January 2013

Argumentation as a Lens to Examine Student Discourse in Peer-Led Guided Inquiry for College General Chemistry

Ushiri Kumarihamy Kulatunga
University of South Florida, ukulatun@mail.usf.edu

Follow this and additional works at: http://scholarcommons.usf.edu/etd

Part of the Chemistry Commons, and the Education Commons

Scholar Commons Citation
Kulatunga, Ushiri Kumarihamy, "Argumentation as a Lens to Examine Student Discourse in Peer-Led Guided Inquiry for College General Chemistry" (2013). Graduate Theses and Dissertations.
http://scholarcommons.usf.edu/etd/4712

This Dissertation is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.
Argumentation as a Lens to Examine Student Discourse in Peer-Led Guided Inquiry for College General Chemistry

By

Ushiri Kumarihamy Kulatunga

A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
Department of Chemistry
College of Arts and Sciences
University of South Florida

Major Professor, Jennifer E. Lewis, Ph.D.
Jeffrey Kromrey, Ph.D.
Xiao Li, Ph.D.
Donileen Loseke, Ph.D.
Robert Potter, Ph.D.

Date of Approval:
June 20, 2013

Keywords: cooperative learning, small groups, Toulmin’s argumentation model, peer leaders, teacher training

© Copyright 2013, Ushiri K. Kulatunga
Acknowledgments

I like to thank Dr. Jennifer Lewis, my research advisor, for her direction, support, and inspiration throughout my graduate career. I deeply appreciate the academic advice, feedback, and the commitment made by the committee members, Dr. Jeffrey Kromrey, Dr. Xiao Li, Dr. Donileen Loseke, and Dr. Robert Potter to make my dissertation a success. A special thank you to Dr. Rick Moog for all his support for the collaborative research of this dissertation project. I also like to acknowledge Janelle Arjoon and Nicole Becker for the inter-rater reliability coding and Teresa Eckart for videotaping the peer-led sessions. I like to thank Dr. Renee Cole, Dr. Chris Rasmussen, and Dr. Marcy Towns for the training with the argumentation framework.

A special thank you to former and current chemical education research group members Alicia Garcia, Keily Heredia, Yujuan Liu, Sachel Villafañe, and Xiaoying Xu for their support and very special friendship. I wish to thank Todd Gatlin and Dr. Santiago Sandi-Ureña for insightful discussions and academic advice. I thank the chemistry department and the National Science Foundation for the financial support that made this dissertation work a possibility.

Finally, I like to thank my family Mithraratne Kulatunga, Anula Kulatunga, Harshanie Kulatunga, and Achira Damian for their love and encouragement.
# Table of Contents

List of Tables .......................................................................................................................... iii

List of Figures ........................................................................................................................... iv

Abstract..................................................................................................................................... vi

I. Introduction ............................................................................................................................. 1
   Need for Teacher Training in Cooperative Learning ......................................................... 1
   Specific Cooperative Learning Approach ............................................................................ 3
   Purpose of This Work ........................................................................................................... 4
   References .............................................................................................................................. 8

II. Method ................................................................................................................................... 13
   Peer-led Guided Inquiry (PLGI) Setting ............................................................................. 13
   Sampling Procedure ............................................................................................................ 14
   Data Collection .................................................................................................................... 16
   Toulmin’s Argumentation Scheme ...................................................................................... 16
   Coding and Data Analysis ................................................................................................. 20
   References .............................................................................................................................. 21

III. Argumentation and Participation Patterns in General Chemistry Peer-Led Sessions .......... 23
   Introduction ........................................................................................................................... 23
   Background and Theoretical Framework .......................................................................... 25
      Role of Interactive Discourse in Cooperative Groups ...................................................... 25
      The Importance of Argumentation in Science Learning .................................................. 26
   Method .................................................................................................................................... 30
      Analytical Framework: Toulmin’s Argumentation Scheme ............................................. 30
      Coding Scheme Based on Toulmin’s Model ..................................................................... 34
      An Analytical Framework for Characterizing Argumentation in Small Groups ............. 38
      Sample ............................................................................................................................... 41
      Data Collection ................................................................................................................ 42
      Coding and Data Analysis ............................................................................................... 43
   Results and Discussion .......................................................................................................... 44
   Conclusions and Implications ............................................................................................... 61
   References .............................................................................................................................. 64
IV. Exploration of peer leader verbal behaviors as they intervene with small
groups in college general chemistry ................................................................. 73
   Introduction .................................................................................................. 73
   Method ......................................................................................................... 78
     Peer-led Process Oriented Guided Inquiry Learning
     (Peer-led POGIL) Setting ......................................................................... 78
     Data Source .............................................................................................. 80
     Coding ....................................................................................................... 81
   Results and Discussion ............................................................................... 84
   Conclusions ............................................................................................... 96
   References .................................................................................................. 100

V. Use of Toulmin’s Argumentation Scheme for Student Discourse to Gain
   Insight About Guided Inquiry Activities in College Chemistry .................. 106
   Introduction ................................................................................................ 106
     Toulmin’s Argumentation Scheme ............................................................ 107
     Types of Questions .................................................................................... 108
     Process Oriented Guided Inquiry Learning (POGIL) ChemActivities
     and the Learning Cycle ........................................................................... 109
   Method ........................................................................................................ 111
     Peer-Led Guided Inquiry Setting .............................................................. 111
     Data Source and Analysis ....................................................................... 112
   Findings ....................................................................................................... 113
     Effectiveness of Prompts ......................................................................... 113
     Directed vs. Convergent Questions .......................................................... 115
     Learning Cycle Components and Arguments ......................................... 116
   Conclusions and Implications .................................................................. 120
   References .................................................................................................. 121

VI. Conclusions ............................................................................................ 125
   References .................................................................................................. 130

 Appendix A: IRB Approval Letter ................................................................. 132
List of Tables

Table 2.1  Group A Demographics ................................................................. 15
Table 2.2  Group B Demographics ................................................................. 15
Table 2.3  Framework Used for Assessing the Quality of Argumentation .......... 19
Table 3.1  Framework Used for Assessing the Quality of Argumentation .......... 39
Table 3.2  Distribution of Student Discourse Episode .................................... 45
Table 3.3  Distribution of the Levels of Argumentation for Group A without Peer Leader Intervention ................................................................. 47
Table 3.4  Distribution of the Levels of Argumentation for Group B without Peer Leader Intervention ................................................................. 48
Table 3.5  Distribution of Individual Arguments (n = 36) among Group A Members ................................................................. 52
Table 3.6  Distribution of Individual Arguments (n=20) among Group B Members ................................................................. 52
Table 4.1  Peer Leader Verbal Behavior Categories ....................................... 82
Table 4.2  Distribution of Peer Leader Verbal Behaviors ............................... 84
Table 4.3  Verbal Behavior Categories and Argument Components ............... 86
Table 5.1  Description of Structure Components of ChemActivities ................ 114
Table 5.2  Characterization of Student Group Responses for Questions with Prompts ........................................................................... 114
Table 5.3  Relationship between Learning Cycle Phase and Presence of Full Arguments ........................................................................... 118
List of Figures

Figure 2.1 Toulmin’s Argumentation Scheme ................................................................. 18

Figure 3.1 Toulmin’s Argumentation Scheme ................................................................. 31

Figure 3.2 Distribution of Levels of Argumentation without Peer Leader Intervention ................................................................. 49

Figure 3.3 Individual Contributions to Co-Constructed Arguments in Group A ......... 53

Figure 3.4 Individual Contributions to Co-Constructed Arguments in Group B ... 54

Figure 4.1 Peer-led argument, from Atomic Size activity, with a single student in which peer leader verbal behavior codes are shown in bold italics and student argument component codes are shown in all capital letters ................................................................. 87

Figure 4.2 Student argument, from The Ionic Bond activity, in which student argument component codes are shown in all capital letters ........... 88

Figure 4.3 Peer-led argument, from The Ionic Bond activity, in which peer leader verbal behavior codes are shown in bold italics and student argument component codes are shown in all capital letters .......... 89

Figure 4.4 Segment of peer-led argument, from Lewis Structures activity, in which peer leader verbal behavior codes are shown in bold italics and student argument component codes are shown in capital letters .................................................................................. 91

Figure 4.5 Segment of peer-led argument, from Atomic Size activity, in which peer leader verbal behavior codes are shown in bold italics and student argument component codes are shown in capital letters .................................................................................. 92

Figure 4.6 Peer-led argument segment, from Coulombic Potential Energy activity, in which peer leader verbal behavior codes are shown in bold italics and student argument component codes are shown in all capital letters .................................................................................. 94

Figure 5.1 Toulmin’s Argumentation Scheme ................................................................. 108
Figure 5.2 Sample argument illustrating the argument components elicited by a convergent question with a prompt. Student responses for each coded argument component are shown inside the ovals.................117

Figure 5.3 Relationship between the type of questions and student response type.................................................................................................................................118

Figure 5.4 Sample argument illustrating the argument components elicited by directed and convergent questions in the different phases of the Learning Cycle. Student responses for each coded argument component are shown inside the ovals .................................................................119
Abstract

This dissertation work entails three related studies on the investigation of Peer-Led Guided Inquiry student discourse in a General Chemistry I course through argumentation. The first study, *Argumentation and participation patterns in general chemistry peer-led sessions*, is focused on examining arguments and participation patterns in small student groups without peer leader intervention. The findings of this study revealed that students were mostly engaged in co-constructed arguments, that a discrepancy in the participation of the group members existed, and students were able to correct most of the incorrect claims on their own via argumentation.

