to check and make sure that- what I'm understanding-</td>
</tr>
<tr>
<td>108</td>
<td>Hilary</td>
<td>I think they will hit more, they don't have to-</td>
</tr>
<tr>
<td>109</td>
<td>Karen</td>
<td>Like they each have to take more turns, but in aggregate, the inside is not being hit more than the outside.</td>
</tr>
<tr>
<td>110</td>
<td>Hilary</td>
<td>Right. Right.</td>
</tr>
<tr>
<td>111</td>
<td>Karen</td>
<td>But because there's fewer molecules, each one has to take more turns.</td>
</tr>
<tr>
<td>112</td>
<td>Hilary</td>
<td>Right.</td>
</tr>
</tbody>
</table>

This long segment was initiated by a Goal 1, say more move. Hilary’s response in turn 100 contains a comment about a larger team which Karen asks about in turn 107, and explicates (for herself) more fully in turns 109 and 111, with Karen positioned to evaluate whether Karen has understood her idea fully (in Turns 110 and 112.).

### 8.1.3 Teacher Leader and Different Teachers

Exchanges between the Teacher Leader and different Teachers in the form of Teacher Leader-Teacher 1-Teacher Leader-Teacher 2 (TL-T1-TL-T2) marked by orange
in the peak graphs were limited as you can see in the above Figures 37 and 38. While segments where the back and forth between Teacher Leader and different Teachers can often indicate more traditional IRE exchanges where the Teacher Leader is posing a known answer question and then phishing for the “right” answer, the orange segments for Lakecastle discussions often involved APT moves or were centered around synthesizing or capturing what the group was in agreement about after discussing an idea. Additionally, some segments that appeared orange on the peak graphs were segments where the Teacher Leader was sticking with the same Teacher but there was a turn where multiple people in the group interjected a response (shown as ‘many’ or “a few’ in the transcript). For example, in Figure 40 we see an orange segment from turns 66-71.

Figure 40: Peak Graph for Lakecastle Biggest Sucker

The transcript shows the Teacher Leader staying with the Hannah but a few from the group interjecting. The CDA program codes the turn “a few” as a new Teacher which leads to the peak graph being orange even though the Teacher Leader was sticking with the same Teacher.

Table 54: Transcript, Lakecastle Peak Graph

<table>
<thead>
<tr>
<th>Turn</th>
<th>Teacher</th>
<th>Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>Teacher Leader</td>
<td>Is there somebody that can re-voice that? Re-state that? What’s actually happening when you expand the room? (4 second pause)</td>
</tr>
<tr>
<td>67</td>
<td>Hannah</td>
<td>So, expanding room A means less puppy impacts are happening in room A.</td>
</tr>
<tr>
<td></td>
<td>Teacher Leader</td>
<td>On what? Where are the impacts important?</td>
</tr>
<tr>
<td>---</td>
<td>----------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>68</td>
<td>A few</td>
<td>On the wall.</td>
</tr>
<tr>
<td>70</td>
<td>Teacher Leader</td>
<td>[nodding] On the walls. Okay.</td>
</tr>
<tr>
<td>71</td>
<td>Hannah</td>
<td>Um, yes, [laughter] Um, in room B, when the stopper was open,...the-more puppies can come in [gestures], and so you're getting more puppy impacts on the wall on wheels from that end, and less of the impacts from the wall on wheels from the other end, and so the [gesturing] -the liquid-the wall on wheels can move up.</td>
</tr>
<tr>
<td>72</td>
<td>Teacher Leader</td>
<td>Do we have, uh, any additions or disagreements?</td>
</tr>
</tbody>
</table>

In the following sections I will analyze what moves the Teacher Leaders used to support these patterns of interaction.

### 8.2 Academically Productive Talk Moves

#### 8.2.1 Overall APT Moves and Moves by Goal

Teacher Leaders at Lakecastle used APT Moves at a high rate (Average of 91 APT moves/hour) with Goal 1, 3 and 5 moves used the most making up 86% of the total APT moves. Goal 2 and Goal 4 moves made up 5% and 9% respectively. Lead Facilitators’ had a similar average of 83 APT moves/hour. Lakecastle Teacher Leaders used APT Moves by Goal at a similar but higher rate compared to the Lead Facilitators as shown in table 14, with the exception of Goal 4 moves. Lead Facilitators used almost twice as many Goal 4 moves than the Teacher Leaders.
Table 55: Average APT Moves/Hour by Goal for Bayedge Teacher Leaders and Lead Facilitators

<table>
<thead>
<tr>
<th></th>
<th>Mean Goal 1 Moves (per hour)</th>
<th>Mean Goal 2 Moves (per hour)</th>
<th>Mean Goal 3 Moves (per hour)</th>
<th>Mean Goal 4 Moves (per hour)</th>
<th>Mean Goal 5 Moves (per hour)</th>
<th>Tot Average APT Moves (per hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Leaders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lakecastle</td>
<td>26</td>
<td>4</td>
<td>21</td>
<td>8</td>
<td>31</td>
<td>91</td>
</tr>
<tr>
<td>Lead Facilitators</td>
<td>22</td>
<td>3</td>
<td>15</td>
<td>15</td>
<td>27</td>
<td>83</td>
</tr>
</tbody>
</table>

Lakecastle Teacher Leaders used APT moves at a high rate in all of the discussions. Because a turn could have more than one code, including more than one APT code, rates were used in order to be able to compare across discussions and Teacher Leaders. Additionally, a look at what percentage of turns included an APT move is also helpful in characterizing the use of these moves. The percentage of Teacher Leader turns that contained APT moves was lower for Lakecastle (30-50%) than for the LDA groups (50-70%). Other moves included direct questioning, including IRE, about the elements of the Air Puppies model as in this example from Bottle on the Table:

Table 56: Transcript, Lakecastle Direct Question

<table>
<thead>
<tr>
<th>Turn</th>
<th>Speaker</th>
<th>Message</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Teacher Leader</td>
<td>Can you say more about the divider wall, what you mean by the divider wall?</td>
<td>Goal 1, Say More</td>
</tr>
<tr>
<td>6</td>
<td>Kate</td>
<td>That the bottle is the divider wall in this model.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Teacher Leader</td>
<td>Okay, and so how could you relate that to the air puppies model that Richard-</td>
<td>Direct question about model</td>
</tr>
<tr>
<td>8</td>
<td>Kate</td>
<td>Right, and so that- that's what I was thinking was then if that wall moved, based on the density- or in this case</td>
<td></td>
</tr>
</tbody>
</table>
space, on either side and if you move the wall, the space is the same so there would fewer (or-more) puppies to-

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Teacher Leader</td>
<td>So Richard called that-</td>
<td>IRE (a closed question with a single correct answer)</td>
</tr>
<tr>
<td>10</td>
<td>Female 1</td>
<td>the wall on wheels?</td>
<td>IRE (repetition and evaluation of correct answer)</td>
</tr>
<tr>
<td>11</td>
<td>Teacher Leader</td>
<td>The wall on wheels, the W.O.W. the, yeah, the Wall on Wheels. So we can use that language if we want to talk about the wall on wheels. So what is the wall on wheels do you think?</td>
<td>Direct question about the model</td>
</tr>
</tbody>
</table>

These direct moves align with the goal of the discussion which is to apply the Air Puppies Model to explain a phenomenon. Since this is the first time Teachers are asked to apply the model, the Teacher Leaders may have used these more direct moves to keep a focus there. Cady commented on this segment and why she was more directed:

So that was I think purposeful because it was relating, this model that Richard had introduced to, the actual physical model in front of us and so, I think I made a quick transition there to say we don't need to talk about the- the divider anymore, we can just call it the wall on wheels cause we have, seen a model that, that works perfectly for that.

Yeah and for me I think this- in this discussion the goal was to- to connect. It was like to say we have this, we saw this happen, we have this, now we have this third, well second phenomenon right we had a phenomenon then a model, and then another phenomenon, and the goal is to like be constantly, connecting them.

For the Biggest Sucker discussion which had the lowest percentage of turns with at least one APT move, other moves included soliciting the step-by-step explanation (e.g. “and then what happens?”). These segments often included APT moves and were used after the ideas had been discussed and the Teacher Leader was then trying to capture on paper what was agreed upon. Similar segments could be seen in the LDA groups. Additionally,
there were segments where a Co-Teacher Leader might interject or where they would repeat what the other said, as in this segment in Soap Bubble:

**Table 57: Transcript, Lakecastle Overlap**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Teacher Leader 1</td>
<td>So it seems like there's some curiosity just about the relationship maybe with that new addition from the last phenomenon, which was the spring, and this new material, soapy material, um, but I wonder if what we really want to think about is how can we represent the temperature addition to this model. So maybe we don't--can we all agree that maybe we don't need to get stuck on the balloon--the soap film versus the balloon. Maybe they act in the same way, but maybe what we really want to account for is this, this temperature.</td>
</tr>
<tr>
<td>42</td>
<td>Teacher Leader 2</td>
<td>Which is really a new rule.</td>
</tr>
<tr>
<td>43</td>
<td>Teacher Leader 1</td>
<td>Which is really a new rule.</td>
</tr>
<tr>
<td>44</td>
<td>Teacher Leader 2</td>
<td>We sort of have to write a new rule.</td>
</tr>
<tr>
<td>45</td>
<td>Teacher Leader 1</td>
<td>Right.</td>
</tr>
<tr>
<td>46</td>
<td>Teacher Leader 2</td>
<td>Don't we?</td>
</tr>
<tr>
<td>47</td>
<td>Teacher Leader 1</td>
<td>So maybe--right. So maybe the question is does the temperature change or do we just add an additional rule to--</td>
</tr>
<tr>
<td>48</td>
<td>Teacher Leader 2</td>
<td>Remember our Lego rules? Like to we need a new temperature Lego rules.</td>
</tr>
</tbody>
</table>

A breakdown of average moves per APT goal across the discussions at Lakecastle is shown in Figure 41.
Figure 41: Average APT Moves Used per APT Goal for Lakecastle

- **Goal 1 Moves.** Goal 1 Moves work to help individuals share, expand and clarify their own thinking. Say more moves made up 60% of the Goal 1 Moves while the remaining 40% were revoicing moves. Lead Facilitators used revoicing moves the most (54%) followed by say more (40%) and think time (e.g. turn and talk to a partner, 6%).

- **Goal 2 Moves.** Moves that help Teachers listen to each other by asking for someone in the group to restate what someone else said were used minimally (average of 4 moves/hour and 5% of total APT moves used). This move was used most in the Biggest Sucker discussion and was used after exchanges when Teachers were discussing a target concept. For example, during the Biggest Sucker discussion after 11 turns discussing what happens when the size of the room (volume) expands, the Teacher Leaders says, “Is there somebody that can
revoice that? Restate that? What’s actually happening when you expand the room?”

- **Goal 3 Moves.** Moves to help Teachers dig deeper into their own reasoning were used at an average rate of 21 moves/hour, which is even higher than the average of 15 moves per hour for Lead Facilitators. Press moves were used the most (average of 11 moves/hour) followed by why (5 moves/hour) and challenge (4 moves per hour). Why moves were used almost twice as often by Teacher Leaders at Lakecastle (5 moves/hour) compared to Lead Facilitators (2 moves/hour).

- **Goal 4 Moves.** Moves to help Teachers reason with others (Goal 4) were used the least at an average of 8 moves/hour compared to an average of 15 moves/hour for Lead Facilitators. Interestingly, Goal 4 moves were used at Lakecastle more than twice as much (13 moves/hour) in the Biggest Sucker compared to the other discussions. Of the Goal 4 Moves used, the majority (70%) were add-on moves that invited participation from others to join in and respond to someone else’s idea (e.g. “What do people think about that?”).

- **Goal 5 Moves.** Goal 5 moves included moves to either solicit or summarize what the group is in agreement on (or not). Goal 5 moves include the facilitator offering a summary or inviting a Teacher to summarize as well as moves to solicit consensus (“do we all agree on that?”) or solicit consensus with a summary (“can we all agree that the bottle is the wall on wheels?”). Moves to solicit consensus made up just over 65% of the Goal 5 moves with 26% of those moves including a summary before asking for consensus. This is similar to the Lead Facilitators for
whom 72% of goal 5 moves were aimed at soliciting consensus with 32%
including a summary. Lead Facilitators and Teacher Leaders used moves to
invite or provide a summary at a similar rate (28% and 35% of Goal 5 moves). A
deeper analysis of how these Goal 5 moves were used at Lakecastle will be
further examined in the next qualitative analysis section.

- **Other Teacher Leader moves.** In addition to APT moves, teacher turns were
coded for wait time, defined as pauses that are 3 seconds or longer. Teacher
Leaders at Lakecastle used wait time ranging from 3-10 seconds before, during,
and after Teacher turns at the same average rate as Lead Facilitators (10
times/hour). Wait time was used after a Teacher Leader prompt. For example,
“Is there somebody that can revoice that? Restate that? What’s actually happening
when you expand the room? (4 second pause)” seen in the Biggest Sucker
discussion. Additionally, the Teacher Leaders used wait time within or after a
Teacher turn as in this example from the Biggest Sucker:

Naomi: So (there) are fewer puppy impacts, once you increase that space. And in
the one that was open, [gesturing], now like you said, we're adding more and
more puppies impacts so there you have more and more puppy impacts, so it's
pushing more-[gestures] (3-second-pause)

In both cases, the wait time allowed space for Teacher voices.

These frequency counts of APT moves only provide a partial story of the use of
these moves. In the next section I will share patterns of their use around the two
qualitative themes used in the analysis of the LDA groups and how that relates to the
Goals of APT.
8.2.2 Patterns in How APT Moves Were Used

The Lakecastle transcripts were analyzed to identify patterns in how the moves were used to support participant engagement and focus and direction with respect to idea development. Teacher Leaders at Lakecastle made space for Teachers to talk, used moves to dig deeper into Teacher’s thinking and to open up the discussion. They supported idea development through focused segments of the discussion, focused attention around ideas to discuss, and synthesis and consensus moves to maintain direction. These two themes with examples from the transcripts and comments from the interviews are discussed below.

8.2.2.1 Theme 1: Using Moves to Support Teacher Engagement and Participation

Lakecastle Teacher Leaders used moves to make space for and invite participation both to work with their own and other’s ideas and with the target concepts of the discussion (e.g. understanding pressure in terms of a ratio of air molecules to space [concentration] versus the sheer number of air molecules.) Table 58 shows the sub-themes for theme 1.

Table 58: Summary of Theme 1 for Lakecastle

<table>
<thead>
<tr>
<th>Theme 1: Using moves to support Teacher engagement and participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making space for participants to talk</td>
</tr>
<tr>
<td>● “No move” and wait time to allow participants to talk to each other</td>
</tr>
<tr>
<td>● Interviews spoke to “being comfortable with the silence” to make the discussion theirs</td>
</tr>
<tr>
<td>Using moves to dig deeper into Teachers thinking</td>
</tr>
<tr>
<td>● Goal 1 and 3 Moves</td>
</tr>
<tr>
<td>● Interviews spoke to sticking with the same participant</td>
</tr>
</tbody>
</table>
Using Moves to open up the discussion to other Teachers and ideas

- Goals 2, 4, and wait time
- Not interjecting so that they talk to each other

8.2.2.1.1 Making space for participants to talk.

Teacher Leaders at Lakecastle made space for participants to talk by not interrupting and using wait time. For example, in Bottle on the Table, the discussion starts with three long participant turns before Cady (Teacher Leader 1) interjects with a Goal 1, say more, move.