The second study, *Exploration of peer leader verbal behaviors as they intervene with small groups in college general chemistry*, examines the interactive discourse of the peer leaders and the students during peer leader intervention. The relationship between the verbal behaviors of the peer leaders and the student argumentation is explored in this study. The findings of this study demonstrated that peer leaders used an array of verbal behaviors to guide students to construct chemistry concepts, and that a relationship existed between student argument components and peer leader verbal behaviors.

The third study, *Use of Tolumin’s Argumentation Scheme for student discourse to gain insight about guided inquiry activities in college chemistry*, is focused on investigating the relationship between student arguments without peer leader intervention and the structure of published guided inquiry ChemActivities. The relationship between argumentation and the structure of the activities is explored with respect to prompts,
questions, and the segmented Learning Cycle structure of the ChemActivities. Findings of this study revealed that prompts were effective in eliciting arguments, that *convergent* questions produced more arguments than *directed* questions, and that the structure of the Learning Cycle successfully scaffolded arguments.

A semester of video data from two different small student groups facilitated by two different peer leaders was used for these three related studies. An analytic framework based on Toulmin’s argumentation scheme was used for the argumentation analysis of the studies.

This dissertation work focused on the three central elements of the peer-led classroom, students, peer leader, and the ChemActivities, illuminates effective discourse important for group learning. Overall, this dissertation work contributes to science education by providing both an analytic framework useful for investigating group processes and crucial strategies for conducting effective cooperative learning and promoting student argumentation. The findings of this dissertation work have valuable implications in the professional development of teachers specifically for group interventions in the implementation of cooperative learning reforms.
I. Introduction

Evolving science education research has produced innovative student-centered instructional reforms for the improvement of student learning (National Research Council, 1996, 2000). Recent research (Blanchard, Southerland, & Granger, 2009; Reiser et al., 2001) argues that the teacher plays a vital role in effectively implementing such innovative instructional reforms. Teachers both at the secondary (Yeany & Padilla, 1986) and tertiary levels (Walczyk, Ramsey, & Zha, 2007) must be educated with new teaching strategies and equipped with the necessary skills in order for the implementation of novel instructional reforms to be effective.

Cooperative learning is a widespread instructional reform both at the secondary and post-secondary education levels (Johnson, Johnson & Smith 1998, 2007; Springer, Stanne, & Donovan, 1999). Cooperative learning is achieved when students work together in groups to accomplish shared learning goals (Johnson & Johnson, 2002). Cooperative learning has shown to be an effective student-centered pedagogical approach that promotes positive student learning outcomes (Johnson & Johnson, 2002; Kirik & Boz, 2012; Slavin, 1996; Webb 1989).

Need for Teacher Training in Cooperative Learning

Teacher training programs have incorporated cooperative learning models in an effort to provide teachers professional development specifically for cooperative learning. Essential elements of these models include, research behind cooperative learning,
important characteristics of cooperative learning, building the cooperative environment through teams, social skills development, implementation issues such as roles of the teacher and group members, group formation, assessment and evaluation, management of the classroom, simple cooperative procedures (e.g. Think-Pair-Share), and complex cooperative methods (e.g. group investigation) (Lyman & Davidson, 2004). A comprehensive study that evaluated teacher training programs tailored for cooperative learning instruction revealed that pre-service teachers learned significantly more on routine components, assigning roles, delegating authority, and composing groups than non-routine components such as developing open-ended tasks, what to do about status problems, and when to intervene in groups (Cohen et al., 2004). Studies have found teachers had difficulty in structuring small group activities where collaboration is necessary for the learning process and including individual and group accountability and finding effective ways to monitor small group activity within the class (Rolheiser & Anderson, 2004). These studies suggest that there is a need for more training elements focused on effective monitoring strategies for the successful implementation of cooperative learning.

In an effort to improve cooperative learning implementation, training has also focused on verbal behaviors of the teachers. The training has focused on several areas including explicit strategic questioning (Gillies & Haynes, 2011), supporting students’ explanations (Webb, 2008), specific communication skills (Gillies, 2004) and instructional strategies on argumentation (Osborne, Erduran, & Simon, 2004). However, literature has shown that there is a scarcity of studies that specifically focus on teacher discourse during cooperative learning (Hertz-Lazarowitz & Schar, 1990; Gillies & Boyle,
These studies suggest that there is a need for more effective group intervention strategies.

In addition to the studies by Cohen (2004) that discuss difficulties teachers face when developing open-ended tasks, there are other studies that suggest teachers need more direction on designing group activities. Teachers face many challenges when creating group activities that enhance collaboration and promote productive student discourse. These studies suggest that teachers can benefit from more targeted training on creating and selecting small group activities.

Overall, thinking about these studies suggest that there is a need for more teacher training elements on group monitoring, teacher intervention during group work, and structuring appropriate group activities, that can benefit teachers. In order to address these issues, it is important to examine the three central elements, students, teacher, and group activities that affect the dynamics of the cooperative classroom. This dissertation work focused on these three central elements of the classroom is expected to address this literature gap by producing effective strategies for group monitoring, intervention, and creating group activities.

**Specific Cooperative Learning Approach**

Peer-Led Team Learning (PLTL) (Gosser, Kampmeier, & Varma-Nelson, 2010; Quitadamo 2009; Sperry, 2008) is a widely used cooperative learning approach. In the PLTL approach, peer leaders facilitate sessions where students work in groups to solve problems. Previous comparison studies have shown higher student achievement for PLTL students both in general chemistry (Drane, Smith, Light, Pinto, & Swarat, 2005)
and organic chemistry (Tien, Roth, & Kampmeier, 2002). Peer-Led Guided Inquiry Learning (PLGI) is a modified version of the PLTL method that is explored in this dissertation.

Peer-Led Guided Inquiry is a cooperative small group learning teaching reform conducted with a large General Chemistry I lecture section (Lewis & Lewis, 2005). In the weekly held peer-led sessions facilitated by peer leaders, students work on targeted chemistry concepts with especially designed material (ChemActivities) in small groups of 3-4. Peer leaders are undergraduate students who have done well in the course or graduate students who facilitate these PLGI sessions. Peer leaders are de facto instructors, therefore, a group of instructors who receive training similar to teachers. An examination of this setting is analogous to any other teacher training. As a result, teacher training can benefit from the findings of this study.

**Purpose of This Work**

Previous studies (Lewis & Lewis, 2005, 2008) that have examined the effectiveness of the PLGI setting demonstrated improved student exam scores. In order to gain a more complete understanding of the dynamics of the PLGI classroom, this dissertation work examines the verbal discourse produced by students working on chemistry problems in small groups. Students, the teacher, and the written activities, the three pivotal elements affecting the dynamics of the cooperative classroom are explored here through three related studies. The first study of this dissertation work, *Argumentation and participation patterns in general chemistry peer-led sessions*, investigates the characteristics of argumentation and participation patterns in small
student groups without peer leader intervention. The second study, *Exploration of peer leader verbal behaviors as they intervene with small groups in college general chemistry*, extends the lens to investigate the function of peer leaders. The third study, *Use of Toulmin’s Argumentation Scheme for student discourse to gain insight about guided inquiry activities in college chemistry*, examines the relationship between student argumentation without peer leader intervention and the structure of published guided inquiry chemistry activities. The expected findings from this dissertation work have implications in producing effective strategies for group monitoring, intervention, and development of group activities.

This dissertation work explores student discourse through a specific lens of argumentation. Argumentation is a crucial element for the advancement of scientific knowledge through scientific dialogue (Kuhn, 1962). The role of argumentation in science discourse has gained prominence in the last 20-30 years. Research has demonstrated many benefits of argumentation on science learning: understanding science concepts (Jimenez-Aleixandre, Rodríguez & Duschl, 2000; Mason, 1996; Osborne, 2010, Zohar & Nemet, 2002), promote thinking and reasoning (Mercer, Dawes, Wegerif, & Sams, 2004; Simon & Maloney, 2007). Therefore, this study investigates the dynamics of the PLGI student groups via argumentation as an initial step towards understanding the functioning of groups.

The first study of this dissertation work, *Argumentation and participation patterns in general chemistry peer-led sessions*, examines the quantity and the quality of student arguments and participation patterns in small student groups without peer leader intervention. The research questions for this study are focused on the frequency of
argumentation, participation patterns of students in co-constructing arguments, and the extent to which students resolve wrong claims. The findings from the first study provide information on both the characteristics of student argumentation and the extent of participation. These findings have implications in teacher training on effective group monitoring strategies that can be used to examine whether students provide evidence and explanations as they build chemistry concepts. Important teacher approaches for getting the students who participate less to participate more, holding individual accountability in groups, are also discussed.

The second study, *Exploration of peer leader verbal behaviors as they intervene with small groups in college general chemistry*, extends the lens to investigate the function of peer leaders. The research questions for this study are focused on the characterization of verbal behaviors, the relationship between peer leader verbal behavior and student argumentation, and the use of the verbal behaviors to help students construct chemistry knowledge. The second study on peer leader verbal behaviors is expected to produce specific communication skills teachers can use to guide students during group work and elicit argumentation, a crucial element for teacher training.