Table 59: Transcript, Lakecastle Making Space

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Hannah</td>
<td>Um, I would say that uh, well I guess if you, you know you capped it normally, you didn't do anything to the air inside or outside in terms of heating or cooling or anything, um, we- the air puppies model kind of defined how the puppies function and what they do, so they just bumble around, randomly- um- they don't stick to anything. Like he was saying we don't necessarily have to go back and figure out how that person figured that out, but we (can) find that already? So what the air puppies do? And so if there's um, the same, um- because you capped it at an even temperature, and didn't change the temperature inside or outside the bottle, there should be the same, uh, density of puppies inside and outside, and they act in a certain way and that keeps the edges of the bottle from either going in or out.</td>
</tr>
<tr>
<td>3</td>
<td>Violet</td>
<td>I also think that the edges of the bottle, are the- what he was referring to as the divider in the middle, and as they're bouncing off each other, some of the- right now, since there isn't any sort of a change, we didn't pour hot water in it. It stays the same.</td>
</tr>
<tr>
<td>4</td>
<td>Kate</td>
<td>I was thinking about the model that he had made and we sort of- it seemed to me that we learned from the model that the one third and two third- that each puppy requires the same amount of space. And so even though there aren't the same number of puppies on the inside of the bottle as there are in this room, that there's the same, um, that they're using the same amount of space in each place. And so the edge of the bottle is the divider wall and it's not moving in at all and then so- the puppies inside and outside must be moving at the same speed in the same space, (...) cube.</td>
</tr>
<tr>
<td>5</td>
<td>Teacher Leader 1</td>
<td>Can you say more about the divider wall, what you mean by the divider wall?</td>
</tr>
</tbody>
</table>

221
Cady spoke about this segment and her intentionality in *not* interjecting.

So I- I waited for three people, to speak right? [Yeah.] So I think some of that for me is- is waiting. So I think that's sort of a talk move right? It's just like letting- letting the discussion happen and take on, potentially try to you know, to let them make the relationships between what they're saying as opposed to me facilitating that.

She went on to discuss that, while it can be challenging to remain silent, it is important so that the Teachers feel ownership in the discussion:

So I remember, feeling the space that was created between my talk…where I sort of have to sit and be like, comfortable with the silence and I think that's really important, um because- because I think even when I work with my own students like if you jump in you're- you're managing and massaging the conversation but you want the conversation to be theirs not, managed by me.

Teacher Leaders at Lakecastle also talked about the tension between making space for Teachers to discuss their ideas while balancing the need to make progress on the target conceptual goals of the discussion. For example, in the Soap Bubble discussion there was a 23-turn exchange about including the idea of elasticity into their models. Cady made space for this discussion and then redirected towards the target concept of the role of temperature on pressure. She reflected on the importance of honoring the ideas that Teachers want to discuss.

So I think- I think letting it- if it's more than one p- like I think if you- if one person brings up something and you, clamp it down quick, you aren't honoring the, the contribution. And …you're not even honoring that- that like- that may have relevance to someone, for explaining, the- the phenomenon at hand… I felt like it honored the, the real, relevance of that but then it was like…we need to agree on the model.
8.2.2.1.2 Dig deeper into Teachers’ thinking.

Lakecastle Teacher Leaders used moves to help clarify and dig deeper into Teachers’ ideas. Segments like the 23-turn episode from Soap Bubble where several participants were talking to each other, were often followed by APT moves that would seek to uncover or clarify Teachers’ thinking. For example, in the Bottle on the Table example, shown above, we see Cady use a Goal 1, say more move where she specifically targets an idea that was mentioned in the long turns that came before and asks what they mean.

In a segment in the Biggest Sucker we see Cady use Goal 3 and Goal 1 moves (a series of revoicing or partial revoicing moves) to uncover Karen’s ideas about how using a syringe helped her understand the two rooms in the model:

**Table 60: Transcript, Lakecastle Dig Deeper**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Karen</td>
<td>I found it a little easier to think about Room A this is why the, syringes are added in there too, that it's easier for me to think about room A, where-to include the straw, when it has the syringe in it, or, like, the mouth is clamped on, so it included whatever parts of my (...) system, that just made that-easier.</td>
</tr>
<tr>
<td>41</td>
<td>Teacher Leader 1</td>
<td>Why? Why did that make it easier for you?</td>
</tr>
<tr>
<td>42</td>
<td>Karen</td>
<td>Um, because in the-phenomenon, like the-the bottles, I think Renee was there when I was describing it this way, as the bottles were given to us was not the phenomenon itself? So it was only when the syringe was in place, or a mouth was on the straw, that the phenomenon was happening.</td>
</tr>
<tr>
<td>43</td>
<td>Teacher Leader 1</td>
<td>So the mouth-</td>
</tr>
<tr>
<td>44</td>
<td>Karen</td>
<td>So considering the straw opened, wasn't-when it was happening, it seemed to be getting in the way a little bit?</td>
</tr>
<tr>
<td>45</td>
<td>Teacher Leader 1</td>
<td>So it was the closing of the room?</td>
</tr>
<tr>
<td>46</td>
<td>Karen</td>
<td>Yeah.</td>
</tr>
</tbody>
</table>
In a similar segment in the Soap Bubble discussion, the Teacher Leader used Goal 1 and Goal 3 moves as well as non-evaluative continue moves (e.g. Okay) with the same Teacher for 8 turns. Cady spoke to sticking with the same participant before using other moves to help open it up to the group.

I notice just in my own discussions with my students that I will do that I often isolate, a single person— And just work with them and let that discussion transform so that either a revoice happens and then I usually ask for a revoice from somebody else.

8.2.2.1.3 Using Moves to open up the discussion to other Teachers and ideas.

The Teacher Leaders at Lakecastle also used Goal 2 and Goal 4 moves to open up the discussion to other Teachers. Goal 4 moves were used before and after long participant exchanges such as this one from Biggest Sucker:

| 11 | Megan | Room A is the str-the air in the straw, room B is the room is the air above the water level [gestures], and..the, uh, the wall of wheels is the water surface [gestures]. So, because the water surface changes, and go down. |
| 12 | Teacher Leader 2 | Does anybody wanna..expand on that, or-or agree or disagree? |
| 13 | Jenna | We-we thought the water surface as well, and then we thought-thought about it a little bit differently because we had some help, um, that maybe it was the-that the wall on wheels is the water, and all of the water [gestures], initially we were thinking the surface because that was where the molecules- |
| 14 | Megan | oh, the whole (nodiding) |
Jenna: The puppies were hitting, that they were hitting the surface and forcing that down, but the wall was-everything moved, which was the entire amount of water (looks-at-Megan).

Megan: [nodding] mm hm, because it's between the two rooms.

Jenna: Right.

Megan: The whole thing.

Jenna: Does the water always have to move? Or have to be able to move? 'Cause I feel like-we automatically say, oh the wall on wheels must be the thing that's moving, but then is that how it always has to be?

Hilary: The whole thing.

Teacher Leader 2: What do people think about that?

In turn 21 we see Sarah (Teacher Leader 2) use a Goal 4 move to have others in the group respond even though Hilary was talking directly to Sarah. She explains why she did this:

Well, um this is a consensus discussion so it really isn’t about me anyway it’s about them so of course I would turn it around and put it on them.

In line 21 the Teacher Leader does not “name the that” she wants the group to respond to. However, in other examples we see specific naming of the ideas to be addressed. In Bottle on the Table the Teacher Leader uses a Goal 2 move in turn 66 that “names the that”

Table 62: Transcript, Lakecastle Open Up 2

<table>
<thead>
<tr>
<th>66</th>
<th>Teacher Leader 2</th>
<th>(3 sec pause) Is there somebody that can re-voice that? Re-state that? What’s actually happening when you expand the room? (4 second pause)</th>
</tr>
</thead>
<tbody>
<tr>
<td>67</td>
<td>Hannah</td>
<td>So, expanding room A means less puppy impacts are happening in room A.</td>
</tr>
<tr>
<td>68</td>
<td>Teacher Leader 1</td>
<td>On what? Where are the impacts important?</td>
</tr>
<tr>
<td>69</td>
<td>A few</td>
<td>On the wall.</td>
</tr>
<tr>
<td>70</td>
<td>Teacher Leader 1</td>
<td>[nodding] On the walls. Okay.</td>
</tr>
</tbody>
</table>
Um, yes, [laughter] Um, in room B, when the stopper was open,...the-more puppies can come in [gestures], and so you're getting more puppy impacts on the wall on wheels from that end, and less of the impacts from the wall on wheels from the other end, and so the [gesturing] -the liquid-the wall on wheels can move up.

<table>
<thead>
<tr>
<th>71</th>
<th>Hannah</th>
<th>Do we have, uh, any additions or disagreements?</th>
</tr>
</thead>
</table>

This exchange and the Goal 4 move in turn 72 allowed for a different Teacher in the turns that follow to join in and express confusion over what happens when the room expands (volume increases).

Additionally, the Teacher Leaders would invite Teachers to engage with others’ ideas by inviting questions instead of offering their own idea. In Bottle on the Table we see the Teacher Leader invite participation in this way:

Table 63: Transcript, Lakecastle Open Up 3

<table>
<thead>
<tr>
<th>42</th>
<th>Meredith</th>
<th>At first I thought (that way)- that is was the air particles in the bottle was able to- was outside the bottle. But now, I'm thinking of it as- that's the wall on wheels and everything around it is pushing on it at the same amount and I'm not really considering what's in the bottle right now.</th>
</tr>
</thead>
<tbody>
<tr>
<td>43</td>
<td>Teacher Leader</td>
<td>So does someone have a question for Meredith about that?</td>
</tr>
</tbody>
</table>

Meredith’s turn was long and potentially confusing. By asking others to respond the Teacher Leader helped support the culture that it is the group that is building the understanding together.

8.2.2.2 Theme 2: Maintaining focus and direction.

Teacher Leaders at Lakecastle used a clear launch focused around the phenomenon being discussed and provided opportunities for Teachers to discuss the target concepts. The
discussions were organized into clear segments focusing on particular concepts, with closure throughout the discussion. The Teacher Leaders used Goal 5 Moves to help synthesize or direct attention to the concepts or mechanisms being discussed. Table 64 shows the three sub-themes for maintaining focus and direction (segments of the discussion, focused attention around ideas to discuss, and synthesis and consensus moves to maintain direction) and the specific moves Teacher Leaders made.

**Table 64: Summary of Theme 2 for Lakecastle**

<table>
<thead>
<tr>
<th>Theme 2: Maintaining focus and direction</th>
</tr>
</thead>
</table>
| **Segments of the discussion.** | ● Launch focused on phenomenon and goal of the discussion  
● Use of moves to focus or redirect segments of the discussion  
● Closure at the end and along the way |
| **Focused attention around ideas to discuss** | ● Goals 1, 2, and 4 to make space to discuss target concepts and challenge use of scientific vocabulary  
● More directed segments  
● Use of understanding of the goals of the discussion to influence the moves they make. |
| **Moves to maintain direction, support convergence, and come to consensus** | ● Goal 5 moves to solicit consensus with summary  
● Summarizing or synthesizing followed by clear, focused direction |

8.2.2.2.1 Segments of the discussion.

Teacher Leaders at Lakecastle began the discussion with a clear launch and used moves to bound segments of the discussion by synthesizing ideas, including closure at the end of the discussion and capturing the ideas on some sort of public record.

**Launch.** Similar to the LDA discussions, Lakecastle Teacher Leaders highlighted the goal of the discussion, focused on the phenomenon being discussed,
reinforced discussion norms, and often provided a clear direction for where to start as in this example from the Biggest Sucker:

**Table 65: Transcript, Lakecastle Lauch**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Teacher Leader 1</td>
<td>So, um, before we have the scientist meeting, um, the purpose is to come to some consensus of the explanation or the reasoning for this phenomenon. So, is there somebody who feels comfortable--...oh, and I also probably should remind you of the norms, did we post them somewhere--?</td>
</tr>
<tr>
<td>2</td>
<td>Meredith</td>
<td>They fell down right over there-</td>
</tr>
<tr>
<td>3</td>
<td>Teacher Leader 1</td>
<td>They fell down, (laughter). Do you all need to be reminded of the (...) norms? Here (turns-the-paper-for-them-to-see)...you all did such a wonderful job.</td>
</tr>
<tr>
<td>4</td>
<td>Teacher Leader 1</td>
<td>(reading) respectful, focused in reasoning, equitable</td>
</tr>
<tr>
<td>5</td>
<td>Teacher Leader 1</td>
<td>Okay. So, e-anyway, we've agreed to these norms, so the question is, could someone remind us of the phenomenon we're trying to explain?</td>
</tr>
<tr>
<td>6</td>
<td>Naomi</td>
<td>I'll do that. (laughter) Um., we're trying to explain, what happened to the two bottles and why it was easier...or faster...to suck [gestures] water out of one or the other.</td>
</tr>
<tr>
<td>7</td>
<td>Teacher Leader 1</td>
<td>Okay. And the one that was easier, to..get the water out of, was the, which one? (looking at Naomi)</td>
</tr>
<tr>
<td>8</td>
<td>Naomi</td>
<td>In our experience, the one with the opened stopper hole.</td>
</tr>
<tr>
<td>9</td>
<td>Teacher Leader 2</td>
<td>Okay. Any questions about the phenomenon?</td>
</tr>
<tr>
<td>10</td>
<td>Teacher Leader 1</td>
<td>Okay, so...let's just start by discussing if, um, w-hat are the components, the..wall on wheels, and the two rooms, or the two air spaces. See what-where we get with that. Does someone want to volunteer to begin?</td>
</tr>
</tbody>
</table>

While the launches varied, including how they revisited the norms, all included a focus on the phenomenon and a mention of the goal of coming to consensus on an explanation for the phenomenon, which helped focus the work of the group.

**Focal segments.** Lakecastle Teacher Leaders used moves to focus the discussion around target concepts or aspects of the model, made space for participants to discuss
those ideas, helped synthesize that segment and then refocused on another target idea. For example, the Bottle on the Table discussions both included a segment focused on mapping the air puppies model onto the real world phenomenon and then a synthesis and relaunch to explain why the bottle is not collapsing. Within each segment, the Teacher Leaders used moves to invite participant-to-participant interaction as well as moves to help them dig deeper. Figure 42 illustrates this for the Biggest Sucker by annotating the CDA peak graph.

Figure 42: Annotated CDA peak graph for Biggest Sucker, Lakecastle showing moves used to maintain focus around key segments.

A similar pattern is seen for the Lead Facilitators as shown in figure 43 below for the Biggest Sucker LDA 1.
Figure 43: Annotated CDA peak graph for LDA 1, Biggest Sucker showing moves used to maintain focus around key segments.

Like the LDA groups, this pattern of clear segments of the discussion focused on key concepts and goals of the discussion can be seen in all three discussions at Lakecastle.

**Closure.** Lakecastle Teacher Leaders helped maintain direction and focus by synthesizing at key points in the discussion. Teacher Leaders often synthesized where the group seemed to be at that point in the discussion before relaunching into a new area of discussion. For example, in Bottle on the Table we see this segment that synthesizes and solicits consensus on the elements of the model before moving to explain why the bottle is not collapsing in turn 41.