The third study, *Use of Tolumin’s Argumentation Scheme for student discourse to gain insight about guided inquiry activities in college chemistry*, examines the relationship between student argumentation without peer leader intervention and the structure of published guided inquiry chemistry activities. The effect of the structure on argumentation is explored with respect to the prompts, questions, and the segmented Learning Cycle structure of these written activities. The findings from the third study have expected implications for teacher training on the element of developing group
activities. This study is expected to reveal important information on the effectiveness of the prompts, type of questions, and the segmented Learning Cycle in promoting student argumentation. Such information on selecting questions or group activities that enhance productive student discourse in cooperative learning can be provided to teachers in professional development.

Studies have shown that teachers have a lack of understanding on effective strategies to promote cooperative learning (Sharon, Shachar, & Levin, 1999; Sharan, Sharan, & Tan, 2013). Research has also demonstrated the challenges teachers face when incorporating student-centered pedagogies such as small group learning as well as the necessity of training to overcome such challenges (Gillies & Haynes, 2004). The importance of teacher training to conduct student-centered instruction has been emphasized for peer-leaders (Tien, Roth, & Kampmeier, 2002), college instructors (Walczyk, Ramsey, & Zha, 2007), and pre-service teachers (Roehrig & Luft, 2006). This study produces novel teaching strategies important for conducting group work in a teaching reform Peer-Led Guided Inquiry Learning in a General Chemistry I setting. Expected implications of this study provide new ideas for training teachers both at the secondary and tertiary levels for facilitating small group learning.

Research also has shown that teachers lack the pedagogical knowledge for implementing activities that promote argumentation (Duschl, Schweingruber, & Shouse, 2007) and has emphasized the importance of training teachers on strategies focused on promoting argumentation that can result in meaningful learning (McNeill, Lizotte, Krajcik, & Marx, 2006). Research has also shown that science teachers’ limited pedagogical knowledge is a barrier towards engaging students in argumentation (Simon
et al., 2006). However, such barriers can be overcome by training teachers with specific communication skills designed for group work that enhance productive student discourse (Gillies & Khan 2008). Therefore, training teachers with strategies that help promote group learning is vital for implementing cooperative learning. The expected findings of this dissertation work produce new strategies that are beneficial for examining small student group discourse and for conducting effective discourse that promotes student argumentation in group settings. Overall, this dissertation provides a novel approach of using argumentation analysis as a lens to understand group processes and student discourse in cooperative learning.

References


II. Method

Peer-led Guided Inquiry (PLGI) Setting

The data used in all three studies of this dissertation were collected in a Peer-Led Guided Inquiry setting in Spring 2008. Peer-Led Guided Inquiry setting (PLGI) is a cooperative inquiry teaching reform for General Chemistry I at a large public university in the southeastern United States (Lewis & Lewis, 2005). The PLGI sessions were held weekly on Fridays for 50 minutes where students worked in groups of 3-4 on targeted chemistry concepts before they see it in lecture. The students worked on specially designed published ChemActivities (Moog & Farrell, 2008). ChemActivities are based on a Learning Cycle approach rooted in constructivism (Bodner, 1986) and Piaget’s (1970) developmental theory. These activities guide students through the Learning Cycle to build chemistry knowledge.

Each PLGI class comprised 5-6 small groups with the total class size ranging from 20-24 students. The small student groups were formed on the basis of prior achievement in math with SAT or ACT scores to ensure mixed ability. In these cooperative groups, students had assigned roles: manager, recorder, reflector, and presenter. The students rotated these roles weekly. The group composition remained constant throughout the semester.

The peer leaders, instructors facilitating these groups were graduate or undergraduate students who received weekly training. During each training session peer leaders first worked on the upcoming ChemActivity as students modeling cooperative
learning. The instructor conducting the training modeled the behavior of the peer leader. Based on the problems and challenges arising from this group work, peer leaders developed appropriate group monitoring and intervention strategies to address these challenges.

Each PLGI session began with a multiple-choice quiz on the previous week’s ChemActivity and a brief introduction by the peer leader. Following the introduction, students worked within the small groups for 20-35 minutes on the ChemActivities depending on the session. During each session, the peer leader facilitated one or two whole class discussions that required students to present some of the work and discuss as a whole class. Some of the key concepts and student questions were also addressed during these whole class discussions. The PLGI sessions ended with each group reflecting on their performance and teamwork and submitting a report to the peer leader.

**Sampling Procedure**

Selection of both the peer leaders and the two small groups were driven by maximum diversity sampling procedure (Daniel, 2012). One of the peer leaders was a chemistry graduate student with three years of teaching experience as a teaching assistant. The other peer leader was a senior undergraduate student majoring in biomedical science who had successfully completed the General Chemistry I course. She did not have any prior teaching background, peer leading was her first teaching experience. The two selected peer leaders were different in their teaching and educational background.
Since literature suggests group compositions based on sex and race/ethnicity can influence group interactions (Webb, 1984), two groups that were very different on sex and race/ethnicity were selected for the study. One of the groups (Group A) comprised four white male students. The other group (Group B) comprised three female students (two Asian, one Black) and one Black male student. The demographics of both groups are provided in Table 2.1 and Table 2.2. Pseudonyms are used throughout this dissertation for students and the peer leaders.

Table 2.1

*Group A Demographics*

<table>
<thead>
<tr>
<th>Student</th>
<th>Sex</th>
<th>Ethnicity</th>
<th>Year</th>
<th>Major</th>
<th>SATM</th>
<th>Course grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scott</td>
<td>M</td>
<td>White</td>
<td>Junior</td>
<td>Business Economics Economics</td>
<td>550</td>
<td>A-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Biomedical Sciences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mike</td>
<td>M</td>
<td>White</td>
<td>Senior</td>
<td>Biomedical Sciences</td>
<td>440</td>
<td>B</td>
</tr>
<tr>
<td>Joe</td>
<td>M</td>
<td>White</td>
<td>Sophomore</td>
<td>Civil Engineering Medical</td>
<td>620</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ron</td>
<td>M</td>
<td>White</td>
<td>Junior</td>
<td>Physical Education</td>
<td>420</td>
<td>C</td>
</tr>
</tbody>
</table>

Table 2.2

*Group B Demographics*

<table>
<thead>
<tr>
<th>Student</th>
<th>Sex</th>
<th>Ethnicity</th>
<th>Year</th>
<th>Major</th>
<th>SATM</th>
<th>Course grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janet</td>
<td>F</td>
<td>Asian</td>
<td>Sophomore</td>
<td>Interdisciplinary Social</td>
<td>580</td>
<td>C-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sciences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Michiko</td>
<td>F</td>
<td>Asian</td>
<td>Freshman</td>
<td>Biology</td>
<td>540</td>
<td>B-</td>
</tr>
<tr>
<td>Sam</td>
<td>M</td>
<td>Black</td>
<td>Freshman</td>
<td>Psychology</td>
<td>530</td>
<td>F</td>
</tr>
<tr>
<td>Monifa</td>
<td>F</td>
<td>Black</td>
<td>Sophomore</td>
<td>Biomedical Sciences</td>
<td>610</td>
<td>A-</td>
</tr>
</tbody>
</table>
Data Collection

Video data was collected from the General Chemistry I PLGI sessions during the Spring 2008 semester. The two focal groups (Group A & B) were videotaped in each weekly PLGI session during the semester by a member of the research team. During the video taping, even though the camera was focused mostly on the focal group, the camera was moved around to capture other groups and the whole classroom in order to minimize the imposition on the focal group and also capture the dynamics of the class. The classroom comprised 4-6 small groups, a total of 20-24 students. An audiotape was placed on each small group table to capture the discourse of all the student groups in the classroom. The microphone set on the focal group table had to be adjusted sometimes to receive clear audio. During the whole classroom discussions, the camera was focused both on the student groups and the peer leader. The data set comprised a total of 24 videos, 12 from Group A and 12 from Group B for the 12 PLGI sessions in the semester. Prior to videotaping the PLGI sessions, informed consent was obtained from all the students and the two peer leaders. Video data was transcribed and used for the coding and data analysis.

Toulmin’s Argumentation Scheme

Toulmin’s argumentation scheme (Toulmin, 1958) was used to analyze the arguments in the PLGI small group discourse. This scheme has been used successfully to analyze arguments in a variety of subjects including college chemistry (Becker et al., 2013; Cole et al., 2012), college mathematics (Stephan & Rasmussen, 2002), middle school (Erduran, Simon, & Osborne, 2004) and high school science (Zohar & Nemet,
Toulmin’s argumentation scheme has been criticized for being more suitable for analyzing the structure of the arguments but not capturing the moral reasoning and the essence of sophisticated arguments (Nussbaum, 2011). There are other frameworks such as the Walton’s Dialogue Theory and Lakatos’ framework for analyzing argumentation. The Walton’s Dialogue Theory distinguishes among different types of dialogue (persuasive, inquiry, quarrel) and also captures the role of the critical questions (Nussbaum, 2011). The Lakatos’ framework (Lakatos, 1970) that comprises indicators of informal argumentation (hard-core, positive and negative heuristics, protective belt) also captures personal knowledge and beliefs. Therefore, these two frameworks are better suited for socio-scientific settings (Chang & Chiu, 2008; Nussbaum, 2011). Since our arguments are scientific and not socio-scientific and our interest lies in the structure of simple short arguments, Toulmin’s argumentation scheme is a fitting framework for our context.