**Table 66: Transcript, Lakecastle Closure**

<table>
<thead>
<tr>
<th>Turn</th>
<th>Teacher</th>
<th>Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>Teacher Leader 1</td>
<td>Okay, so he used a box, with a wall on wheels between it. So, again, can someone maybe revoice what Lucy said about the connection she's making between the model with the straight lines and this?</td>
</tr>
<tr>
<td>34</td>
<td>Megan</td>
<td>So the box could be this room.</td>
</tr>
<tr>
<td>35</td>
<td>Teacher Leader 1</td>
<td>Okay. One of the boxes? Okay.</td>
</tr>
<tr>
<td>36</td>
<td>Megan</td>
<td>One of the boxes could be this room. And the wall- so we have- remember when he did like- four out of twelve of the air puppies were on one side, and six of the twelve were on the other side? It was proportionate. So that's- you could see the whole room is that box. And this- proportionately, the air molecules are the same within that bottle and with outside- (outside the bottle).</td>
</tr>
</tbody>
</table>
And so those would be one side of the box, is the outside, the other side of the box is the inside and then what's the wall on wheels? (T-gesturing-to-chart-paper-drawing) (3-seconds)

It's the wall of the bottle. (a-few-comments-happening-at-once)

So can- I just want to make sure we're okay with this, because I'm hearing it from multiple people but I don't know if everybody is at peace with this. That inside the bottle, is what I'm hearing, is one of the rooms of air. And the whole outside is another room of air.

By soliciting consensus with a summary, the Teacher Leaders are providing some closure to that part of the discussion before moving on.

I have to make those- those jumps for everybody so that everyone is on the same page…it's-that's how you build consensus, right, I guess is to say, lemme throw something out there that would be a- you do this really well too like I think, just say okay from what I can hear it sounds like, we're all moving in this direction are we moving in this direction? Does this sound right?

Lakecastle Teacher Leaders also provided Closure at the end of discussions by making sure that the agreed upon ideas were captured in some sort of public record. For example, in Bottle on the Table, the Teacher Leader is capturing the ideas on the chart paper as they go and asks what should be added to their current public record, “Do you- I know we have to wrap it up. Do you want me to add- write anything about that?” and, after 6 participant turns uses a Goal 2 move to solicit the summary from participants, “Can someone maybe- because we have a lot of voices, I wonder is there someone that could just say that very succinctly?” Cady reflected on this segment and why asking for someone else to provide the summary is useful:

I think that's, really important, to document, in some sort of public record form but also, it like, I think what's also, potentially good- good about that is that you, you might get someone else who was not just participating in that, to try to sum it up so, um, it- it reinvites, I think the larger community, to the question is there anything that we can agree upon?
She goes on to explain why keeping a public record is important to be able to refer back to as the group builds new understandings with each new phenomenon that is explored:

So, um, so I think it's- I think it's important to- to write them down because they can- because misconceptions can creep back in and I think, if, if we agree upon that then then becomes like the transition to this next idea, but if we don't write it down, I think- I think um, persistent preconceptions or misconceptions can creep back in. And people forget. And I think- I think that- it seems to me like, when we're building science understanding the idea is to, agree upon things so that that can be in service to the next thing that you do but if you don't have that in public record form you can't refer to it all the time.

In summary, Like the Lead Facilitators, Teacher Leaders at Lakecastle helped provide direction through bounding segments of the discussion and providing closure throughout and at the end of the discussions.

8.2.2.2 Focused attention around ideas to discuss.

The Teacher Leaders at Lakecastle used APT moves to make space for Teachers to discuss target concepts. The Teacher Leaders reflected on being clear about the target concepts and goals for a discussion and how those influenced the moves that they made. For example, during the Bottle on the Table, Sarah was trying to record the ideas that were being discussed on the group’s public record (chart paper). She realizes that the group is not actually in agreement on this important idea and makes space for the group to continue to discuss before capturing their agreed upon ideas.

Table 67: Transcript, Lakecastle Focused 1

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>Teacher Leader</td>
<td>What did you say about spacing? Random?</td>
</tr>
<tr>
<td>66</td>
<td>Many</td>
<td>Random. Same spacing as outside.</td>
</tr>
<tr>
<td>67</td>
<td>Teacher Leader</td>
<td>Random but was spacing important?</td>
</tr>
<tr>
<td>68</td>
<td>Many</td>
<td>Yeah.</td>
</tr>
<tr>
<td>69</td>
<td>Kate</td>
<td>I think it should be the same spacing because-</td>
</tr>
</tbody>
</table>
Will there be more on the inside? In order to fight off the outside?

Okay, so I think we need to talk about is spacing important 'cause it sounds like we are in different places.

The idea of “spacing” of the air molecules is an important concept to help understand pressure in terms of number of air molecule hits per unit area, a target concept of this discussion. Additionally, the mechanistic explanation behind this Bottle on the Table phenomenon (the fact that an empty, capped 2-liter bottle does not expand or contract) is that because the concentration of air molecules (number of air molecules per unit volume) inside and outside the bottle are equal, the frequency of air molecule hits (number of air molecule hits per unit area) between the inside and outside of the bottle will be the same. Sarah sees that there is still confusion about this idea and focuses the discussion there.

In the Biggest Sucker, there are 86 turns out of 187 total turns focused on explaining how changing the volume of one of the spaces (your mouth/lungs) is what allows you to be able to drink out of a straw. During these turns there are segments where the Teacher Leader is using APT moves that specifically “name the that” to focus the discussion (e.g. turn 66: “Is there somebody that can revoice that? Restate that? What's actually happening when you expand the room?” 4 second pause). There were also Teacher Leader moves in this discussion of volume changing where the Teacher Leader is more direct in her statements to help the group walk through the step-by-step explanation:
Table 68: Transcript, Lakecastle Focused 2

<table>
<thead>
<tr>
<th></th>
<th>Teacher Leader</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>-what hap-what do you do next, or what happens in your body?</td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>Georgia</td>
<td>Your lungs expand. [gesturing] [chatter]</td>
</tr>
<tr>
<td>98</td>
<td>Hilary</td>
<td>Then you choke.</td>
</tr>
<tr>
<td>99</td>
<td>Violet</td>
<td>Your tongue moves back.</td>
</tr>
<tr>
<td>100</td>
<td>Teacher Leader</td>
<td>Yeah, okay, [gesturing] and then what happens?...And then what happens, Wendy?</td>
</tr>
<tr>
<td>101</td>
<td>Violet</td>
<td>It makes the-room bigger, your annex opens [gestures]</td>
</tr>
<tr>
<td>102</td>
<td>Teacher Leader</td>
<td>Wha-how? Why? Where?</td>
</tr>
<tr>
<td>103</td>
<td>Violet</td>
<td>Where?</td>
</tr>
<tr>
<td>104</td>
<td>Teacher Leader</td>
<td>In where did the room-so, when you move that tongue, wh-where-now what's the room?</td>
</tr>
<tr>
<td>105</td>
<td>Female 1</td>
<td>The back of your throat. Right?</td>
</tr>
<tr>
<td>106</td>
<td>Violet</td>
<td>Your-your mouth,</td>
</tr>
<tr>
<td>107</td>
<td>Female 2</td>
<td>Your esophagus,</td>
</tr>
<tr>
<td>108</td>
<td>Mindy</td>
<td>Your respiratory system.</td>
</tr>
<tr>
<td>109</td>
<td>Teacher Leader</td>
<td>Sure, right, so-what have you just done to the room, by just pulling your tongue back?</td>
</tr>
<tr>
<td>110</td>
<td>Mindy</td>
<td>We-just, open it all up. Make it bigger</td>
</tr>
<tr>
<td>111</td>
<td>Teacher Leader</td>
<td>[nodding] Bigger. Okay, which causes..?</td>
</tr>
</tbody>
</table>

These moments that have the Teacher Leader asking more closed questions that have an answer (versus more open that invite discussion) came later in the discussion after the group had discussed the ideas more. Cady discussed how the work that the Teachers did individually and then in small group before they came to the whole group discussion supported her ability to help lead these consensus discussions:

I mean I think a shared experience that everyone participates in and is active around is really important. I think the way that we drove towards these discussions was there was a lot of private, and then group- small group, like, there was- like there was moments of consensus building even within small groups so, everyone got- everyone worked on a model on their own, and then they worked on a group model, and that's what those all are or those are small groups working,
to come up with an agreed upon- so I think there were levels of agreement that were already in place, that- that get you here to like a large group discussion.

This is reflected in these segments of the discussions that we see across the LDA and Teacher Leader sites where the facilitator works with the group to capture a step by step explanation using more directed facilitator moves.

One idea that was emphasized in both the Teacher and Facilitator Pathways was the intentional use of more everyday language that all participants can use, access, and understand as they use the Air Puppies Model to explain phenomenon. This is in contrast to using scientific words (e.g. pressure, density) that often “black box” the mechanisms and meaning behind them, and therefore might be masking a lack of deeper conceptual understanding. The idea of developing the conceptual understanding before applying the shorthand vocab can both help level the playing field for all Teachers in the group to access and make sense of the phenomenon even if they don’t have the vocabulary and can also lead to deeper understanding because explaining something without shorthand language is more challenging. Teacher Leaders at Lakecastle often helped Teachers use the ideas of the Air Puppies Model (e.g. so what do we know about air puppies?) as they tried to explain the phenomenon. They also helped participants stick with the Air Puppies Model language:

**Table 69: Transcript, Lakecastle Focused 3**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>Naomi</td>
<td>(In) room A, that's now been expanded, we had more space for those air puppies, so they are-striking with less force [gesturing] and there's-less, am I allowed to use the word pressure or no? not yet? So more, impacts, puppy impacts</td>
</tr>
<tr>
<td>64</td>
<td>Teacher Leader</td>
<td>(...) we're talking about the puppies</td>
</tr>
</tbody>
</table>
As a result, the Teachers in all three discussions stuck with the Air Puppies Model language. One participant, Hannah, spoke during the Biggest Sucker discussion how using this language was both frustrating and helpful in increasing her understanding:

> It's-it's part-part-part of it is me grappling with the fact that I have always, like, I haven't-I've never explored this whole [gesturing] like situation, so it makes me a little angry, [laughing] to think that my idea of like what sucking and whatever is just like I need to revaluate that, (laughter). And, it's, I know that this is funny,

137  Zoe

> We're laughing, we're laughing because we're right there with you.

138  Mindy

> And I 'm having-the language piece for me with the air puppies and things like that, was really difficult for me, to-to get, but I feel like I am excited about what I just learned. [many-laughter-chatter-applause-go-Hannah]

139  Zoe

The Teacher Leaders noted that knowing the conceptual goals of the discussion to guide their moves. This is evident in the 23-turn exchange during the Soap Bubble discussion where the group talked about the elasticity of the soap film before Cady redirected towards the target concept of the role of temperature on pressure. Cady reflected on why she made this move using the conceptual goals of the discussion:

> I felt like we had come to consensus that that material if elastic could change shape, but that the model was still missing the temperature, element and that, the purpose was not to argue, about like what happens within the- the- the wall on wheels and the material it's made of but that we had to like we were driving to temp- to temperature and we needed- we needed that to explain the water bottle phenomenon

8.2.2.3 Synthesis and Consensus moves to maintain direction.

Goal 5 moves include moves to solicit or summarize what the group is in agreement on (or not). More than 60% of the Goal 5 Moves used by the Teacher Leaders at Lakecastle included some form of summary (either provided by the Teacher Leader or
extended as an invitation for the Teachers to summarize). For example, after 22 turns discussing what the elements of the model are in the Bottle on the Table discussion the Teacher Leader asks if the group is in agreement on the sides of the bottle being the Wall on Wheels:

Can I um, just 'cause I would like to get the things that we've come to consensus on- on this diagram on this model right here. And I just want to go back to can we all agree that the bottle is the wall on wheels? So I would like somebody to speak up if they are not feeling okay about that right now.

The discussion continues for another 16 turns before she again solicits consensus with a summary of what she thinks they are in agreement on:

So can- I just want to make sure we're okay with this, because I'm hearing it from multiple people but I don't know if everybody is at peace with this. That inside the bottle, is what I'm hearing, is one of the rooms of air. And the whole outside is another room of air.

This is in contrast to more general statements that the Teacher Leader could have made such as, “do we all agree?” The Teacher Leader is both working towards the pedagogical goal of getting the group to consensus on an explanation as well as helping Teachers synthesize what is being discussed so that they are all on the same page.

Cady discussed her role in helping focus the discussions:

I think my role as a facilitator is to, know what I have in mind, and like, and let the group, wind a little bit until- until we start hearing something coming up multiple times and then you like- you really sit in- in that space and say, you're saying this and you're saying this and you're saying this and that all seems to be like, similar, [Can we put that together.] yeah can- let's put that together.

She went on to say that this was a shift in the way that she facilitated discussions:

And I remember when we first started doing scientist meetings I would just let them go because, initially we were like oh we're not supposed to be really involved and I was like these aren't- these aren't getting us to the science ideas that we're trying to- to consensus on and so, the strong- you know the strong
facilitation ends up feeling, like an important...Yeah it keeps us, you know moving in the- in the direction...

During Soap Bubble the Teacher Leader solicited a synthesis of the new rule that the group was agreeing on regarding the role of changing temperature on pressure:

So let's write a new rule and see if we can adjust the model to account for that. Does that sound okay? Alright so does anyone want to--maybe someone who hasn't shared see if they can summarize what they heard around the rule? It might help us revise.

This move to synthesize and capture the ideas that the group is discussing can help the goal of all participants being clear on the ideas being discussed so that they can then reflect on and react to those ideas. Cady commented on this segment and how her use of this consensus move to not only synthesize the ideas but also to get others involved:

So I think, you know I was driving to consensus, right? So what can we agree on? And then there was like we sort of like bumped out of a norm, right? Where people multiple people were talking and agreeing and, so then I just said like, so we- so do we all agree or can- is there something we can write that we can all agree on and I think that's, really important, to document, in some sort of public record form but also, it like, I think what's also, potentially good- good about that is that you, you might get someone else who was not just participating in that, to try to sum it up so, um, it- it reinvites, I think the larger community, to the question is there anything that we can agree upon?

In the Biggest Sucker discussion, we see the Teacher Leader use the small group models that are represented on posters to help do this synthesis:

Um, thoughts on, the, the-um, rooms and the wall, 'cause I wanna make sure that everybody is being heard here, if you are not comfortable with-our two rooms, is there one that shows the two rooms really nicely behind me? (turns-around-to-look-at-small-group-posters-behind-her)

Later in the same discussion Teachers had multiple turns discussing why changing the volume of one room made the water get pushed up the straw and included Teacher Leader moves of “Naming the that” to be discussed, a restate move asking others in the
group to restate the explanation, Goal 4 moves asking for agreement and disagreement, and multiple times where they talked through the step by step explanation. However, there was not a final synthesis of those ideas, instead the Teacher Leader suggested that the group pick one of the small group models to use as the group summary,

    Well thank you, and um-you know, it would-it we didn't draw a consensus model, um, I wonder though if anyone happened to notice if one-if we had a couple minutes, if there was one that-could be the consensus model

    Finally, Cady spoke about the importance of modeling this synthesis along the way with her Teachers. She explains that without this synthesis or closure the discussion can feel too messy or not support making progress on the science concepts so teachers may not want to try.

    I think if I didn't do it I think it would be hard for someone who's, trying to figure out how to lead these discussions, to understand that yeah you can get all the ideas on the table but ultimately, if you...don't do this then you're just gonna end up with a very messy brainstorming session which doesn't like, leave you with any anchor...I also just think it's- I think it's messy and I think people who, p-teachers who see this as messy, won't do it because, it doesn't lead them to where they want to go, right? Because it's messy because it's all the first time- first time talk is like, it's not clear, you know?

She indicates that these Goal 5 Moves are important both for coherence in the discussion as well as in supporting Teachers in translating these moves to their own classrooms.

    In summary, discussions led by Teacher Leaders at Lakecastle were marked by a clear focus around target concepts and explanations with clear segments of the discussion marked by a specific launch, focused segments around key content, and closure.