As shown in Figure 2.1, there are several components of an argument. The *claim* is the conclusion that one arrives at based on the data; in our setting the claim often was the answer to a question in the ChemActivity. The *data* is the evidence that must be considered in order to form the claim. The evidence typically constitutes information or procedures, for our setting, molecular weights, number of electrons or protons are some examples. The *warrant* is the justification one needs to provide to connect the evidence to the claim. Typically in our setting, it is an explanation students provide to connect the evaluated evidence to their answer. The claim, data, and warrant constitute the core of the argument. Stronger and more complex arguments may contain additional components backings, rebuttals, and qualifiers. A *backing* validates the warrant and
provides authority to the argument. A rebuttal is a counter-claim or a refutation of any of the components of the argument. A qualifier is a limiting condition under which the claim holds true. For our context, backings and rebuttals were relatively uncommon and qualifiers were almost non-existent.

Figure 2.1. Toulmin’s Argumentation Scheme

Erduran et al.’s (2004) work on analyzing arguments in student discourse in middle school science played a vital role in the development of an analytic framework for the student discourse in our setting. Since our interest lies both in the strength of the argument and the extent of participation, a participation component was added to Erduran et al.’s Toulmin’s Argumentation Pattern (TAP) model and the levels were also modified to capture the elements of arguments in our student discourse better. For example, Level 1 of Erduran et al’s framework comprised only a claim, which does not constitute an argument in our setting, therefore, is not given a level. For our setting, a
claim must be presented with the data and warrant (argument core) to be considered an argument. Our framework also distinguishes between individual (Levels I1 & I2) and co-constructed arguments (Levels C1, C2, C3), Erduran et al.’s framework relied mainly on the presence of rebuttals to determine the argument strength. Since the student discourse in our context did not frequently contain rebuttals and we were interested to see if the students at least produced the core of an argument, the levels of our framework relied more on the distinction of the core and higher-level arguments and the contribution of individuals in the group to co-construct the arguments as shown in Table 2.3

Table 2.3

<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Level I1</td>
<td>claim, data, warrant(s) provided by one student</td>
</tr>
<tr>
<td>Arguments</td>
<td>Level I2</td>
<td>claim, data, warrant(s) provided by one student, backing(s) provided by the same student</td>
</tr>
<tr>
<td></td>
<td>Level C1</td>
<td>claim, data, warrant(s) provided by more than one student</td>
</tr>
<tr>
<td>Co-constructed</td>
<td>Level C2</td>
<td>claim, data, warrant(s) and backing(s) provided by more than one student</td>
</tr>
<tr>
<td>Arguments</td>
<td>Level C3</td>
<td>claim, data, warrant, and a rebuttal provided by more than one student (with or without backing)</td>
</tr>
</tbody>
</table>

In this framework, a clear distinction is made between arguments constructed by one student (individual arguments) and arguments co-constructed by students collectively. Another important distinction is made between basic arguments containing
only the core of the argument (I1, C1) and higher-level arguments containing additional components, backings and/or rebuttals (I2, C2, C3).

**Coding and Data Analysis**

The coding of the transcripts was conducted while watching the respective videos. First the student episodes within the small group, peer-led episodes, and whole class discussions were identified within each transcript. The identified student episodes within the small group and peer-led episodes were coded with the Toulmin’s Argumentation Scheme (Figure 2.1) for this dissertation work. If the episode contained at least the core of the argument (claim, data, warrant), it was labeled as an argument and assigned a level based on the analytic framework (Table 2.3). The peer leader discourse in the peer-led episodes was further coded with the verbal behavior categories described in the method section of Chapter IV. For each study, at least three coding passes were conducted for each transcript. The first coding pass for each transcript typically took 5-6 hours and each subsequent coding pass about 2-3 hours.

In order to establish the inter-rater reliability for the coding, 10% or 20% of the transcripts were coded by another chemistry education doctoral student at the same or different institution depending on the study. The details of the inter-rater reliability for each specific type of coding are given in the method section for each study. Cohen’s kappa (Cohen, 1960) was reported as a measure of the inter-rater reliability since it takes the proportion due to chance also into account.
References


III. Argumentation and Participation Patterns in General Chemistry Peer-Led Sessions

Introduction

The effectiveness of cooperative group learning in post-secondary education has been the subject of much study (Johnson, Johnson & Smith, 1998; Springer, Stanne, & Donovan, 1999). One common approach to group learning is Peer-Led Team Learning, or PLTL (Gosser, Kampmeier, & Varma-Nelson, 2010; Quitadamo 2009; Sperry, 2008), in which students work in groups on problems with a peer leader, a student who has previously taken the same course and performed well. Peer leaders also undergo appropriate training and receive ongoing support throughout the semester to ensure they are prepared for working with students. Previous studies have shown that peer-led sessions can enhance student performance in chemistry. A comparison of participants in peer-led sessions with non-participants showed that students who participated in the peer-led sessions earned higher final grades in general chemistry (Drane, Smith, Light, Pinto, & Swarat, 2005) and in organic chemistry (Tien, Roth, & Kampmeier, 2002). Studies also have shown that peer-led sessions have helped students’ cognitive and personal growth (Micari, Streitwieser, & Light, 2006). Recently, we have investigated the use of a slightly modified peer-led group learning approach associated with a large lecture section in general chemistry (Lewis & Lewis, 2005). Peer-Led Guided Inquiry (PLGI) is a cooperative small-group inquiry learning method in which students co-construct targeted chemistry concepts through specially designed paper-and-pencil activities. The major
differences with the PLTL approach are that the student groups are smaller (three or four students) with assigned individual roles, there is only one peer leader responsible for five or six groups in a room, and the materials that the students are working with are specially designed to develop, rather than reinforce, important course concepts. In our previous work, we have investigated questions of effectiveness and equity in this group-learning context (Lewis & Lewis, 2008). Although we have seen that the approach has merit in terms of improving student exam scores in general chemistry, the sources of this improvement are not completely clear. In particular, one significant issue that bears examining is the nature of discourse within the student groups, including the relationship between this discourse and student performance. Are all of the students involved in the discussions, or does one person tend to dominate and “provide the answers”? What relationship, if any, can be seen between student participation in this discourse and overall student performance? Does the discourse contain the components of scientific argumentation, including the presentation of evidence rather than simply the generation of responses? Do the groups generate incorrect answers or inappropriate conceptual constructions that are not corrected? In this work, we examine these questions through the lens of the Toulmin argumentation scheme (Toulmin, 1958). In order to do so, we modify an analytical framework from the work of Erduran and coworkers (Erduran, Simon & Osborne, 2004) to address our specific research questions.
Background and Theoretical Framework

Role of Interactive Discourse in Cooperative Groups

Educational researchers have emphasized the importance of student interactions in cognitive restructuring during group work. Group feedback and sharing of ideas help students in a group reformulate ideas and construct new knowledge that they might not have established on their own (Slavin, 1977). Wittrock (1974) focused on the active role that the learner plays when reformulating this information. Wittrock’s model, which emphasizes the generative process of learning in which the learner is able to link new information to prior knowledge, has been applied by Webb (1980) in understanding learning in group settings. In these situations, students can help each other to evaluate their existing knowledge in light of new information and to alter or replace the existing knowledge if needed. More recently, in a review of literature relating to the role of discourse in group work, Nussbaum (2008) provides evidence that cognitive elaboration remains an important perspective for researchers seeking to understand collaborative discourse. Nussbaum concludes that collaborative discourse is most likely to lead to improvements in students’ understanding of content when they have the opportunity for sustained practice with instructional norms that promote elaboration. In this context, the long history of cooperative learning as a “success story” (Slavin, 1996) can be seen as the classic case of a long-term intervention aligned with principles of cognitive elaboration.

Research has also demonstrated that successful cooperative learning is achieved by interactions and co-regulated engagement in the shared problem space (Roschelle & Teasley, 1995). Interactivity, which occurs when more than one student contributes to the discussion, has been identified as one of the necessary components for highly effective
cooperative learning (Reusser, 2001). The level of interactivity among peers is dependent both on the frequency of interactions and also the extent to which these interactions influence the peers' cognitive processes. In our view, for the group process to produce changes in an individual’s previously held ideas or beliefs, the individual must engage in argumentation with other group members to reformulate and restructure those ideas and opinions.

The risk that some students will not be engaged in the group process is always a concern for real-world implementations of cooperative learning, and researchers have suggested that multiple-ability grouping is preferable to ability-matched grouping, because low achievers often do not have much success in ability-matched groups (Evans, 1991; Slavin, 1990). However, a recent study of student discourse during a high school ecology project showed that knowledge was constructed in a meaningful and efficient way only between students with similar abilities (Rozenszayn & Assaraf, 2011).

Esmonde’s (2009) excellent review of mathematics education and cooperative learning introduces the idea of intersubjectivity and reinforces the proposition that fruitful research in this area will move away from a focus on group composition and toward an examination of the nature of students’ participation. As will be shown below, argumentation has sufficient importance for science learning that an examination of student contributions to the co-construction of arguments within a group can provide useful insights.