    Teacher Leaders used Goals 1, 2, and 4 APT moves to focus attention around the target concepts and explanations in the discussion, redirecting and elevating participant ideas for others to work with. Goal 5 synthesis and consensus moves played a central role in
the discussions and the move of summarizing or synthesizing at key points of the discussion followed by a clear, focused direction for where to go next further supported this theme of maintaining focus and direction.

8.3 Nature of the Teacher Turns: Reasoning and Co-Construction

Another way to characterize the discussion is to examine the substance of Teacher turns. Teacher turns at Lakecastle included reasoning as well as multiple turns that included co-construction of ideas between Teachers.

In this section I will present results regarding the length and substance of Teacher turns in terms of depth of their response and whether their response included reasoning or explanation. I will then share results around how Teachers are interacting with each other using indicators of co-construction of ideas.

8.3.1 Depth of Teacher Response: Reasoning/Explanation

Productive discussions involve Teachers deepening their understanding by making meaning through talk. During these discussions the Teacher Leader worked to encourage Teachers to share their reasoning including longer and more complex responses. Figure 44 shows the substance of the Teacher turns (reasoning or explanation) using the P1-P3 codes. Turns coded with P3 included an explanation of their thinking, P2 turns included a complete thought but no explanation or reasoning, and P1 turns consisted only of a word or phrase.
Figure 44: Substance of Teacher Turns using P1-P3 codes

Over 71% of Teacher turns were coded as a P2 or P3 (grey and orange bars) with 37-52% of Teacher turns including reasoning or explanation (P3). Short P1 responses made up less than 18-20% of the Teacher turns. These rates are similar to those from the LDA discussions (68% P2 or P3 with 50% P3; P1 less than 30% of the Teacher Leader turns for all but one discussion).

A typical exchange would include a combination of P1-P3 turns where Teachers had the space to clarify or say more about their ideas as in this example for Bottle on the Table:
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>Kate</td>
<td>I was thinking about the model that he had made and we sort of- it seemed to me that we learned from the model that the one third and two third- that each puppy requires the same amount of space. And so even though there aren't the same number of puppies on the inside of the bottle as there are in this room, that there's the same, um, that they're using the same amount of space in each place. And so the edge of the bottle is the divider wall and it's not moving in at all and then so- the puppies inside and outside must be moving at the same speed in the same space, (...) cube.</td>
<td>P3</td>
</tr>
<tr>
<td>5</td>
<td>T</td>
<td>Can you say more about the divider wall, what you mean by the divider wall?</td>
<td>Goal 1</td>
</tr>
<tr>
<td>6</td>
<td>Kate</td>
<td>That the bottle is the divider wall in this model.</td>
<td>P2</td>
</tr>
<tr>
<td>7</td>
<td>T</td>
<td>Okay, and so how could you relate that to the air puppies model that Richard-</td>
<td>Goal 3</td>
</tr>
<tr>
<td>8</td>
<td>Kate</td>
<td>Right, and so that- that's what I was thinking was then if that wall moved, based on the density- or in this case I actually drew a little grid, like okay so they all fit in the same amount of space, on either side and if you move the wall, the space is the same so there would fewer (or-more) puppies to-</td>
<td>P3</td>
</tr>
<tr>
<td>9</td>
<td>T</td>
<td>So Richard called that-</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Female 1</td>
<td>the wall on wheels?</td>
<td>P2</td>
</tr>
<tr>
<td>11</td>
<td>T</td>
<td>The wall on wheels. the W.O.W. the, yeah, the Wall on Wheels. So we can use that language if we want to talk about the wall on wheels. So what is the wall on wheels do you think?</td>
<td>Goal 3</td>
</tr>
<tr>
<td>12</td>
<td>Georgia</td>
<td>So, I would say the wall on wheels is the container, and also the wall on wheels in all of the examples he gave us- the wall eventually stopped. So given the idea that you were talking (looking-at-Kate) about space- eventually the wall stops so that's why it's not getting- because they're equal on both sides because given the amount of space around all of the molecules,</td>
<td>P3</td>
</tr>
<tr>
<td>13</td>
<td>T</td>
<td>So what's equal?</td>
<td>Goal 3</td>
</tr>
</tbody>
</table>
In this example we see the Teacher Leader pushing for elaboration using Goal 1, Goal 3, and Goal 4 APT moves as well to encourage the Teachers to say more or to respond to others’ ideas.

8.3.2 Depth of Teacher Turns: Co-construction of ideas

An important goal of these discussions and dialogic teaching is to get participants to think with others where the participants and the facilitator work together to co-construct meaning. An examination of how Teachers at Lakecastle were working together to co-construct meaning revealed high rates of co-construction for the Bottle on the Table (123 co-construction moves/hour) and Biggest Sucker (67 co-construction moves/hour) discussions and fewer turns coded as co-construction for the Soap Bubble (49 co-construction moves/hour). Co-construction rates for Lakecastle were higher than the LDA groups for Bottle on the Table (98/hour) but lower for the other two discussions (Biggest Sucker 92/hour and Soap Bubble 72/hour). Though the Lakecastle Biggest Sucker and Soap Bubble discussions show segments where Teachers worked with each other’s ideas, the discussions are also marked by segments where the Teacher Leader was trying to capture the ideas on chart paper leaving little Teacher co-construction during
those segments. Additionally, for the Soap Bubble, the Teachers were referring to and
commenting on the small group posters that were posted on the wall as in this turn:

Hannah: (referring-to-the-small-group-posters) The one right above it, that you go
above that, um, I think they did a better job than us of showing the rooms and the wall on
wheels that's now elastic and no longer on wheels. Um, because that's the way we showed
it on our old poster, with kind of the curve, and we—

It is clear that Hannah is working with the ideas of other Teachers, however, this turn was
not coded as co-construction since it did not meet the criteria of the specific codes.

On average, clarify own moves which includes clarification in response to a
prompt from a Teacher or from the Teacher Leader made up 40% of total co-construction
moves while Add-on, Agree/Disagree, and Ask for Clarification made up almost 60% of
the co-construction moves and varied by discussion (e.g., Biggest Sucker had the highest
percentage of agree/disagree while Bottle on the Table was higher for asking for
clarification). Figure 45 shows the breakdown of Teacher co-construction moves as a
percentage of the total co-construction moves.
In summary, Teachers used many co-construction moves (ranging from 123 to 49 per hour across the 3 different consensus discussions) to work with each other’s ideas. They used lower rates than LDA discussions for Biggest Sucker and Soap Bubble but a higher rate for Bottle on the Table. The nature of consensus discussions, which often have segments when the Teacher Leader is trying to capture the step-by-step mechanistic explanation that the group is in agreement on, may pose challenges or fewer opportunities for this co-construction. Even though the rates were lower, segments where Teachers added on to others’ ideas, asked for clarification, and clarified their own ideas without interruption by the Teacher Leader were common indicating that the Teacher Leaders provided space for Teachers to talk to each other. Since one of the goals of these discussions is to allow for the co-construction of ideas between participants, providing opportunities these opportunities for participants to work together is important.
8.4 Summary of Research Question 2 and 3: Lakecastle

This chapter focused on research question 2 (What are the characteristics of talk when Teacher Leaders enact whole-group consensus discussions with Teachers during science PD?) and question 3 (How does the facilitation of whole-group consensus discussions by Lead Facilitators compare to the Teacher Leaders’ enactment of the same discussions?). Similar to the LDA sites, Lakecastle discussions had high participation rates characterized by multiple Teacher turns and Teacher-to-Teacher exchanges where the Teachers were working with others’ ideas without Teacher Leader intervention. The Teacher Leaders at Lakecastle also frequently used turn depth, staying with the same Teacher for more than one turn to clarify or challenge their ideas. Teacher interaction during Lakecastle discussions also showed multiple Teachers working with each other’s ideas as shown with the co-construction moves. Teacher turns were longer and more frequent than Teacher Leader turns, and included explanation and reasoning.

Teacher Leaders at Lakecastle used APT moves at a similarly high rate as Lead Facilitators across discussions and most frequently with Goal 1, 3, and 5 moves. Lakecastle Teacher Leaders used moves to make space for and invite participation both to work with their own and other’s ideas and with the target concepts of the discussion. They used moves to maintain focus and direction including a clear launch focused around the phenomenon being discussed and opportunities for Teachers to discuss the target concepts. The discussions were organized into clear segments focusing on particular concepts, with closure throughout the discussion. The Teacher Leaders used Goal 5 Moves and “naming the that” to help synthesize or direct attention to the concepts or mechanisms being discussed. Teacher Leaders stated that their moves were guided by
the goal of the discussion, both the target conceptual goals as well as the pedagogical goals of helping the group come to consensus on an explanation.

In the next chapter I will discuss the implications of these results as well as compare findings from Bayedge and Lakecastle.
CHAPTER 9
DISCUSSION

9.1 Introduction

This study sought to address two gaps or challenges in the work on professional learning for science education: the need to build capacity for teachers to orchestrate productive talk and the development of PD leaders to lead the professional learning. The purpose of this study was to examine aspects of an approach to PD designed to develop Teacher Leaders’ knowledge of student-centered, dialogic practices and at the same time, prepare these Teacher Leaders’ to lead such PD. More specifically, this study focused on the following research questions:

1. **What are the characteristics of talk when Lead Facilitators enact whole-group consensus discussions with Teacher Leaders during science PD?**
   a. What academically productive talk moves do Lead Facilitators use and how do they use them? What rationale do they provide?
   b. What are participants doing in terms of reasoning and co-construction of ideas?
   c. What talk patterns are evident in the ways participants interact with the facilitator and each other?

3. **What are the characteristics of talk when Teacher Leaders enact whole-group consensus discussions with teachers during science PD?**
   a. What academically productive talk moves do Teacher Leaders use and how do they use them? What rationale do they provide?
   b. What are Teachers doing in terms of reasoning and co-construction of ideas?
   c. What talk patterns are evident in the ways Teachers interact with the Teacher Leader and each other?

3. **How does the facilitation of these whole-group consensus discussions by the Lead Facilitators compare to the Teacher Leaders’ enactment of the same discussions?**
The analysis of data collected through video-taped whole group consensus discussions and interviews revealed two key foci (themes) regarding the discourse tools and strategies that Lead Facilitators and Teacher Leaders used, how they compared between these groups of Facilitators, and why Facilitators made the moves they did. The results provide insight into the tools, strategies, and PD structures that can support the development of skilled PD providers. In this chapter I will discuss the results by first highlighting the similarities across sites, share a key difference in how moves were used to support idea development at Bayedge in contrast to Lakecastle and the LDA sites and then shift to implications of this study for preparing Teacher Leaders to lead PD around APT. Finally, I will discuss limitations of this study and future research directions.

9.2 Similarities across sites

We know that not just any talk will lead to deep understanding where the participants are positioned as thinkers working to co-construct understanding (e.g. Anderson et al., 2011; Michaels & O’Connor, 2015b; Michaels et al., 2008; Resnick et al., 2015). This study used Michaels and O’Connor’s construct of “Academically Productive Talk” (APT) to describe talk that leads to deep conceptual understanding and is respectful, equitable, and focused on reasoning (Chapin & O’Connor, 2003, 2007; Michaels et al., 2007). Teaching that is more dialogic in nature, such as APT, helps students access and communicate their ideas, reflect on their current understanding, and reason scientifically (Michaels & O’Connor, 2012; Michaels et al., 2008; Windschitl, 2013); it also has been shown to impact student learning and transfer across academic
domains (Adey & Shayer, 2001; Bill et al., 1992; Chapin & O’Connor, 2004; Mercer et al., 2004, 1999; Resnick et al., 2015; Shayer, 1999).

The analysis presented in the preceding chapters used the Framework of APT to characterize the discourse by identifying the tools and strategies that Lead Facilitators and Teacher Leaders used when enacting whole-group consensus discussions during PD and how they compare. Results revealed that, similar to the Lead Facilitators, Teacher Leaders at both Bayedge and Lakecastle used APT moves at a high rate. This is an important finding as these APT moves replace the more typical “Evaluation” move in the third turn of the IRE pattern, which has been shown to be the default “recitation” pattern across teaching/learning contexts in the US (and around the world). Moreover, Teacher Leaders at both Bayedge and Lakeside used the conceptual and pedagogical goals of the discussion to guide their use of those moves in discussions that were characterized by high levels of participant-to participant-interaction and co-construction of explanations.

Talk moves were used to encourage reasoning and to dig deeper into Teachers’ ideas as well as to help Teachers work with each other’s ideas. Bayedge Teacher Leaders used moves focused on eliciting Teacher ideas and helping Teachers work with others (Goal 1, wait time, and Goal 4) and somewhat less on digging deeper (Goal 3). Moves to support consensus and synthesis (Goal 5) were centered around asking if the group was in agreement (consensus) with fewer moves to help synthesize the ideas. Similarly, Lakecastle Teacher Leaders used moves to elicit ideas (Goal 1) and help participants dig deeper into their own reasoning (Goal 3) as well as Goal 5 Synthesis/Consensus moves to support that interaction; though, they used fewer Goal 4 moves aimed at supporting working with other’s ideas. Lead Facilitators used many Goal 1, Goal 3, Goal 4, and Goal
5 moves across discussions. Goal 2 moves designed to get Teachers to listen carefully to each other were used minimally across both Lead Facilitator and Teacher Leader sites (perhaps not needed much in these cohorts of adult participants, skilled in group discussion). However, when used they centered around important target concepts.

Despite the noted differences in the particular APT moves used, the Teacher Leaders used the moves to position Teachers towards the content and each other (Correnti et al., 2015). This is in contrast to the more typical and authoritative IRE discourse pattern which positions the Teachers as trying to get the right answer and emphasizing correctness over reasoning (Michaels et al., 2004). By modeling these moves both the Lead Facilitators and the Teacher Leaders demonstrate how discussions can be used to support Teachers’ own students in deep sensemaking and how to position their students as thinkers and collaborative knowledge builders. Such discussions help to shift the power from the teacher as the holder of knowledge to more authentic co-construction of knowledge (Mehan & Cazden, 2015; Michaels & O’Connor, 2012; Michaels et al., 2004; O’Connor & Michaels, 2007; Resnick & Schantz, 2015).

Facilitating PD for adult learners, much like teaching students in a classroom is complex. The PD leaders must balance participants’ different goals and needs and make decisions on the fly to best support those needs (Jacobs et al. 2017). Like the Lead Facilitators, the Teacher Leaders at both sites were aware of and articulate in explaining that both the conceptual and pedagogical goals of the discussion influenced the moves that they made. Both Bayedge and Lakecastle Teacher Leaders used moves to help Teachers discuss the target conceptual ideas and used their understanding of those goals to provide a clear rationale for why they focused on some ideas over others.
Additionally, they cited the pedagogical goal of the discussion, namely helping the group come to consensus on an explanation, as central to their role as facilitator helping the Teachers, “do the figuring out”. This is important in light of Zhang et al.’s (2011) study of the strategies that experienced facilitators used to promote productive discussion among teachers. They found that sometimes questioning and revoicing strategies were disruptive instead of productive when they were not carefully and selectively used to solicit and highlight important ideas.

The CDA Peak Graphs (Chen, Clarke, and Resnick 2015) provided a visual of the turn taking patterns, highlighting sections of the discussion where there were different interactions that could then be more closely examined. Discussions across the sites showed high levels of participant-to-participant interaction and co-construction where Teachers were talking to each other, not just to the Facilitators. During these exchanges, Teachers were asking questions, challenging ideas, and agreeing or disagreeing. This social construction of knowledge in exchanges where Teachers were “interthinking” (Mercer, 2004) is an ultimate goal of APT. The Teacher Leaders often set up these exchanges using APT Moves to open up the discussion by inviting additional ideas or agreement/disagreement. Additionally, the Teacher Leaders used wait time and intentionally not interjecting to make space for these interactions. By making this space and using moves that disrupt the traditional discourse patterns, the Teacher Leaders are modeling how the Teachers can be the ‘more able others’ (Vygotsky, 1986) serving as resources for each other.