The Importance of Argumentation in Science Learning

An argument can be thought of as the justification of claims with empirical evidence and reasoning. Argument construction can be either individual or social, and the
two are often related in science learning. As Jimenez-Aleixandre & Erduran (2008) point out, “social dialogue offers a way to externalize internal thinking strategies embedded in argumentation” (p.12). Examination of the role of argumentation in science discourse has been gaining prominence over the past two decades. For example, some researchers have found that the teaching of argumentation strategies can improve the quality and quantity of student arguments at the elementary school (McNeill, 2011), high school (Osborne, Erduran, & Simon, 2004; Venville & Dawson, 2010) and college level (Nussbaum, Sinatra, & Poliquin, 2008; Yu & Yore, 2012). Others have investigated how the lack or presence of argumentation can have a corresponding impact on science learning. Duschl and Osborne (2002) argue that an absence of dialogical argumentation in the classroom could result in a reduction in science learning. Research has demonstrated the positive effect of argumentation on understanding of science concepts and improving reasoning skills both in elementary school children (Mason, 1996; Mercer, Dawes, Wegerif, & Sams, 2004; Simon & Maloney, 2007), high school students (Jimenez-Aleixandre, Rodríguez & Duschl, 2000; Zohar & Nemet, 2002; de Lima Tavares, Jimenez-Aleixandre & Mortimer, 2010) and college students (Aydeniz et al., 2012). These studies employed qualitative analysis of student utterances during argumentation or quantitative pre/post-test designs to explore students’ knowledge gain. The results indicate that an increase in students’ knowledge of science itself can be attributed to their engagement in argumentation.

Considering the importance of argumentation to science learning, research findings that demonstrate students’ struggles with argumentation highlight the need to create opportunities for students to develop strong argumentation skills. For example,
students have trouble explaining phenomena based on data (McNeill & Krajcik, 2007; Sandoval & Millwood, 2005) and they often do not provide reasoning to justify the claims that they do make (L. Kuhn & Reiser, 2005; McNeill & Krajcik, 2007). These studies have demonstrated that the nature of the task or structure of the class activities can have a substantial impact, either facilitating or hindering opportunities for students to engage in argumentation. One approach to enhancing student performance is to provide students with the opportunity to work in a group setting in which evaluation of scientific evidence and argumentation is employed. Improvements in argumentation skills can be achieved via such group discussion even without teacher intervention, as shown by research with South African high school students (Lubben et al., 2009). In addition to supporting the growth of argumentation skills, allowing students to engage in argumentation collaboratively is thought to help students correct incorrect ideas by building consensus (Berland & Lee, 2012) and enhance students’ scientific reasoning and understanding of scientific concepts (Osborne, 2010). Amigues (1988) showed that cooperative student groups performed better than individuals on science activities and Sampson and Clark (2009a) reported that, even though groups did not produce better arguments than students who worked individually on initial tasks, students who had been part of collaborative groups during those initial tasks did better on mastery and transfer tasks than did students who had worked alone. These results are again consistent with the general observation that cooperative learning methods have the potential to enhance student learning (Barron, 2003; King, 1992, 1998; Springer et al., 1999).

Most of the studies on argumentation have been conducted in K-12 settings on biological science concepts (e.g. Berland & Hammer, 2012; Zohar & Nemet, 2002) and
socio-scientific issues (e.g. Evagorou & Osborne, 2013; Venville & Dawson, 2010). Although argumentation studies in university-level chemistry are limited, recent work used argumentation as a lens to examine student discourse in physical chemistry classrooms to analyze students’ conceptual progress and uncover normative classroom practices (Cole et al., 2011), and to investigate how students develop particulate-level justifications for claims in thermodynamics (Becker et al., 2013). Another study explored the impact of an argumentation-based pedagogical intervention on general chemistry students’ conceptual understanding of gases (Aydeniz et al., 2012). These studies do not explicitly examine the nature of student contributions and production of arguments within small group discourse. Our study investigates the nature of college-level general chemistry student discourse with respect to student participation in the construction and co-construction of arguments within the Peer-Led Guided Inquiry cooperative learning environment. Our focus is on un-mediated group discourse - that is, discourse that occurs when the group is working alone, unassisted by an instructor or other external facilitator. When working in a classroom with multiple small groups, un-mediated group discourse is frequently the predominant experience that students have as “group work.” In addition, this approach enables us to directly investigate a concern that many instructors may have: when left on their own, groups may be likely to go “off track” and generate incorrect answers, or be dominated by one person who does all of the work and simply tells the other students “the answers.” Our concerns regarding the nature of participation and our appreciation of the role of argumentation in promoting science learning lead directly to our research questions:
1. How frequently are various levels of individual and co-constructed argumentation observed within small student groups?

2. What patterns of participation in argumentation by individual students are observed in these groups?

3. To what extent do students in small groups resolve originally incorrect claims?

Collectively, these address our central question, “What are the characteristics of student group argumentation in the Peer-Led Guided Inquiry sessions of a General Chemistry I course, for arguments without peer leader intervention?”

**Method**

*Analytical Framework: Toulmin’s Argumentation Scheme*

There are many analytical frameworks (Sampson & Clark 2008) that can be used to assess the quality of student argumentation. For example, Enderle et al., (2010) recently developed an observation protocol that focuses both on social interactions as well as argument structure to assess the quality of arguments in the classroom. One approach that has been widely used by science educators for the defining and examining of arguments is Toulmin’s argumentation scheme, presented in his seminal work, *The Uses of Argument* (Toulmin, 1958). According to Toulmin’s model (Figure 3.1), an argument contains several specific components. The *claim* is the conclusion at which one arrives. The *data* consists of evidence, information, facts or procedures that lead to the claim that is being made. The *warrant* explains how the data or evidence leads to the claim. These three components (claim, data, warrant) are essential and constitute the *core* of the argument. Stronger arguments contain a *backing* that explains why the warrant has
authority and provides the validity for the core of the argument. Additional components that may be present in more complex arguments are the rebuttal (a counter claim or a refutation of any of the components of the argument) and a qualifier (a limiting statement describing the conditions under which the claim holds true). In the student discourse analyzed for this work, these additional components were relatively uncommon, with qualifiers almost completely absent.

Figure 3.1. Toulmin’s Argumentation Scheme
One criticism of Toulmin’s argumentation scheme is the challenge in identifying and differentiating between warrants and backings (Keith & Beard, 2008). Others have critiqued it for the lack of warrants and backings in particular educational settings (Naylor, Keogh & Downing, 2007). Toulmin’s argumentation framework has also been criticized for catering better to a “monologue” rather than a “dialogue” (Plantin, 2005), for lacking the details needed to analyze dialectical arguments due to its general and wide categories (Duschl, 2008), and for losing the overall meaning when analyzing arguments (Furberg & Arnseth, 2009). Researchers also have found that the determination of whether a particular statement should be considered as a claim, data, warrant or backing is context dependent (Duschl, 2002, 2008), which can be a potential drawback. Toulmin’s argumentation scheme has also been criticized as catering to short argument structures (Chang & Chiu, 2008); however, this “flaw” is an ideal fit for the short (1-5 minutes) arguments (Kelly & Chen, 1999) occurring in the PLGI setting. A recent review on argumentation frameworks (Nussbaum, 2011) has also critiqued Toulmin’s argumentation scheme as more suitable for determining the structure of arguments, and not the best tool for sophisticated arguments containing multiple schemes and/or moral reasoning.

Notwithstanding these criticisms, Toulmin's argumentation scheme has been successfully used to analyze argumentation in a broad spectrum of educational contexts, including studies in mathematics (Stephan & Rasmussen, 2002; Weber, Maher, Powell, & Lee, 2008), science (Becker et al., 2013; Cole et al., 2011; Foong & Daniel, 2011; Jimenez-Aleixandre et al., 2000; Sampson & Clark 2009b; Zohar & Nemet, 2002), and English (Mitchell, 1996). Toulmin’s argumentation scheme has also been used as an
analytical tool for the assessment of student work (Gotwals & Songer, 2009) and the quality of arguments (Abi-El-Mona & Abd-El-Khalick, 2011). Recently, Erduran and coworkers developed and applied Toulmin’s argumentation scheme to the analysis of science discourse in middle school science classrooms (Erduran, Simon, & Osborne, 2004). The analytical framework that they use to examine the strength of student argumentation is referred to as Toulmin’s Argumentation Pattern (TAP). This approach has been modified by other researchers to better fit their specific research purpose. In a study designing and validating an instrument to assess younger students’ arguments, Evagorou, Papanastasiou, and Osborne (2011) modified the TAP framework with alterations such as defining the lower levels as “contradicts the claim or no response (level 0), “appeal to authority (level 1)” and the highest level to be the “most convincing argument containing data, warrant and rebuttal (level 4).” Evagorou has also modified TAP by incorporating the number of pieces of evidence presented in arguments as an additional measure of the argument quality (Evagorou, Sadler & Tal, 2011).

For our purposes, it is the presence of the components of argumentation and who is contributing these components that is of interest. Thus, we extend and complement these previous efforts by applying our own modification of TAP to analyze argumentation in small groups of students in a post-secondary general chemistry context. Toulmin’s argument components are exactly relevant to evaluate the presence or absence of data and reasoning in students’ discourse. Toulmin’s scheme facilitates the identification of which component was provided by which student, revealing participation patterns. In comparison to alternative frameworks such as Walton’s
Dialogue Theory, Toulmin’s argumentation scheme is a better choice for our current research focus (Nussbaum, 2011).