Another interaction pattern between the Teacher Leader and a Teacher is turn depth, measured by the number of contiguous turns by the same Teacher with the
Teacher Leader. Sticking with the same Teacher, particularly when using non-evaluative feedback moves such as APT moves, can signal that the Teacher Leader values the Teacher’s ideas and can “set the table” for others to work with the ideas. For Bayedge there were multiple segments in 2 of the 3 discussions where the Teacher Leader stayed with a Teacher using APT moves to uncover or probe their thinking. However, while the Teacher Leaders at Bayedge did work with a Teacher to uncover their thinking, they did not readily help synthesize that segment by either “naming the that” or soliciting a restate before opening it up to the group. Lakecastle discussions also used extensive turn depth in 2 of the 3 discussions and identified this as a strategy they use in their rationale. In those segments the Teacher Leaders often used APT moves to uncover or probe Teachers’ thinking. Since a prerequisite of making sense with others is to have clearly explicated ideas to work with, this turn depth can support the important APT goal of helping learners make sense together and to position them so that their ideas are important and helpful for the progress of the group. By taking the time to dig deeply into one person’s ideas it signals to both the speaker and others in the group that their ideas are important and can help position all students as capable of engaging in academic discourse focused on conceptual learning (Mehan & Cazden, 2015; Michaels & O’Connor, 2012; Michaels et al., 2004; O’Connor & Michaels, 2007; Resnick & Schantz, 2015).

In summary, Teacher Leaders used APT moves to uncover Teachers’ thinking, a prerequisite for social construction of knowledge, and to support them in working with each other’s ideas. Through modeling of such moves Teachers experienced a more equitable discourse structure and role of the leader of the discussion as a facilitator and a
contributor to the co-construction of knowledge. In order to engage with the practices of science called for in the NGSS such as developing and using models, constructing explanations, and argumentation from evidence students must go public and work with the reasoning of others. Providing opportunities and the culture that supports this engagement in practice is essential (Michaels & O’Connor, 2012). Results of this study show that talk moves as implemented by the Teacher Leaders and Lead Facilitators have the potential to make the implicit knowledge of how to engage in these scientific practices explicit. Ford (2007) highlights the role of both construction of new knowledge and critique of scientific ideas in helping students understand scientific practices. Some talk moves (e.g. Goal 3 Why, Challenge, and Press moves) can position the teacher as the critiquer by helping students consider problems with claims or chains of evidence, which can serve to move the content understanding and at the same time help model the practice, so that students can begin to critique and question others’ ideas (Ford, 2007). The use of these Goal 3 moves in the discussions of the Teacher Leaders and Lead Facilitators is an example of positioning the Facilitators as contributors to co-construction of knowledge while at the same time building the capacity for the Teachers to do this work themselves. Over time, apprenticing students (including Teacher Leaders and Teachers in this case) into this kind of work via tools like talk moves in science could have a profound effect on how students see themselves. As Driver points out, “learning science involves…becoming socialized to a greater or lesser extent into the practices of the scientific community with its particular purposes, ways of seeing, and ways of supporting knowledge claims” (Driver et al., 1994, p. 8). Furthermore, learning the language of a discipline is an important part of being seen as literate in that field (Gee,
Michaels, & O’Connor, 1992; Guzzetti, 2001). By focusing on reasoning and helping engage students in argumentation (e.g., do you agree and why?) these Teacher Leaders can help their Teachers build this understanding of scientific practice that can then be transferred back to the classroom.

The fact that the Teacher Leaders’ discussions were marked by a focus on target conceptual goals and that these goals were central in their rationale for the moves they made is encouraging. However, there were key differences between the Bayedge compared to Lakecastle and the LDAs in how the Teacher Leaders supported Teachers in making progress towards target concepts. These differences will be discussed in the next section.

9.3 Differences Across sites: Supporting Idea Development

Leading discussions centered around phenomena where multiple ideas are elicited and valued while at the same time helping the group move towards target conceptual understanding is challenging but necessary to shift to more equitable forms of discourse where students are “figuring out” instead of just “learning about” science (Michaels & O’Connor, 2017; Reiser et al., 2017). Academically Productive Talk (APT), is talk that is productive not only in engaging learners in the sensemaking (participant engagement) but also in making progress on idea development (Chapin & O’Connor, 2003, 2007; Michaels et al., 2007; Scardamalia & Bereiter, 2006; Zhang et al., 2011). There can be a tension, then, between these dual goals of getting learners to talk and reason while also constructing deep conceptual understanding. An examination of the ways Teacher
Leaders supported Teachers in making progress towards target concepts revealed some key differences between sites and between the Teacher Leaders and Lead Facilitators.

**9.3.1 Bayedge: Limited Goal 5 Moves and ‘Naming the That’ to Maintain Focus and Direction**

Moves to maintain focus and direction were used differently at Bayedge than in the LDA sites. Lead Facilitators used APT and other moves to maintain focus and direction around target concepts and explanations in the discussion. Analysis of the Lead Facilitators led to the development of a new set of codes which I call Goal 5 or Consensus/Synthesis moves. Goal 5 moves included moves to either solicit or summarize what the group is in agreement on (or not). Goal 5 moves include the facilitator offering a summary or inviting a Teacher to summarize as well as moves to solicit consensus (“Do we all agree on that?”) or solicit consensus with a summary (“Can we all agree that the bottle is the wall on wheels?”). Goal 5 synthesis and consensus moves played a central role in the Lead Facilitator’s discussions. Summarizing or synthesizing key points of the discussion followed by a clear, focused direction for where to go next helped maintain focus and direction. An example of this appears in Biggest Sucker, LDA1:

(4-second-pause) So it sounds like we're pretty- we're feeling pretty good about our rooms now, especially if we add in that you- that there has to be something that you do, um, to make that room- that-that the mouth has to be included. There's something you have to do, um.. in this room, wherever you're calling number 2, to make the room bigger. Is that correct? Yes? Okay. Um, so-so we can map our elements pretty well, and and we've already sort of eeked into the explanation now in words, and so let's hear some people talk a little bit about.. the explanations that you see up here on the posters and-and where the-where we're in agreement or where we might still have some gaps.
Furthermore, the Lead Facilitators purposefully used APT moves to focus and guide the discussion around targeted conceptual ideas through explicitly naming or revoicing the ideas that they wanted participants to attend to (what I refer to as “naming the that”). An example of “naming the that” is in the Biggest Sucker, LDA 1, “Yeah, so someone talk a little bit- anybody who represented it that way with a mouth or lips or something over it, tell me about that as being part of the room.” This is in contrast to a more general, “can someone tell me about that”. While such moves were present at Lakecastle, they were only occasionally used in discussions at Bayedge.

Instead of soliciting or providing a summary the Teacher Leaders at Bayedge would ask if there was anything else someone would like to add (“So with the- is there still some confusion or questions that people might have... about how/why the bottle is not being crushed?”). Without synthesizing the ideas being discussed along the way, the discussion felt less focused and may have left Teachers unsure about what the group actually agreed upon at various points in the discussion. Furthermore, Teacher Leaders at Bayedge made moves that opened up the discussion more generally (e.g. anyone want to add on to that?) instead of specifically naming the ideas that a Teacher raised to be discussed. Therefore, while Teachers were discussing target concepts, the Teacher Leaders were less likely to pick up those ideas to make sure that all in the group were on the same page.

Why is the use of Goal 5 and other moves to maintain focus and direction important in these discussions? There is an ongoing tension for facilitators during discussions between helping participants in deepening their conceptual understanding while also providing the space for participants to co-construct meaning. As Michaels and
O’Connor point out, “simply opening up the conversation to student thinking” is “not enough to ensure coherence in a discussion” (2015b, p. 12). Without helping the group synthesize the ideas being discussed both along the way and at the end of the discussion, there is little for the Teachers to hang on to. If teachers feel that these discussions are more about “process” but can’t see how the discussion helped them make progress on conceptual goals, they may be less likely to take the time to make meaning through discussion with their own students.

9.3.2 Lakecastle: “Strong Facilitation” if you want to “get somewhere”

In contrast to Bayedge, Lakecastle Teacher Leaders readily synthesized ideas throughout the discussion using Goal 5 moves to provide or solicit a summary as part of seeking consensus. Teacher Leaders at Lakecastle synthesized where the group seemed to be at that point in the discussion before relaunching into a new area of discussion. They spoke to using moves where they summarized but then checked with the group to see if that is where the group was to help get “everyone on the same page”. In that way, they are guiding the discussion but using the ideas that the Teachers are providing. Additionally, they spoke about using moves like asking for someone in the group to summarize not only to help clarify for the group but also to invite other voices into the discussion.

Cady referred to the importance of “strong facilitation” in order to help the group make progress on idea development. She noted how over time she learned that without this strong facilitation her students were not making progress on important ideas. Cady’s comment implies a widespread misconception among teachers. The shift to students
doing more of the talking often gets translated as “just let them talk” with little teacher guidance beyond encouraging participation. However, in discussions where collective knowledge construction is the goal, the teacher must play an important role in guiding and synthesizing the ideas along the way; skills that are not without tension. Cady and Stephanie both noted that for discussions to be productive, they had to have a clear understanding of the conceptual goals of the discussion. At the same time, they both spoke to the unscripted nature of these discussions and the tension between getting them “somewhere” and honoring their ideas. They noted that while the moves they make to help move the group towards target concepts may not be the “right” ones, they try and use the Teachers’ ideas to facilitate and guide the discussion.

Like Lead Facilitators, Teacher Leaders at Lakecastle occasionally used more directed moves interspersed with APT Moves. For example, Lakecastle Teacher Leaders directed Teachers to connect back to the Air Puppies Model in the early Bottle on the Table discussion (e.g. “Okay, and so how could you relate that to the air puppies model…?”). Similarly, Zhang et al. (2011) found that the facilitators in their study used a variety of discourse strategies together to achieve participant engagement and idea progression and argued for analyzing discourse strategies working together versus identifying single successful strategies. This is echoed by Mortimer and Scott (2003) who speak of a range of talk formats and moves they make depending on the purpose. These directed moves along with moves that “name the that” can be helpful in supporting Teachers in gaining a “grasp of practice” (Ford, 2007) and can make visible important aspects of the target concepts (Manz & Renga, 2017). As Ford (2007) points out, teaching in this way does not mean “a pedagogical ‘letting go” nor does it imply that
“‘anything goes’ or the teacher has no voice” (p. 419). In rigorous academic discussions where knowledge building is the goal, the facilitator plays an important role beyond just managing turns and participation (O’Connor & Snow, 2018).

In summary, while Lakecastle Teacher Leaders made moves to synthesize key points in the discussion, thereby helping maintain focus and direction, Bayedge Teacher Leaders did this to a lesser extent. What do these findings mean for teachers and the Teacher Leaders? One of the goals of the PD is to support teachers in using APT to support all their students in deepening understanding and seeing themselves as capable thinkers and learners. If teachers perceive these discussions as being more about “process” than conceptual development, then they may be less likely to implement meaning-making through discussion in their teaching. This may be more likely in domains such as science where teaching is often still viewed as “delivering and covering” of content instead of co-construction of knowledge. Given the uneven uptake of skill at combining process (or engagement) with focused and directed idea development in these two cohorts, this raises the question of the need for more targeted discussion and practicing of this in professional learning programs such as NGSX. Combining moves of process and conceptual development and modelling best practices of how to implement these moves into teaching practice may need to be explicitly addressed in both the Facilitator and Teacher Pathways. Getting Teacher Leaders (and Teachers) to pick up and use the APT moves might be easier to support in PD than getting participants to see how to use the moves strategically in order to integrate engagement (explicating and sharing ideas) with focused and directed conceptual development of key ideas in consensus building. The findings in this study of Lead Facilitators and 2 groups of
Teacher Leaders suggest the complexity of this integration, and the complexity of skill and awareness of purpose and participants that it requires. But it is key if the goal of talk is more than just engagement with ideas but collective progress in conceptual development – that is, focused and directed idea development in collaboration with others.

9.4 Implications for Preparing teacher leaders

Leading discussions during PD is a challenging practice and requires knowledge, tools, and frameworks to support the development of facilitators to lead and model this work in PD. Patterns in the rationale Teacher Leaders provided and their enactment of the discussions suggest some key aspects of the preparation that supported their work: intentional attention to the conceptual and pedagogical goals of the discussions and other activities in the PD Pathways; experiencing the PD themselves as learners to deepen content understanding and understand the trajectory of the science concepts in the Pathway; and opportunities to use tools and frameworks to reflect on their role as facilitator. The results of this study show challenges with using moves to synthesize ideas during the discussion (e.g. Goal 5 synthesis and “naming the that”), which points to the need for more explicit attention to these newly identified moves.

Teacher Leaders need to be skilled in responding in the moment to the ideas being raised by their Teacher participants during the discussions that they lead. In order to do this, they need to be clear on the learning goals at both the program and activity level. All Teacher Leaders stressed that both the conceptual and pedagogical goals of the discussions were important to their way of facilitating the discussions; and this was
evident in the moves they made. They specifically mentioned this as a key aspect of what they learned during the Facilitator Pathway, and that they implemented this in their facilitation of their Teacher groups and in their own classrooms.

Studies of PD Leaders in math show that without this focus and awareness on goals PD leaders struggled to know when and what to highlight leaving discussions superficial (R. Elliott, Kazemi, Lesseig, Mumme, Carroll, & Kelley-Petersen, 2009; Jacobs et al., 2017; Tekkumru-Kisa & Stein, 2017a). All Teacher Leaders in this study noted the importance of experiencing the PD and the discussions themselves as learners as important to their preparation, how the way they engaged in the discussion as a participant influenced the way they facilitate the discussion, and how experiencing the phenomena and discussions helped deepen their content understanding. Thus, the results of this study point to the need of PDs that prepare Teacher Leaders to intentionally attend to identifying and clarifying the conceptual and pedagogical goals of each discussion (and activity within the PD) and to experience these discussions as learners and facilitators.

These results support previous research on preparing PD providers in math and science who suggest that engaging in the specific science or math content is important for preparing facilitators to lead content rich discussions (Elliott, Kazemi, Lesseig, Mumme, Carroll, & Kelley-Petersen, 2009; Higgins et al., 2017; Lesseig et al., 2017; Roth et al., 2017). This may be particularly important for science PD that is designed to immerse Teachers in a coherent series of phenomena where participants are incrementally developing and revising an explanatory model. Without experiencing the full trajectory themselves first, it would be difficult for the Teacher Leaders to know when to push and
when an idea will be revisited in future discussions. Understanding this trajectory influenced the moves the Teacher Leaders made (e.g. early phenomena required more focus on understanding elements of the model so they pushed for elaboration around those ideas) as well as how this more coherent approach (instructional phenomena building on each other) was different from how they taught before.

A deep understanding of the content has been identified as an important aspect of PD Leader knowledge in order to be able to create learning opportunities and to lead key discussions designed to increase teacher understanding (Hilda Borko et al., 2014; Jacobs et al., 2017; Lesseig et al., 2017; Roth et al., 2017). Engaging in and making sense of the complexity of science concepts can support the development of content understanding. The Teacher Leaders at Bayedge noted the challenge of having enough content knowledge to support all the Teachers in their groups. Both Chris and Jill (Bayedge) who are elementary teachers mentioned having less content and feeling intimidated by the fact that they were working with upper level teachers. However, they identified the support of the tools (e.g., Talk Moves Checklist) and Facilitator Pathway in being able to lead the discussions:

Yeah and it, it was intimidating because of, umm they’re high school teachers middle school teachers that focused on this, I had never taken a physics class in my life…ummm I had never taken uhh upper level chemistry, you know like I just, lacked the content knowledge. But I felt so good about my facilitation training and I trusted the NGSX process and the tools, so I had, I held on to the tools extra tight to overcompensate.