**Coding Scheme Based on Toulmin’s Model**

Previous investigators have noted that developing a coding scheme based on Toulmin’s argumentation model can be a challenging task (Erduran et al., 2004). As mentioned previously, the process of identifying the various components of an argument’s core and backing can be difficult and context dependent; a robust coding scheme is therefore essential. We developed the coding scheme used in this work from definitions provided by Toulmin for each component and from examples of coded arguments in previous studies (Erduran et al., 2004; Stephan & Rasmussen, 2002). The goal of this initial coding was to identify the components of each argument (data, claim, warrant, backing, rebuttal) and to note which member of the group provided the component. This part of the analysis is based on the approach first described by Erduran et al. (2004) and used successfully in undergraduate chemistry courses by others (Cole et al., 2011; Becker et al., 2013); it is also similar to the approach used recently to analyze argumentation in a socioscientific context by middle school pairs (Evagorou & Osborne, 2013). As described in these previous efforts, we looked for cues in the student utterances such as “so” or “because” to assist in determining how a particular contribution was operating within a specific exchange.

Before describing the coding scheme in more detail, we first present a description of the written materials used as the basis and catalyst for group discourse in the PLGI setting. These paper-and-pencil materials, referred to as ChemActivities (Moog & Farrell, 2008), are designed to be used by students in groups of three or four, with the instructor
(or peer leader) serving as a facilitator who listens to the discussion and intervenes only when necessary. The activities are structured to guide students through an investigation of presented data, figures, or verbal descriptions to build chemical concepts. Many of the guiding questions contain scaffolds such as “why” or “explain” that elicit explanations for the answers. For example, the activity dealing with atomic and ionic radii begins with a reminder about the previously-established periodic trends in first ionization energy. Then a data table indicating the valence shell, core charge, and atomic radius of numerous atoms is presented. Through a series of guiding questions, the students are led to recognize the trends in atomic radii across a period and down a column, and they are prompted to articulate explanations for these trends in terms of the atom’s core charge and valence shell. The students are then asked to apply these concepts by predicting the radii of three atoms not listed in the table, and explaining how they arrived at their estimates. Thus, these materials are not typical drill worksheets or collections of typical homework or exam questions; rather, they are specifically structured to promote analysis and interpretation, discussion, and student articulation of reasoning.

We used the following rubric to anchor the coding procedure. An answer offered by a student to a ChemActivity question, whether simple (e.g., two electrons) or more complex (e.g., ionization energy increases as the effective nuclear charge increases) is considered a claim. The chemical information the student used as evidence to arrive at that claim is labeled as data. For instance, a balanced chemical equation, a mathematical formula, or a variable from a mathematical formula that the students used as evidence to support a claim would be identified as data. In some cases, a claim or the data may be presented as part of the question in the activity. A warrant is an explanation of how the
data or evidence leads to the stated claim; scientific reasoning and explanations offered by students using associated course concepts to support their answers are considered warrants. Sometimes warrants are mathematical, for example, a mathematical operation including an explanation of the operation. An elaboration of an explanation, an offer of valid common patterns, or explicit reference to chemistry theories and laws or previously learned concepts by the students in order to expand their warrants is labeled as a backing. Finally, a counter claim offered by one student to oppose a claim offered by another student is considered a rebuttal. Within an argument, components other than the claim can also be rebutted, and those are also labeled as rebuttals (Stephan & Rasmussen, 2002; Toulmin, 1958). As mentioned previously, qualifiers were extremely rare in this study, and were not coded.

The presentation of a claim on a new topic or in response to a question in the ChemActivity defined an episode. Episodes and arguments are not synonymous; in order for an episode to be classified as an argument, it must contain all of the elements of the core of an argument. Thus, only those episodes of student discussion that contain at least a claim, data, and a warrant are considered to be arguments. Although these three core components were not always articulated in this order, all were required to be present for the episode to be classified as an argument. In the higher levels of argumentation, a backing and/or rebuttal would also be present. Note that this approach differs from the TAP framework originally described by Erduran et al. (2004) in which an argument need not contain all three of the core components that we require. This is a reflection of the different focus of our work on the production of full arguments rather than “the quality of opposition or rebuttals in the student discussions” (Erduran et al., 2004). In addition, in
our study, almost all of the episodes (and arguments) were directly prompted by the questions in the ChemActivities.

The following excerpt of an episode that constitutes an argument provides an illustrative example of the application of this coding scheme. Codes are shown in parenthesis in capital bold face letters (CODE). The small group (Group A) consists of four students: Scott, Joe, Mike and Ron. All names used are pseudonyms. In this episode, the students are working on a ChemActivity concerning dipole moments. They are answering the question (number four): “Why is the dipole moment zero for CCl₄?” The appropriate Lewis structure for CCl₄ had been drawn by the students previously on the activity page. The equation (µ = q x d) for calculating the dipole moment had also been introduced earlier in this activity.

*Dipole Moment Argument*

[00:36:26.10] Joe: Yeah, what number are we on?


[00:36:33.28] Mike: Oh yes

[00:37:04.05] Mike: So it's zero (CLAIM) because of distance, right? (DATA)

[00:37:06.20] Scott: Because of distance between the center of charge is zero.

Yeah. (WARRANT)

[00:37:08.26] Joe: What? Why is it?

[00:37:19.12] Mike: Just like the other...the CO₂ because there's no distance between the center of the charges. (BACKING)
Although these students may not use the language that experts would employ or provide full explanations of their thinking, they do articulate the various components of an argument. Mike begins by restating the claim presented in the question that the dipole moment of \( \text{CCl}_4 \) is zero. (In general, the claim is not included as part of the question or prompt in the ChemActivities, although it is occasionally present, as in this example.) In addition to stating the claim, he provides the evidence for this claim: “the distance.” Therefore, “because of distance” is coded as data. Scott then expands on that evidence of distance by explaining that the claim is true because the distance between the centers of charge is zero. Since Scott is explaining how the evidence led to the claim, this statement is labeled as a warrant. At the very end, Mike validates the core of the argument by illustrating that their claim and the reasoning is justified: the \( \text{CO}_2 \) molecule they had previously analyzed also had a distance between the center of charges of zero, and they had previously concluded that in that case the dipole moment in \( \text{CO}_2 \) is zero. Here he is providing a backing - validating the argument by referring to a previous example in which analogous reasoning holds true.

*An Analytical Framework for Characterizing Argumentation in Small Groups*

The application of the coding scheme as demonstrated in Table 3.1 provides the basis for characterizing the various arguments that are produced by the student groups. The two factors that are of particular relevance in our investigation are 1) whether any additional components (backing, rebuttal) beyond the core are present, creating a “stronger” argument; and 2) whether more than one student contributes to the construction of the argument. As mentioned previously, earlier work by Erduran *et al.* (2004) on argumentation in science discourse played an important role in the
development of an appropriate analytical framework for characterizing argumentation in our context.

Table 3.1

*Framework Used For Assessing the Quality of Argumentation*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Arguments</td>
<td>Level 1</td>
<td>claim, data, warrant(s) provided by one student</td>
</tr>
<tr>
<td></td>
<td>Level 2</td>
<td>claim, data, warrant(s) provided by one student, backing(s) provided by the same student</td>
</tr>
<tr>
<td>Co-constructed Arguments</td>
<td>Level 1</td>
<td>claim, data, warrant(s) provided by more than one student</td>
</tr>
<tr>
<td></td>
<td>Level 2</td>
<td>claim, data, warrant(s) and backing(s) provided by more than one student</td>
</tr>
<tr>
<td></td>
<td>Level 3</td>
<td>claim, data, warrant, and a rebuttal provided by more than one student (with or without backing)</td>
</tr>
</tbody>
</table>

The various levels of argumentation that Erduran and coworkers identified in TAP served as a starting point for our framework, presented in Table 3.1. However, as with some previous workers (Evagorou, Papanastasiou, & Osborne, 2011; Evagorou, Sadler & Tal, 2011), several adaptations were necessary to deal with the particular circumstances and goals of the study. Our focus is on the production of arguments that contain, minimally, all three of the core components, whereas Erduran *et al.* determined the level of argumentation primarily by the strength and presence of rebuttals, independent of the presence of all of the core components. For example, Erduran *et al.*'s Level 1 consists of an argument containing only a claim, which we identify as an
“episode” but not an “argument.” Thus, an episode that included only a claim by itself was not assigned a Level, and was not counted as an argument. In addition, an important characteristic of an argument in our context is whether it is provided completely by one student (an individual argument) or involves more than one member of the group (a co-constructed argument). Thus, we differentiate between these two types of argument in our scheme, with Levels I1 and C1 designating arguments that include the core only, and are either individually presented (I1) or co-constructed (C1). Erduran et al.’s Level 2 is somewhat analogous to our Levels I2 and C2: backings must be present. The presence of a backing indicates a stronger argument, because a backing explains why the warrant has authority and may also elaborate on the reasoning used to arrive at the claim from the data. However, Erduran et al. did not require all three components of the core to be present in Level 2 as we do for all of our Levels. Because the contrast between individual and co-constructed arguments was not a focus of study for Erduran et al., the distinctions between their Levels 3, 4, and 5 were based on the strength of the rebuttal presented in an argument. This approach is apt in their context because their study focused on debatable socioscientific issues, with many different perspectives present and more than one valid answer possible. Our study, however, involves chemistry questions and problems that generally anticipate one correct answer, although there may be multiples ways to arrive at that answer. Thus, there were relatively few rebuttals provided in our context, and categorizing the arguments based on the strength of the rebuttals was less relevant than simply considering whether or not a rebuttal was present. Therefore, Level C3 describes a co-constructed argument that contains a rebuttal from a member of the group other than
the individual who presented the rebutted claim. Level I3 for individual arguments is not included in our coding scheme because there were almost no instances of self-rebuttal.

Note that the argument presented above (Dipole Moment Argument) is classified as Level C2 because it contains a backing and is a co-constructed argument, with more than one student contributing at least one component.