It is worth noting that Lakecastle Teacher Leaders (elementary and middle school teachers) who did more of the synthesizing and directing throughout the discussion did not mention concerns about their content understanding. Bayedge Teacher Leaders led
strong discussions where participants were discussing target concepts, but perhaps without the confidence in understanding the content, they were more likely to focus on getting the group to talk and interact versus pausing to clarify and synthesize the ideas. This suggests that more explicit support both for those Goal 5 moves and processing the content is needed. While Teacher Leaders were provided with the rationale behind particular moves for Goals 1-4, Lead Facilitators did not offer the same rationale for and explicit attention to Goal 5 synthesis moves; though, they implicitly used such moves.

Experiencing the discussions and engaging in the PD as learners is not enough to prepare Teacher Leaders to lead the PD themselves with fidelity to the goals of the PD (Higgins et al., 2017; Jackson et al., 2015; Jacobs et al., 2017; Lesseig et al., 2017; Perry & Boylan, 2017; Kathleen J. Roth et al., 2017). Both the Teacher Pathway and the Facilitator Pathway included other important topics and multiple opportunities to focus on specific, targeted instructional strategies around productive talk. Teacher Leaders were provided with tools, frameworks for facilitation of adult learners, opportunities to analyze videos of facilitation, specific attention to planning and preparation, and rehearsals. Such a PD program supports the identified features of effective science PD (S. Wilson et al., 2015) as well as the suggested approaches to preparing PD leaders in science (Roth et al., 2017; Tekkumru-Kisa & Stein, 2017a; Zhang et al., 2011). Patterns in the way the Teachers Leaders enacted the discussions using APT moves and staying true to the pedagogical goals suggest that that this approach to facilitator preparation from multiple perspectives is useful. Even when the Teacher Leaders were not as confident with their content understanding they were able to utilize the tools and strategies presented in the PD.
Finally, an awareness of how Teachers learn and viewing their learning as a progression versus filling in missing ideas was an important theme in earlier studies in supporting math and science PD Leaders (Jackson et al., 2015; Roth et al., 2017). Central to this is the ability to build and support a learning community where there is a culture of risk taking and collaborative knowledge building. This was a big focus in the NGSX Facilitator Pathway. Patterns in the facilitation of the discussions indicate that the Teacher Leaders were aware of this and supported it as they referenced and revisited norms, invited participation, stayed with participants to uncover their ideas, and made it safe for Teachers to express confusion.

PD designed to support Teachers in experiencing the same coherent, phenomenon-based, student-centered, and discourse-rich science experiences as we hope to provide for students will require models for facilitation that make the knowledge and skills needed to support such experiences explicit. Results of this study supports the need to engage Teacher Leaders in the PD themselves as learners and to provide opportunities to reflect on those experiences in order to deepen content understanding, understand the goals of each activity, and to develop a culture that supports all learners. Teacher Leaders in this study might have implemented specific moves designed to support idea development by synthesizing the discussion more consistently, if these moves and their purpose would have been explicitly discussed and practiced. Though teachers will come to PD with different prior experiences and knowledge, future PD should carefully assess the needs of the participants and adjust the PD accordingly, just as we expect teachers to adjust their instruction to their students’ needs.
9.5 Limitations

This study has several limitations which will need to be reexamined in future research. First, this study provided an in-depth look at only two sites implementing PD for their Teachers. However, the qualitative methods used allowed for in-depth examination of the complexities of leading whole group dialogic discussions in PD (Rossman & Rallis, 2012). Additionally, the focus on two different generations of the PD and the rich description of the experiences of both skilled and novice facilitators and how they acquire relevant knowledge and practice can help inform how to design professional learning opportunities (Wilson et al., 2015). Therefore, while only two sites were studied, the detailed analysis informs improvement of the current PD, which will then need to be assessed with more groups in order to help generalize the findings.

Another limitation is that while all of the Teacher Leaders were novices at facilitating PD, they had a range of previous experience with enacting APT in their own classrooms. Since I did not assess Teacher Leaders’ prior knowledge and expertise on APT it could be that Teacher Leaders without such knowledge would need additional support and have other needs in order to successfully implement APT. Many, but not all, had previous professional development on APT. Because the discussions were co-facilitated and since the unit of analysis was the study group and not the individual Teacher Leaders, the influence of this previous experience cannot be determined. An examination of how APT is enacted by Teacher Leaders who are more novice at leading such discussions would be an important extension of this work.

As one of the Lead Facilitators for the PD I needed to be careful to acknowledge and reflect upon my role and position as researcher and how this might have impacted my
observations. My involvement with the development of the Facilitator Pathway and my experience with APT and leading whole group discussions could have clouded my observations. Additionally, since I was analyzing discussions that I had led I needed to utilize methods to manage this dual role. I sought to manage this by utilizing member checks with other researchers in the Discourse Coding Research Group and with the Teacher Leaders. I utilized analytical memos while doing the analysis to track any moments of how I was feeling about this role conflict (researcher and Lead Facilitator). Future studies should include analysis of other Lead Facilitators in order to more fully describe the practices of experienced facilitators in order to inform and improve PD programs designed develop skilled facilitators so that PD can be scaled up to reach more teachers.

9.6 Future Research

This study raises many additional questions and areas for future research. First, an important result of this work was the development and refinement of codes indicative of APT in the work of Teacher Leaders’ as they led whole group science discussions. The newly identified Goal 5 Moves should be further examined with a bigger set of PD transcripts.

This study examined the impact on Teacher Leader knowledge and skills regarding enacting APT. An obvious next question is how this focus on APT impacts teacher learning. Returning to the nested conceptual framework for teacher learning with PD (Lauffer, 2010), research in the Student’s Domain that examines how the PD impacts teacher action is needed.
For example, examining classroom discourse to see if these Goal 5 Moves are being utilized with students would be an important contribution to the tools available for teachers to support APT. In a similar vein, this study suggests some specific revisions be made to the Facilitator Pathway – with more explicit focus on Goal 5 moves and strategic ways of integrating both process and idea development moves. If such revisions are made, it would be important to document the next generation of Teacher Leaders to see if their use of synthesizing and summarizing moves and “naming the that” improves in skill and consistency (across all of the consensus discussions).

While there is evidence that utilizing dialogic discourse and building a culture of collaborative knowledge building can have impacts on student learning and transfer of that learning, it is not happening in many classrooms. APT is a high leverage instructional strategy that may help address the big shifts called for in the NGSS where
students are positioned as knowers and thinkers working to “figure out” instead of just “learn about” (Reiser et al., 2017). However, this will require scaling up effective models of professional learning around building a culture of collaborative knowledge building. Examining how this Teacher Leader Preparation can be improved and scaled up within the limited time and resources available for teacher professional learning will be important.

9.7 Conclusion

Opportunities for students to incrementally deepen their understanding of science ideas through engagement in science practices and to engage in complex reasoning and argumentation through classroom talk is limited in most K-12 science classrooms (Driver, Newton, & Osborne, 2000; Lemke, 1990; Michaels, Shouse, & Schweingruber, 2008; Mortimer & Scott, 2003; C. O’Connor, Michaels, & Chapin, 2015; Reinsvold & Cochran, 2011; Scott, Mortimer, & Aguiar, 2006; Weiss, Pasley, Smith., Banilower, and Heck, 2003; Wilson, Schweingruber, & Nielsen, 2015). Leading discussions centered around phenomena where multiple ideas are elicited and valued while at the same time helping the group move towards targeted conceptual understandings is challenging but necessary to meet the shifts in science teaching and learning called for in the Framework and the related NGSS (National Research Council, 2012; NGSS Lead States., 2013b, 2013a). This study adds to the limited research on models of PD that support classroom discourse in science and prepare the PD leaders charged with leading this PD (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Luft & Hewson, 2014; Wilson et al., 2015). Results revealed that Teacher Leaders used APT moves at a high rate and used
the conceptual and pedagogical goals of the discussion to guide their use of those moves in discussions that were characterized by high levels of participant to participant interaction and co-construction of explanations. Engaging in the PD themselves as learners and providing opportunities to reflect on those experiences in order to deepen content understanding, understand the goals of each activity, and to develop a culture that supports adult learners appears to be important in this preparation.

By modeling these moves both the Lead Facilitators and the Teacher Leaders demonstrate how discussions can be used to support Teachers’ own students in deep sensemaking and how to position their students as thinkers and collaborative knowledge builders. Such discussions help to shift the power from the teacher as the holder of knowledge to more authentic co-construction of knowledge where students are positioned as thinkers and knowers with epistemic agency (Mehan & Cazden, 2015; Michaels & O’Connor, 2012; Michaels et al., 2004; Miller, Manz, Russ, Stroupe, & Berland, 2018; O’Connor & Michaels, 2007; Lauren B. Resnick & Schantz, 2015). Moves where the Teacher Leaders were guiding the discussion by synthesizing ideas and naming the ideas they want the group to attend to were unequally taken up, indicating further work is needed in supporting Teacher Leaders with moves that can support idea development while at the same time ensuring that the Teachers are doing the sensemaking. As Michaels and O’Connor (2015a) point out, just using talk moves does not ensure coherence in a discussion. This study supports their call for continued work on how to help Teacher Leaders know when to use certain moves and what an appropriate progression is for learning about talk tools if we are to scale up the PD needed to help shift classroom practice around productive talk.

270
## APPENDIX A

### SUMMARY OF UNITS AND FOCUS IN NGSX TEACHER PATHWAY

<table>
<thead>
<tr>
<th>Unit</th>
<th>Unit foci</th>
<th>Perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How do we develop and use models?</td>
<td>Developing and using models to explain matter phenomena&lt;br&gt;Connecting the experience to key shifts in the Framework</td>
</tr>
<tr>
<td>2</td>
<td>How can we evaluate and revise models based on evidence?</td>
<td>Revising models based on evidence&lt;br&gt;Identifying key characteristics of science practices</td>
</tr>
<tr>
<td>3</td>
<td>How does discussion support argumentation, explanation, and modeling?</td>
<td>Analyzing practices in classroom discussion&lt;br&gt;Updating model of science practices</td>
</tr>
<tr>
<td>4</td>
<td>How do we build a classroom culture that supports public reasoning?</td>
<td>Analyzing talk moves in classroom discussions</td>
</tr>
<tr>
<td>5</td>
<td>How do we help student argue from evidence for a particle model of matter?</td>
<td>Analyzing a middle school classroom case of students developing models to explain air phenomena</td>
</tr>
<tr>
<td>6</td>
<td>What types of tools help students refine models over time and develop deep explanations of science phenomena?</td>
<td>Analyzing a high school classroom case of students engaging in argumentation to model air pressure phenomena</td>
</tr>
<tr>
<td>7</td>
<td>How do we bring three-dimensional learning into our own classrooms?</td>
<td>Integrating science practices to adapt existing instructional units</td>
</tr>
</tbody>
</table>

**Note:** 3D Learning means the vision of learning laid out in the Framework for K-12 Science Education that identifies science learning as an integration of 3 Dimensions: science and engineering practices, disciplinary core ideas, and crosscutting concepts.
APPENDIX B

INFORMED CONSENT

NGSX VT Participant Survey + Consent

The NGSX PD and Research Study

Welcome to NGSX – the Next Generation Science Exemplar System. You have been selected by your district to participate in an NGSX pathway with a group of colleagues. The goal of NGSX is to support participants in learning about the new vision of science called for in the NRC Framework for K-12 Science Education and the Next Generation Science Standards, and taking this vision into your own classrooms. You will be you doing and learning some science about the physics of matter, emphasizing the scientific practices of modeling, argument from evidence, and constructing explanations — three key practices that the NRC Framework and NGSS are expecting students to participate in as they do and learn science.

The researchers who developed NGSX have found it helps teachers, teacher coaches, and administrators learn about the changes in science classrooms needed to support the ideas of the Framework for K-12 Science, and NGSS. The researchers are hoping to make these PD sessions even better, and are studying how to improve it to help meet people’s needs.

So the researchers are asking your help. You are being asked to participate in a research study of the use of the NGSX PD system. Participation is completely up to you. Whether you choose to participate in the research or not, it will not affect anything about your participation in the NGSX PD sessions.

It’s important to stress that you are not being evaluated. We are interested in your learning and participation in your study group, and your reflections about these PD resources, so that we can improve the learning experiences for future colleagues and science teachers in your state and all over the country.

If you choose to participate in the research study, you will be asked to complete a short survey at the beginning and end of your PD experience. Researchers will observe some of your PD sessions, and will ask a subset of you to participate in interviews. All data collected will be kept confidential.

If you choose to participate in the study, photographs and short audio or video excerpts may be used for research, publications, presentations at scientific meetings, and online professional development of teachers and teacher coaches at a password-protected secure site. Any discussions of results of the study will not reveal any individual information about the participants.

Participation is completely up to you. All data will be kept confidential, and will not be shared with any school, district, or state administrators or institutions. The next page contains a research study consent form that explains the research procedures in more detail. Please read the consent form, The NGSX PD and the research study and then answer Yes or No to the Consent questions about your participation.

If you have any questions, you can contact the Principal Investigator for this research study, Professor Brian Reiser, School of Education & Social Policy, Northwestern University (Study #00200732), at 847-467-2205.
NGSX Study Group-Participant Consent Form

Title: Next Generation Science Exemplar System  
Principal Investigator: Brian J. Reiser, Northwestern University  
Supported By: Connecticut Dept. of Education; Illinois I-STEM Math Science Partnership; Michigan Dept. of Education, Vermont Science Initiative

What is the purpose of this study?  
You are being asked to participate in a research study investigating the ways in which teachers, coaches, and administrators perceive the changes involved in bringing the Framework for K-12 Science and the Next Generation Science Standards (NGSS) into their classrooms, and how these reforms influence planning and implementing classroom instruction. You are being asked to participate in this study because you are participating in professional development (PD) using The Next Generation Science Exemplar system (NGSX). The purpose of this study is to better understand how teachers, coaches, and administrators learn about the implications of the Framework and NGSS for classroom teaching. The findings will help inform the design of more effective professional development programs.

What will I do if I choose to be in this study?  
You may choose to participate in all of the research activities described here, some of the activities, or may choose not to participate in any part of this research study. If you choose to participate:

• You will be asked to fill out an online survey at the beginning and end of the PD (30-45 mins each) to ascertain your beliefs, understandings, and reflections about science teaching and The Framework and NGSS. The survey will be given through this web site and you will complete it outside of the NGSX sessions. All of your answers will be identified with a code number to protect your identity when used for research purposes.

• You may be asked to participate in up to three individual or group interviews where you are asked questions about your understanding and attitudes toward NGSS, and how you are thinking about the effects NGSS may have on classroom teaching. Questions will also ask about work you have done during the NGSX sessions. Interviews will last 20-30 minutes and will be scheduled outside of the NGSX session time, usually before or after the session. The interviews will be audio and videorecorded.  
You have the right to review and edit the recording to delete any material you do not want recorded. You may choose not to answer any of the questions. You may also ask us to turn off the recorder at any point in the conversation.

• A sample of your written reflections in the NGSX system will be collected for the research. Individual identifying information will be removed, and your work will be identified with a code number.

• Researchers will observe some of your NGSX study group sessions. As part of these observations, we will be photographing and video recording the discussions to understand how teachers, coaches, and administrators perceive the ideas in NGSS and the challenges in bringing NGSS into classrooms. These recordings will subsequently be transcribed, but pseudonyms will be
used for each teacher, and no identifying information will be used when analyzing the research data or in scientific publications or presentations.

**What are the possible risks or discomforts?**
Your participation does not involve any risks other than what you would encounter in daily life. In addition, your decision to participate in the research will not affect your ability to participate in these professional development opportunities.

**What are the possible benefits for me or others?** You are not likely to have any direct benefit from being in this research study. However, this research is expected to yield knowledge about how to help teachers, coaches, and administrators learn about the Framework and NGSS, and to inform the design of more effective professional development.

**What alternatives are available?** You may choose to participate in all parts, some of the parts, or not participate in any part of this research study. If you do not wish to participate in this study, it will not affect any aspect of your participation in these professional development experiences.

Financial information: Participation in this study will involve no cost to you. You will not be paid for participating in this study.

**What are my rights as a research participant?** If you choose to be in this study, you have the right to be treated with respect, including respect for your decision whether or not you wish to continue or stop being in the study. At any time in the study, you may decide to withdraw from the study. If you withdraw, no more information will be collected from you. If you indicate you wish to withdraw, the researcher will ask if the materials already collected in the study can be used.

Choosing not to be in this study or to stop being in this study will not result in any penalty to you or loss of benefits to which you are otherwise entitled. Choosing to not participate or to withdraw from this study will not affect your ability to participate in any of the PD opportunities. Choosing to not participate or to withdraw from this study will not result in any penalties or negative reviews from the facilitators, investigators, or Northwestern University.

If you want to speak with someone who is not directly involved in this research, or if you have questions about your rights as a research subject, contact the Northwestern University Institutional Review Board (IRB) Office. You can call them at (312) 503-9338 or send e-mail to irb@northwestern.edu.

What about my confidentiality and privacy rights? Participation in this research study may result in a loss of privacy, since persons other than the investigator might view your study records. Unless required by law, only the study investigator, members of the investigator’s staff, the Northwestern University Institutional Review Board, and representatives from the Office for Human Research Protections (OHRP) have the authority to review your study records. They are required to maintain confidentiality regarding your identity.

All survey responses and samples of work will be represented using code numbers or pseudonyms rather than your name. Pseudonyms will be used in all transcriptions of NGSX sessions. Results of this study may be used for teaching, research, publications, and presentations at professional meetings. If your individual results are discussed, your identity will be protected by using a number or fictional name rather than your name or other identifying information. Your name will never be used in any report. Personal information about you will never be reported any school, district, or state administrators.
Audio/video recordings: At the end of this consent form, you will be given the option of allowing us to take photographs of the PD sessions, and to make audio or video recordings of the group interviews and NGSX sessions. Photographs of the sessions can include what is written on the whiteboard or on flip charts. Audio or video recordings will be short excerpts (2 to 6 minutes) of group interviews and discussions during PD sessions. These photographs and recordings may be analyzed for research, and used in presentations at scientific meetings to illustrate how participants learn about the implications of the Framework and NGSS for classroom teaching. These photographs and recordings may be also be used for online professional development of teachers, coaches, and administrators at a password-protected secure site, that will help prepare educators to facilitate professional development related to the Framework and NGSS.

If your individual results are discussed, your identity will be protected by using a number or fictional name rather than your name or other identifying information, and no personal information about you will be included in the presentation.

Who should I call if I have questions or concerns about this research study? If you have any questions during your time on this study, call us promptly. You can contact Brian Reiser at (847) 467-2205 or via email at reiser@northwestern.edu. If you have any questions about your rights as a research subject, you may call the Institutional Review Board Office of Northwestern University at (312) 503-9338.

1. I have read this form and the research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told who to contact. I will receive a copy of this consent form after I submit it. [Please check Yes or No for each of the following]

   - Yes
   - No

   I agree to answer survey questions about my experiences.

   I give permission for my work in the NGSX online system to be collected and analyzed.

   I agree to participate in interviews about my experiences.

   I give permission for my NGSX sessions to be photographed, audio or video-recorded for data analysis.

   I give permission for photographs, audio or video recordings of the NGSX sessions, which may include my face, to be used for workshops and online training of PD facilitators at a password-protected secure site.

2. Please indicate your name as your digital signature on this consent form.

3. What is your 20XX Vermont Study Group?
APPENDIX C
INTERVIEW PROMPTS

Before watching…reflect briefly on the following:

• What was the goal of the discussion?

• What do you remember about the discussion? How did you plan for the whole group discussion?

Play portions of the video. Pose questions:

• What do you remember about this segment of the discussion?

• Why did you decide to make that move there?

• How did you know to make that move?

Questions regarding challenges:

• What is the most difficult or challenging thing about implementing whole group discussions?

• What were some early challenges? How different now?

Other question prompts:

• What’s similar or different about consensus discussions compared to other whole group discussions?
• What’s challenging?
• What is the goal?
• How do you end a discussion?
## APPENDIX D

### RULES FOR TRANSCRIPTION

Transcription conventions for all formats (Excel, Word, etc.)

<table>
<thead>
<tr>
<th>Character(s)</th>
<th>Meaning</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>, (comma)</td>
<td>end of a phrase (an idea unit or tone group) that signals “more to come”</td>
<td>There is typically a brief pause after a “more to come” phrase (but not always). If the pause is not noticeably long, you don’t need to notate it.</td>
</tr>
<tr>
<td>. (period)</td>
<td>end of phrase (an idea unit or tone group) that signals “I’m finished with that thought”</td>
<td>This doesn’t mean that the person necessarily stops talking, just that the phrase ends with a feeling of completion. It’s kind of akin to the end of a sentence, but don’t think about it as a written period. The person could use it with a partial phrase. Just ask yourself if you could stop the recorder right there and feel OK about not hearing more from the person.</td>
</tr>
<tr>
<td>? (question mark)</td>
<td>indicates a question (either because of intonation, or syntax)</td>
<td>Use this whenever you know that the person has asked a question, or when (because of the rise in intonation) it sounds like a question. After a “more to come” phrase, there might be a rise in intonation, but this is not a question. Use “?” for clear cases of questions, or very marked cases of question-like intonation.</td>
</tr>
<tr>
<td>- (dash)</td>
<td>false start or self-correction, clearly an interruption of a thought</td>
<td>Typically, the person interrupts in the middle of a word or right after a word, and then repeats it or shifts to a new word. It’s not signaling the end of a thought – but a mistake or hesitation. Very common when doing “first draft” talk (thinking on one’s feet about a complex idea). Also some people do it more than others. (NOTE: We used to use a double dash (--) but word turns that into a different character (—). So just use a single dash.</td>
</tr>
<tr>
<td>... (three periods, no spaces)</td>
<td>a measurable pause (typically about 1.5 to 2 seconds or more)</td>
<td>This is a noticeable pause, not just the normal pause that comes at the end of thought (either “more to come” or “I’m finished with the thought.”) If it’s a very</td>
</tr>
<tr>
<td>between, but with a space on each side</td>
<td>long pause (like more than 4 seconds), you can time it on the video, and report it. It would look like this: ... and um ... (5 seconds) so then I went inside. Typically, when it’s short and you don’t measure it, it looks like this: ... and um ... so then I went inside.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>.. (two periods)</td>
<td>Brief break in timing Sometimes in the middle of an idea unit, there’s just a break in timing, not a real pause, and not a self-correction. You can use .. to indicate this.</td>
<td></td>
</tr>
<tr>
<td>(...) (parentheses with 3 dots inside)</td>
<td>Unintelligible If you have a guess about what’s being said you can put the words in parentheses: (an elephant) or just leave it out (...)</td>
<td></td>
</tr>
<tr>
<td>(laughter)</td>
<td>Indicate verbal nuances in parentheses – such as (chuckles), (raises voice), (softly), (sneezes), (sighs), (speaks slowly) You don’t have to agonize about this, just put in information if you think it’s important – or if it’s very noticeable and you want the transcript reader to know this.</td>
<td></td>
</tr>
<tr>
<td>[raises hand]</td>
<td>Indicate gestures or non-verbal nuances in brackets This is a judgment call. Add this information if you think it’s important.</td>
<td></td>
</tr>
</tbody>
</table>
## APPENDIX E

**TALK MOVES CODING MANUAL**

### Goal 1: Share, Expand, and Clarify Moves

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
</table>
| SAYMORE  | A SAYMORE move elicits new information about the same topic *from the current speaker*. The canonical form of this move is “Can you say more?” or “Can you expand on that?” but this label also encompasses requests for examples, (“Can you give an example?”) and requests for clarification of meaning (“What do you mean by X?”), as well as fill in the blank statements with question words (wh-in-situ questions, “The water had more what?”). This is also coded when teacher asks the current speaker to repeat. *Note that a move that elicits information about another topic or information from another speaker is not a SAYMORE.* | “Okay. Can you say a little more about that?”  
“Okay what do you mean that they belong to the earth? Can you kind of explain that a little bit more”  
“The water had more what?”  
“Ally will you repeat that again for us?”  
“Can you say that again? I don’t think everyone heard you.” |
| REVOICE  | In a revoicing move, the teacher repeats or rephrases some or all of what the student has said, and then asks the student to verify whether or not the teacher’s revoicing is correct. This move gives the teacher a way to focus the group’s attention, while crediting the students as originators of key ideas.  
*A move that asks for clarification but is not a restatement of a speaker’s idea is not a revoicing.*  
*A move that restates a speaker’s idea but does not ask for clarification is not a revoicing. Code only if there is a question mark or a confirmation from the student indicating a check for understanding.* | So you’re saying there was a room inside and then out here was a room. And you just happened to bound yours by a box?  
“T: So you think the amount of space these take up depends on the room that they’re in or the house that they’re in?  
S: yes”  
T: Let me see if I’ve got you’re thinking right.  
T:So it’s going to go up, not down, is that right?  
Is that your question, Morgan, or are you saying including the cap (...)? |
| TIME TO THINK | Teacher uses a verbal move (such as saying “I want everyone to think about it for a moment” or “Let’s all think about this”) to indicate that students should | “Let’s all take a minute to think about that” [silence]  
“I’m seeing the same hands up right now so I would like to hear...” |
pause and think. Includes time spent reading a prompt.
Teacher asks students to reflect on a current topic in writing.
Teacher splits the class into groups or pairs and elicits talk on a specific topic.

from others so I will wait for everyone to get their ideas together because I do want everyone to get a chance to share their thoughts.” [silence]

“I want everyone to take a minute and read the question. [silence]”

“And then I want you to actually turn to a partner next to you. Maybe just talk about it for a quick second. How do you-how would you compare the volumes of liquids? Go ahead and turn to someone next to you”

“I want everyone right now to take just a minute to maybe jot down their predictions, ‘cause we’re going to be testing this out.”

---

### Goal 2: Listen Moves

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESTATE</td>
<td>A RESTATE move elicits a restatement or repetition of one speaker’s idea from another speaker. It may be directed at one person, or asked to the whole class. Crucially, it is not directed at the current speaker.</td>
<td>“Ok, is there anyone who understands what Jasmine is saying and might want to maybe say it a different way to help the rest of us understand? ”</td>
</tr>
</tbody>
</table>

Can anybody rephrase what-what Erin just said? To help us, to make sure that we’re all on the same page.

Can somebody else say it? What-what-what (...) was just saying about.. number of puppies in a given volume and its connection to pressure, its connection to hits?

Can somebody else say that? Somebody else we haven't heard from? Just say- you can-you can repeat exactly what she said but for your own- make sense of that. Why- what's the difference? Why is it that it's hard to drink out of this one?
## Goal 3: Press for Reasoning or Evidence Moves/ Dig Deeper

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
</table>
| WHY    | A WHY move is a press for reasoning. It elicits reasoning or rationale from the current or designated speaker or to the group or asks for evidence                  | “Why? What is it about container A or the liquid in A that makes you think there’s not a lot in there?”  
                                                                                                              | “What is your evidence?”  
                                                                                                              | “How do you know?”                                                                                                           |
| CHALLENGE | Challenges a claim of the current speaker or to the group in order to elicit more information. May provide information or a counterexample.  
Teacher may also present thought experiments with imagined data.                                             | But I thought I heard you say they have a higher likelihood of hitting the inside, which makes me wonder if that’s true then why isn't the bottle just (...) blowing out?  
                                                                                                              | “Ok, but when you said there were leaves that might be falling from trees, do trees – are trees only made up of leaves?”  
                                                                                                              | “How do you know it didn’t rise? Did you measure it?”  
                                                                                                              | “Well let’s imagine that this was made of copper”  
                                                                                                              | Well let's think about the contrast, let's think about the contrast. Let's fill both of them, let's fill both of them to the very top. There's nothing- water's at the very brim. Could you still drink out of this one? |
| Press (for reasoning, explanation, or modeling) | **Press for Explanation**  
- Press for Mechanism  
- Press for-evidence  
- Press for reasoning  
- Can you connect that to the model elements?  
- How would you show that with a model? | Stephanie; Random but was spacing important? (chorus of yeahs)  
                                                                                                              | Colleen; Okay, and so how could you relate that to the air puppies model that Richard-So can somebody show that on one of these maps? (points to their models) 'Cause I- it's- it- I don't know that it's clear to everybody. Maybe on the box one, the um- Colleen your groups. Can you explain.. this movement- open system, look at the open system right now.  
                                                                                                              | But what quality of the bottle, of that is enabling you to think that it is the wall on wheels in the first place? Even if it is different than that. |
Goal 4: Think With Others Moves

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
</table>
| ADD ON | Asking “Who can add on?” invites participation from anyone to join in and respond to someone else’s idea.  
This differs from RESTATE in that it is not a request for restatement or clarification, but rather solicits a response or addition to an idea.  
*does anyone have a different idea? anyone represent that differently is a 4*  
“Does anyone have a different idea? Anyone represent that differently is a 4.

| WHO EXP | A WHO EXP (“Who can explain?”) elicits an explanation of one speaker’s idea from another speaker.  
*What do we think that means? What do you think Amalia means when she says it causes physical breakdown?*  
“Does anybody else think about (...)? Did other people think about that when they were sort of brainstorming? Did anybody find a way to visually represent that? Is it heard that being talked about at a few of the tables. Steph, what did you want to say?”  
“Anyone else agree with Ally that, well, because this is metal it has to have more volume, because metal’s heavier? Does anyone disagree with that, and can explain why they might disagree with that?”  
“Does that fit with what people were saying like concentration? (then looking at female 4) Like you have the same size space on either side and the same number in there?”  
“Okay, what do people think? Is that (...) is that meshing with the ideas that we have on the table so far about this concentration?”  
“Does this idea make sense to people?”  
“Anyone else agree with Ally that, well, because this is metal it has to have more volume, because metal’s heavier? Does anyone disagree with that, and can explain why they might disagree with that?”  
“Does that fit with what people were saying like concentration? (then looking at female 4) Like you have the same size space on either side and the same number in there?”  
“Okay, what do people think? Is that (...) is that meshing with the ideas that we have on the table so far about this concentration?”  
“Does this idea make sense to people?”  
What do people think of that? So if the number of puppies in a given volume is more than on- than in the same exact volume somewhere else, then you’re gonna have more hits. (...) this idea of- of in a given volume, in this given volume or this given (...) space, can be any space- any size we want, right?”

| AG_DA  | AG_DA asks for agreement or disagreement from (the current speaker?) someone other than the current speaker, or the group.  
Note that “Who wants to respond to that?” “What do you think of that idea?” are implicit requests for agreement and disagreement, asking to apply reasoning to someone else’s ideas. These implicit moves are coded as AG-DA  
“Anyone else agree with Ally that, well, because this is metal it has to have more volume, because metal’s heavier? Does anyone disagree with that, and can explain why they might disagree with that?”  
“Does that fit with what people were saying like concentration? (then looking at female 4) Like you have the same size space on either side and the same number in there?”  
“Okay, what do people think? Is that (...) is that meshing with the ideas that we have on the table so far about this concentration?”  
“Does this idea make sense to people?”  
What do people think of that? So if the number of puppies in a given volume is more than on- than in the same exact volume somewhere else, then you’re gonna have more hits. (...) this idea of- of in a given volume, in this given volume or this given (...) space, can be any space- any size we want, right?”