Sample

This investigation focused on two groups of four students facilitated by two different peer leaders in separate rooms. None of the students were chemistry majors, but all were taking the course to satisfy a major requirement. Group A consisted of four white male students (Scott, Mike, Joe & Ron) ranging from sophomore to senior in class year, with an undergraduate peer leader majoring in biochemical science and peer leading for the first time. Group B consisted of three female students and one male student, ranging from freshman to sophomore in class year. Two of the female students are Asian (Michiko & Janet) and the other female student (Monifa) is Black. The male student (Sam) is also Black. The peer leader of Group B was a chemistry graduate student with some prior peer leading experience. Maximum diversity sampling (Patton, 2002) was used to select the two focal groups. These groups were chosen because of their difference in diversity with respect to sex, race/ethnicity, and class year. Both groups were mixed ability based on SAT scores; however, the coders did not have access to the SAT scores or the student final grades in the course at the time of coding the discourse and classifying the arguments. Each group’s student composition remained constant throughout the semester. Each student was assigned a role within the group each week.
All the students except for Sam and Janet in Group B were present for all twelve peer-led sessions. Sam was absent for four sessions and Janet was absent for one session.

The peer leaders attended a training course that met throughout the semester under study. The instructor for this one-credit course was a chemistry faculty member with substantial experience and expertise in small group facilitation. During the first hour of each two-hour weekly session, all of the peer leaders for the general chemistry course worked in small groups on the ChemActivity that the students would encounter in the upcoming peer-led sessions. The second hour was devoted to discussion of potential student difficulties and misconceptions and possible strategies to deal with these issues.

**Data Collection**

The 50-minute PLGI sessions each included about 20 students and were held on Friday of each week. The two focal groups (A and B) were videotaped during each of their twelve weekly peer-led sessions during the Spring 2008 semester. The whole classroom was videotaped in order to capture the dynamics of the class and also to minimize any imposition on the focal group. The audio portion of each session was transcribed for analysis. Informed consent was obtained from all students and the two peer leaders prior to videotaping the sessions.

Each session began with a quiz and a brief procedural introduction by the peer leader indicating which sections of the designated ChemActivity were to be completed. The students then worked on the activities in their small groups. During a typical session, the peer leader would facilitate one or two whole-class discussions of important or difficult questions or concepts, and the session would end with a written group report that included some reflection on the group’s performance during the session. The time spent
in small group work each week ranged from 20 to 35 minutes. There was only a
difference of a few minutes between Groups A and B for any given week; this small
difference reflected the varying amount of time the respective peer leader spent on the
quiz, introduction, and whole class discussions. Thus, both groups under study had
roughly equal amounts of time available for small group work. The number of arguments
that occurred during this small group work time was tallied as the frequency of arguments
for our study.

**Coding and Data Analysis**

The argumentation data for each session were obtained by reviewing both the
video recording and the corresponding transcript. Episodes were initially identified on the
transcripts while watching the videos, and the corresponding student statements were
coded as described in the coding scheme above. Finally, the presence (or absence) of an
argument was established for each episode, and a Level was assigned based on the
framework presented in Table 1. A second rater, blind to the coding of the initial rater,
analyzed two transcripts containing about 10% of the total number of arguments. Three
different aspects of the analysis were compared to check inter-rater reliability. First, the
identification of the presence of an argument was examined; there was 100% agreement
between the two raters. Next, the question of whether an argument was co-constructed or
individual was investigated. Cohen’s kappa for the inter-rater reliability for the coding of
individual vs. co-constructed arguments was 0.62, which is substantial agreement (Landis
& Koch, 1977). Finally, the inter-rater reliability for the coding of argument components
was 0.64, which is also substantial agreement (Landis & Koch, 1977). The arguments
within the groups were also classified to indicate whether or not the peer leader was
involved in the process. Roughly 80% of the arguments observed within these two groups were produced without peer leader intervention. However, the analysis presented in this study involves only those episodes in which students worked on their own, without any interaction with the peer leader during the discussion. That is, all of the results presented here are for episodes and arguments in the absence of peer leader involvement or intervention.

**Results and Discussion**

Before we address our research questions, we first examine all of the episodes (including those that are not arguments) to determine the extent to which students support the claims that they put forward with at least some data. This is an important issue to address because some previous reports have shown that students often offer claims without any data as support (McNeill & Krajcik, 2007; Sandoval & Millwood, 2005). Therefore, it is important to analyze all of the episodes to get a measure of how often the students offer support for their claims – even if no warrant is present. For this purpose, all of the episodes in the two focal groups were tallied and placed into three categories: claims, claims with data only, and arguments (Table 3.2).

As shown in Table 3.2, only a small percentage of claims are presented in this setting without any data to support them (Group A-11%, Group B-14%), in contrast to the previous work mentioned above. Notably, the majority of claims are supported by both data and warrants; that is, most of the episodes resulted in the construction of arguments (Group A: 75%, Group B: 64%; overall: 69%). These results are promising
Table 3.2

*Distribution of Student Discourse Episodes*

<table>
<thead>
<tr>
<th>ChemActivity</th>
<th>Group A Claims Only</th>
<th>Group A Claims &amp; Data</th>
<th>Group A Arguments</th>
<th>Group A Total</th>
<th>Group B Claims Only</th>
<th>Group B Claims &amp; Data</th>
<th>Group B Arguments</th>
<th>Group B Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balancing Chemical Equations</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Limiting Reagent</td>
<td>3</td>
<td>1</td>
<td>8</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Coulombic Potential Energy I/Enthalpy of Atom Combination</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Coulombic Potential Energy I/Shell Model I</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Shell Model II</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Atomic Size</td>
<td>0</td>
<td>1</td>
<td>11</td>
<td>12</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>The Ionic Bond</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>13</td>
<td>2</td>
<td>4</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Lewis Structures I &amp; II</td>
<td>4</td>
<td>3</td>
<td>9</td>
<td>16</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Lewis Structures III &amp; IV</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>12</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Dipole Moment</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Intermolecular Forces</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>15</td>
<td>19</td>
<td>105</td>
<td>139</td>
<td>21</td>
<td>33</td>
<td>96</td>
<td>150</td>
</tr>
</tbody>
</table>

(11%) (14%) (75%) (14%) (22%) (64%)

because they indicate that the students in this study are generally providing evidence and reasoning to justify their claims as part of their discourse, and they are doing so in the absence of direct prompting or intervention from the facilitator. Previous work (Jimenez-Aleixandre *et al*., 2000) suggests that students understand and learn chemistry concepts better when they are able to support their answers with evidence and reasoning instead of just making unsupported claims. From this perspective, this PLGI setting appears to provide a productive learning environment. We now proceed to a discussion of each of the research questions.
1. How frequently are various levels of individual and co-constructed argumentation observed within small student groups?

Tables 3.3 and 3.4 provide, for Groups A and B respectively, the number of arguments at each Level without peer leader intervention for each PLGI session. The Tables also show the total number of arguments at each Level for each of the groups; this distribution is also provided as a bar graph for comparison purposes in Figure 3.2. Although there is a statistically significant difference in the proportion of arguments that are co-constructed between the two groups ($n = 201; d = 1; \chi^2 = 4.5; p < 0.05$), both groups have a substantial number of arguments that are produced by individuals and that are co-constructed, with a large majority of the arguments containing only the core.

These data indicate that a significant majority of the arguments without peer leader intervention were co-constructed in both groups. This result suggests that, in most cases, when one student provides a claim as part of an argument, at least one other member of the group contributes a component of the argument – data, warrant, backing or rebuttal. In fact, of the 289 total episodes produced by these two groups throughout the semester, 145 (50%) resulted in co-constructed arguments, with the other 50% of episodes being either individual arguments (56 or 19%) or non-argument episodes (88, or 30%). Thus, the typical discourse in these groups can be reasonably characterized as discussion, rather than a monologue from one individual. This is of significance because some instructors (and students) may be concerned that a single student in the group (generally, the “strongest” student) would generate all of the answers and the other group members would simply write them down. These data suggest that is not the dominant paradigm for working through the ChemActivities in this setting. We further address the
issue of who is contributing to the arguments and in what ways in our examination of research question #2 below.

Table 3.3

*Distribution of the Levels of Argumentation for Group A without Peer Leader Intervention*

<table>
<thead>
<tr>
<th>ChemActivity</th>
<th>Level I1</th>
<th>Level I2</th>
<th>Level C1</th>
<th>Level C2</th>
<th>Level C3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balancing Chemical Equations</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Limiting Reagent</td>
<td>4</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Columbic Potential Energy I</td>
<td>3</td>
<td>-</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Enthalpy of Atom Combination</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Columbic Potential Energy I</td>
<td>4</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Shell Model I</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Atomic Size</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>The Ionic Bond</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>-</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Lewis Structures I&amp;II</td>
<td>2</td>
<td>-</td>
<td>6</td>
<td>1</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Lewis Structures III &amp; IV</td>
<td>3</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Dipole Moment</td>
<td>3</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Intermolecular Forces</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>4</td>
<td>47</td>
<td>8</td>
<td>14*</td>
<td>105</td>
</tr>
</tbody>
</table>

* 4 out of the 14 arguments in Level C3 also contained backings.*
### Table 3.4

*Distribution of the Levels of Argumentation for Group B without Peer Leader Intervention*

<table>
<thead>
<tr>
<th>ChemActivity</th>
<th>Level I1</th>
<th>Level I2</th>
<th>Level C1</th>
<th>Level C2</th>
<th>Level C3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balancing Chemical Equations</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Limiting Reagent</td>
<td>2</td>
<td>-</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Columbic Potential Energy I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enthalpy of Atom Combination</td>
<td>3</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>1</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Columbic Potential Energy I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell Model I</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Shell Model II</td>
<td>2</td>
<td>-</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Atomic Size</td>
<td>1</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>The Ionic Bond</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Lewis Structures I &amp; II</td>
<td>2</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Lewis Structures III &amp; IV</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Dipole Moment</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Intermolecular Forces</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>0</td>
<td>46</td>
<td>8</td>
<td>22*</td>
<td>96</td>
</tr>
<tr>
<td><strong>Total by Argument Type</strong></td>
<td>Individual</td>
<td>Co-constructed</td>
<td>20 (21%)</td>
<td>76 (79%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 5 out of the 22 arguments in Level C3 also contained backings.
Figure 3.2. Distribution of Levels of Argumentation without Peer Leader Intervention.