"282"
**Goal 5: Come to Consensus Moves**

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
</table>
| SOLICITING CONSENSUS                | Facilitator poses statements to see what the group is in agreement on (or not). | Where are we now?  
Do we all agree? Does EVERYONE agree?  
Colleen; So what's the wall on wheels? Can we agree on that, in this case?  
Colleen; I wonder, is there anything we can agree upon?  
Stephanie; Okay, so I think we need to talk about is spacing important 'cause it sounds like we are in, different places.  
Colleen: Maybe if we can take it back, and maybe if we can talk and re-direct and see- maybe if we can first come to consensus on where the wall on wheels is and what are the two rooms we're talking about.  
Colleen: So with the- is there still some confusion or questions that people might have.. about how/why the bottle is not being crushed?  
Deanna: Okay, so who would like to continue this story? It's a- because we have agreement on rooms, and the wall itself, are there- let's check again. Anybody think that the wall is something- potentially something else? I like that you shared that idea of opening (...). |
| SOLICITING CONSENSUS WITH SUMMARY   | Facilitator synthesizes some or all of what is agreed upon or where there is disagreement and asks for agreement.  
Do we have consensus that the WOW is.... | So I'm- so I'm hearing a couple ideas. I'm hearing that.. um we have a lot more outside right than inside in terms of sheer number? But the concentration or the frequency of hits is the same, inside and out. And we have a few different ways that people have represented this, and then we have an explanation for why that frequency- why the ones are hitting the same inside and out. So I'm gonna- let's see if we can combine some of these ideas to represent what's up here. So if I put air puppies inside the bottle, right, what should I do with air puppies outside the bottle to sh- to represent this idea that we're thinking of right now?  
00:17:16.08]; Stephanie; So can- I just want to make sure we're okay with this, because I'm hearing it from multiple people but I don't know if everybody is at peace with this. That inside the bottle, is what I'm
Deanna: Are we comfortable with that? We'll call this room A- well whichever (...). One room is this whole room, and the other room we'll say is inside the bottle, okay? And the wall was what?

Colleen: Can someone maybe- because we have a lot of voices, I wonder is there someone that could just say that very succinctly?

Deanna: So to summarize, can one person just summarize why that bottle's not collapsing before we go to break?

So it sounds to me like we have consensus on… So we've got two situations here where when you make that room bigger, things spread out. And then you have less frequent hits- we have that up here, right? And we have it again here.
## APPENDIX F

### CO-CONSTRUCTION MOVES CODING MANUAL

<table>
<thead>
<tr>
<th>DEFINITION</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGREE/DISAGREE</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Instances in which students state explicitly that they agree or disagree with another student's or the group's idea. | • I agree with that, yeah. That's what I said.  
• Or it could be like- I-I could agree with that, I could see that.  
• There aren't more inside.  
• I agree with this um the collisions I'm not sure I agree with the (spacing). I feel like we need them- we're using for having so many particle- so many puppies but not so many collisions in my- cause one of the things we're talking about is proportional spacing and I feel like that's being contradicted now. |
| Needs to be agreeing with an idea NOT just confirming a revoicing/ask for clarification (the word right is often NOT an indicator of agree) | The participant 2 turn in this example is NOT an agree (it is an example of clarify own):  
Participant 1: So what you're saying is not the bottom (...) touching the floor, that's not part of the wall.  
Participant 2: Right, I think that there is definitely air molecules hitting both sides, but for it to be able to move I didn't see it as a (...). |
| Agree-yeah, yes, I agree, I see that,  
Disagree- Not, no, aren’t, but | The participant 2 turn in this example is NOT an agree (it is an example of clarify own):  
Participant 1: Can you try and say more (...) like if.. um.. things were different like that we could end up squishing not just the sides of the bottle but also the bottom to the top, is that kinda what you're getting at?  
Participant 2: Yeah, yeah if you took it down to the bottom of the ocean in the water, um left that.. a- actually would I collect it as it is and (took) it out (...). |
| In this example, the female adds her idea which, in fact is different from what heather is saying (heather is saying number not ratio) but there is no marker of agree or disagree so NOT an AGDA. | Heather: Um, I think it’s a model of equilibrium, in terms of the number of air puppies is somewhat equivalent inside the bottle as (...) the number of air |
puppies outside the bottle. And the wall on wheels is the (plastic) siding, which perhaps is moving a little bit but it’s not- it’s not visible to the naked eye. (Aziza recording what she is saying on chart paper)

F: (speaking to Heather)(pointing to what she has written) So you’re saying that there’s the same number of puppies on the inside of the bottle as there is on the outside of the bottle?

Heather: yeah

Female: They're the same ratio.

**ASK FOR CLARIFICATION**

Includes: **ASK FOR CLARIFICATION Or CHALLENGE**

<table>
<thead>
<tr>
<th>Request to a peer, the group, or teacher for clarification of his/her idea.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenge an idea (without an overt marker)</td>
</tr>
<tr>
<td>Includes revoicing questions—working to get on the same page with others.</td>
</tr>
</tbody>
</table>

“What do you mean when you say..?”

Can you say that one more time just- I'm not- say that one more time.

So what you're saying is not the bottom (...) touching the floor, that's not part of the wall.

Can you try and say more (...) like if.. um.. things were different like that we could end up squishing not just the sides of the bottle but also the bottom to the top, is that kinda what you're getting at?

**RESTATE OR CLARIFY OTHER**

Instances of restating or clarifying a peer’s or the group’s idea (NOT clarifying their own idea).

What I hear Laura struggling with is something that I think is worth exploring a little, which is how is it if there are so many more air puppies outside.. this bottle, that it's not more pressure outside? And that- I think that's worth.. talking about a little more.

So maybe we're saying that.. the sides of the bottle.. are walls on wheels that are really slippery, and maybe the top and the bottom are not as slippery, and the cap is even less slippery.

So can you clarify and say there’s the same number hitting the bottle inside and outside- hitting the wall on wheels. Right? So if you have an equal number hitting the wall on wheels outside as you do inside. **Even though**
she says “so can you clarify” she is not saying that as a question but rather to offer her clarification. NOTE: the person before asked the group a question/challenge. This participant decided to answer. So she is clarifying OTHER not own.

### ADD-ON-

If there are markers or some evidence of other codes, then the other code takes priority.

| Student adds on to a peer’s idea, without an overt marker of agreeing, disagreeing, clarifying, or challenging. Just adding their own thought is not an add-on. It needs to be clear that they are building on the idea before. | “Um I also wanted to add on to Louie’s..”  
… And like Amy was saying, …  
And to piggy back on that I’m also thinking ratios. So there’d have to be (...) of a space to molecules ratio- they’d have to be the same approximate number of molecules per amount of space, whatever we decided, and that's for there to be a kind of equal room…  
In this example, the female adds her idea but there is no indication that it is connecting or building on heather’s idea so NOT an add-on |
| --- | --- |
| Clear that building on or working with another’s idea. Markers like **so that means or so there** help show that grabbing an idea and connecting to it.  
A so, just by itself will **not** rise to an add on-but if there is a so with something that indicates that they are grabbing an idea, it can be an add-on | F: (speaking to Heather)(pointing to what she has written) So you’re saying that there’s the same number of puppies on the inside of the bottle as there is on the outside of the bottle?  
Heather: yeah  
Female: They're the same ratio.  
So there if we kept the bottle closed and added more air molecules into this room suddenly, then the bottle would collapse because there'd be more air molecules pushing on the bottle from out here. But as long as we keep it as it is right now, at the same amount of pushing from both sides…so the ratio- if we-if we increase- |

### CLARIFY OWN

| Clarify **own** idea in response to a request for clarification. The request might be a question, a revoice, a | Right when I- when I drew it as analagous, I drew it floating in the center because the forces are all equal. So it was- there was no top or bottom in-in my drawing. |
challenge. Or earlier statements that the person said on the topic (but would need to clearly say-just to clarify even if didn’t get asked right then).

Includes responses to a revoice move in that it puts on the table an idea to work with. Therefore, if they say “yeah” in response to a revoice, that counts as a clarify own.

You could have an instance of clarify own that does not follow preceded by a request for clarification as in when a person indicates that they are clarifying something that they said earlier with a clear marker like “just to clarify or what I meant”

<table>
<thead>
<tr>
<th>No they're the same number of collisions inside and outside. But I'm trying to reason why that is because I know I had more air puppies outside, so the reason that I'm qualifying in my head that they're the same number of collisions is because these are spaced further apart so there's less chance that they will hit than inside.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitator: Is that your question Morgan or are you saying including the cap (...)?</td>
</tr>
<tr>
<td>Participant: The whole plastic piece.. is the wall on wheels.</td>
</tr>
<tr>
<td>F: And you're saying, Erin, that's because they have more places to go, whereas the ones inside the box wouldn't-they don't really have many options. (Erin nodding)</td>
</tr>
<tr>
<td>P: (...) though, I don't think it's less collisions, I think it's less collisions with the box cause you know puppies outside are gonna collide with-</td>
</tr>
<tr>
<td>:</td>
</tr>
<tr>
<td>T: So you're saying there was a room inside and then out here was a room. And you just happened to bound yours by a box?</td>
</tr>
<tr>
<td>P: Yeah</td>
</tr>
</tbody>
</table>
APPENDIX G

DEPTH OF PARTICIPANT RESPONSE CODES (P1-P3)

Modified from based on the coding scheme from Pimental and McNeill (2013).

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
</table>
| P3   | The contribution includes a complete thought which resembles a sentence and includes an explanation of his/her thinking OR explains someone else’s reasoning, model, or representation. Often includes linguistic markers like “because”, “so”, “if,” or “that’s why”, or “that” that indicate the presence of reasoning. | Um, I assume kind of the-the frequency of collisions was the same on the inside and outside, or both rooms, even if the like actual number of air puppies wasn't the same, so kinda distributed evenly.  
So, if you imagine a three dimensional box, the bottle was not on the top or the bottom the bottle was in the center. It was suspended. (so marker helps identify that she is providing her reasoning)  
So maybe we're saying that.. the sides of the bottle.. are walls on wheels that are really slippery, and maybe the top and the bottom are not as slippery, and the cap is even less slippery. "maybe" here is considered a marker of reasoning. It's explanatory reasoning, but in this case, it seems to be focusing on implicitly reasoning, explaining what's different in the two cases  
Example of explaining what someone else is saying:  
You were- it sounds like you (were) using the spacing not to represent.. the density- or how the concentration of air puppies but instead to represent the likelihood of hitting like the walls (...) |
| P2 | The contribution includes a complete thought which resembles a sentence but no explanation of his/her thinking is included. When asked "What do you mean?" - - if the answer is just explaining what a term means, it's a P2. If the answer is an explanation with reasoning, or any sort of overt reasoning (like "I think it's XXX because when this happens, this happens, so that means..."), then it's a P3.  
When I- when I drew it in my notebook, I drew it... floating. I drew the bottle in the center of...the air puppies box. 
There's more air puppies in space than there are in this bottle.  
Facilitator: And what do you mean by surface area?  
Sara: Like the square inches, the surface area. The bottle (...) the wall on wheels. (P2) |
|-----------------|-------------------------------------------------------------------------------------------------|
| P1 | The contribution consists of a word or phrase only.  
Heavier walls.  
Yeah.  
The container- the... plastic |
APPENDIX H

DESCRIPTION OF FOCAL PHENOMENA AND AIR PUPPIES MODEL

AIR PUPPIES MODEL

After constructing initial explanatory models, the teachers are provided with a tool for thinking about the behavior of air molecules called the “Air Puppies Model”. This model provides a set of elements and rules for how air molecules behave when they interact with objects.

The model includes two “rooms” where air molecules move freely (called air puppies because they just “bumble” about like newborn puppies – they have no intentions, don’t stick to each other, and thus can’t pull but only push on things) and a “wall on wheels” (W.O.W.) that separates the two rooms.

One important model characteristic of the W.O.W. is that it is as if on frictionless rollerskates and can move if pushed on by the air particles. Teachers map these elements of the model on to real world phenomena.

In the case, above where there are an equal amount of “air puppies” the W.O.W. will wobble back and forth a bit as it is hit by the randomly moving air puppies, but it will not, on average, move to the left or the right. It will stay in the middle.

However, in the case where there are more air puppies in the same room size as shown in the image to the right, the room with more air puppies will move the wall to the left as they hit the wall with more frequency than the puppies in the other room.
BOTTLE ON THE TABLE

Participants have been introduced to a model for understanding air pressure called the “Air Puppies Model” through video simulations and discussion. This is their first attempt to apply this model to explain a phenomenon. Participants are shown an empty 2 liter bottle with the lid on. They are asked the following: Consider a plastic bottle, with the cap on, sitting on a table. Why doesn’t the bottle collapse if the air is pushing with a force of 14.7 pounds on every square inch of the bottle?

In this case, the sides of the bottle are the Wall on Wheels. Inside the bottle is one “room” and outside the bottle is another “room”. The air puppies are hitting with the same frequency inside and out so the bottle does not collapse.

BIGGEST SUCKER

Participants are asked to drink from a straw using two different bottles: one has a small hole in the stopper while the other has no hole in the stopper. Participants observe that it is much easier to drink out of the bottle with the hole in the stopper. Participants apply the Air Puppies Model to create explanations for this phenomenon in small groups on chart paper before coming to the consensus discussion.

In this case, the water is the Wall on Wheels. Room A is inside the bottle above the water level and the Room B is the air inside the straw. When someone puts their mouth on the straw and draws their tongue back, they make Room B bigger. This allows the air puppies in Room B to spread out so they hit the WOW less frequently. Meanwhile in Room A, the air puppies continue to hit with the same frequency as before (which is now more than Room B) so the air puppies push the water up the straw. More air puppies can enter through the hole in the stopper and continue to push the water.
SOAP BUBBLE

Participants dip the mouth of a 2-liter bottle into a soap solution so that the mouth of the bottle has a soap film covering the opening. They then place the bottom of the bottle in a bucket of hot water and observe that the bubble increases in size. When they place the bottle in cold water, the bubble shrinks down into the bottle. Participants apply the Air Puppies Model to create explanations for this phenomenon in small groups on chart paper before coming to the consensus discussion. Participants are also encouraged to articulate a new rule to add to the model about temperature.

In this case, the WOW is the soap film. Room A is inside the bottle and Room B is outside the bottle. Before the bottle is placed in hot or cold water, the frequency of air puppy hits inside and outside the bottle is equal so the soap film does not move. When the bottle is placed in hot water, the air puppies inside the bottle warm up and begin moving faster which means they can hit the WOW more frequently and with more force compared to the outside so the bubble grows. When the bottle is placed in the cold water, the air puppies inside the bottle slow down and hit the wall on wheels less frequently compared to the outside so the air puppies outside push the bubble back in and down into the bottle.
BIBLIOGRAPHY


296


298


300