The distributions shown in Figure 3.2 indicate two additional points of interest. First, we see that arguments at Levels I1 and C1, which contain only the core, are more frequent than the stronger arguments that contain backings and/or rebuttals (Levels I2, C2, C3) for both groups. For Group A, 79 out of 105 arguments (75%) and for Group B, 66 out of 96 arguments (69%) contain only the core. The relative number of arguments with backings is very low: 16/105 for Group A and 13/96 for Group B. These low percentages of arguments with backings (15% for Group A; 14% for Group B) indicate that students do not often elaborate on their reasoning, validate their explanations by providing relevant chemistry theories or laws, or explicitly articulate that they are applying previously learned concepts to new examples. However, a higher percentage of co-constructed arguments (24/145 = 17%) contain backings than do individual arguments.
This finding suggests that students are more likely to elaborate on their reasoning when co-constructing arguments in a group rather than making individual arguments. Thus, promoting the use of collective argumentation in student groups may be one strategy to increase the presentation of backings and thereby strengthen student arguments.

The low percentage of Level C3 arguments indicates that these students did not frequently provide rebuttals during group discussions. Other research also has discovered a lack of rebuttals in student arguments (Chen et al., 2011). Perhaps not surprisingly, rebuttals generally were observed when incorrect claims were put forward. However, relatively few incorrect claims were presented, resulting in the low number of rebuttals observed. It is important to note, however, that in almost all cases in which incorrect claims were presented, the group was able to resolve them and agree on the correct claim through their interactions (including the presentation of a rebuttal). This finding will be discussed further below when the resolution of wrong claims is addressed.

2. What patterns of participation in argumentation by individual students are observed in these groups?

There are two contexts in which to examine this question: for individual arguments and for those that are co-constructed. Because the patterns of involvement within a group may be different in these two distinct circumstances, we examine each context separately, and then compare the results. Tables 3.5 and 3.6 present the data concerning individual arguments (Levels I1 and I2) within each group.

One interesting result is that there is no necessary correlation between the production of individual arguments and the overall performance of the student in the
course. That is, chemistry content knowledge as measured by the final course grade is not necessarily the primary indicator of who is presenting individual arguments. Note that in Group A (Table 3.5), the final course grade tends to mirror the relative contribution of individual arguments; however, this is not the case for students in group B (Table 3.6). There are two important and related points to be made with respect to this observation. First, the relative “strength” of a student does not determine the relative contribution of “answers” from that student that include evidence and reasoning. In Group A, the individual (Scott) who contributes 61% of the arguments has the highest chemistry content knowledge as measured by the final course grade. In Group B, the individual with the highest final course grade (Monifa) contributed the fewest individual arguments per session. Second, the two groups did not behave similarly. Although not a focus of this study, the interplay between group composition, individual personality, background knowledge and other factors likely influences the patterns of contribution of individual arguments. Note that Group A is a relatively homogeneous group of four white males and Group B is a heterogeneous group with respect to race and gender, with Sam, who did not pass the course, as the only male student among three females in Group B. Previous research (Webb, 1984) has shown that group compositions that isolate one gender can lead to interactions that can be detrimental to learning. Thus, demographic isolation could be a factor that hindered Sam’s participation in argumentation and his success in the course.
Examining the extent to which the particular demographics of these two groups are responsible for the differences in contributions of individual arguments is beyond the scope of this work. However, one final important point can be made. Our framework, based on Toulmin’s argumentation scheme and a modification of TAP targeted to our research questions, enables us to identify and codify the differences between these two groups.
We now turn our attention to an examination of the participation patterns in co-constructed arguments. Figures 3.3 and 3.4 present the relative contributions of each student for each argument component as a percentage of the total number of occurrences of that component in all of the arguments without peer leader intervention. Several differences are apparent from a comparison of these two figures. The pattern of contributions in Group A is essentially the same for all of the components (with the exception of a variation for rebuttals, which will be addressed below) whereas in Group B the pattern of contributions varies across the components.

![Figure 3.3. Individual Contributions to Co-Constructed Arguments in Group A](image)

Figure 3.3. Individual Contributions to Co-Constructed Arguments in Group A
In Group A, Scott contributes the most for all of the components, with Mike second for all but the rebuttals. Joe and Ron each make about 10-15% of the contributions in all categories, with the exception of rebuttals where Mike rarely contributes and Ron provides 25% of the remarks. This pattern generally mimics the relative contributions of individual arguments described above. In contrast, the results for Group B are quite different. There is no constant pattern of contributions for the various components as there is for Group A (although Sam does generally contribute the least of any member of the group). The two female students, Janet and Michiko, who equally dominated the production of individual arguments also contribute substantially to each of the components of the co-constructed arguments, but Monifa also participates in the co-constructed arguments to a significant extent, much more than the 10% of individual arguments that she produced. Thus, in Group B the co-constructed arguments reflect a

**Figure 3.4.** Individual Contributions to Co-Constructed Arguments in Group B
much greater degree of interaction and discourse involving all members of the group, whereas in Group A the co-constructed arguments tended to involve primarily two group members.

As noted above, one exception to the pattern of discourse in Group A involves the relative contribution of rebuttals. Scott provided about 60% of the rebuttals. This is consistent with his domination of the production of individual arguments and his high overall course grade. Scott’s role as the dominant participant in arguments was due to the lack of contribution by other group members and was not reflective of an “alienating leader” who was not interested in what the other group members had to say or who imposed ideas on the others (Richmond & Striley, 1996). According to the videos, Scott did not interrupt other students’ responses and left room for others to respond to questions. Scott had confidence in his understanding of the material, tended to produce answers and explain his thinking to the other males in his group, and when someone else provided a claim that he thought was incorrect, he would indicate his disagreement and provide his alternative claim. Of note, however, is that Mike is providing almost no rebuttals, but Ron is providing many more. In fact, Ron provides a greater percentage of rebuttals than any other argument component. Of interest is a comparison of Ron’s pattern of contributions to those of Sam in Group B. Each of them provided only 2 individual arguments over the entire semester. They both provided a low percentage (about 10%) of contributions to the cores of co-constructed arguments – with the exception of Sam’s contribution of about 20% of Group B’s data. However, there is a difference in their relative contributions of backings and rebuttals, the elements of stronger arguments. Sam’s contributions in these areas remain very low – the lowest
contributions in Group B. But Ron has higher contributions in these areas than in the core components, and he replaces Mike as the second highest contributor of rebuttals in the group. Ron provided roughly equal numbers of rebuttals to claims made initially by Scott and by Mike. Of interest is the fact that Ron and Sam each had the lowest math SAT score in their respective groups; in the end, however, Ron earned a C in the course, and Sam did not pass. Ron’s ability to contribute backings and rebuttals may be an indication of (or reflection of) his better grasp of some of the important concepts in the course. The relationship of the production of backings and rebuttals to overall success and understanding is an area for possible further investigation.

Both groups showed a discrepancy among group members with regard to the individual arguments; however, there are some differences in the participation patterns of the two groups. In Group A, one student (Scott) dominated in providing individual arguments in comparison to the other three group members. In Group B, two students (Michiko and Janet) took the lead in offering individual arguments and the other two were less engaged in individual arguments. Observations and coding of the videos showed how this difference in the participation pattern in the two groups resulted in Group B having more opportunity for collaborative argumentation. This discrepancy in the participation structure of the two groups also would explain the much higher percentage of Level C3 arguments with rebuttals in group B in comparison with group A (Figure 3.2). The Group B environment, where most of the members contributed some to the construction of arguments, unlike in group A where one member dominated most of the contribution, allowed a favorable atmosphere that promoted rebuttals. In Group B students also occasionally split into two pairs, with each pair working separately on a
problem instead of as a whole group. This arrangement frequently promoted rebuttals between the pairs. This type of pairing of students within a group in cooperative learning has been observed previously (Daubenmier & Bunce, 2008). Our analytical framework enabled us to uncover these two different participation patterns. The ability to identify such patterns is important because it provides a context for implementation of an intervention that targets a specific participation pattern within a student group.

3. To what extent can students in small groups resolve initially incorrect claims without peer leader intervention?

Although working in groups can have numerous benefits, one possible concern is that the students will generate incorrect answers or ideas that will create or reinforce misunderstandings and misconceptions. This may be of particular concern in situations such as ours, in which the instructor is not present and the peer leader is relatively inexperienced in both classroom management and in helping students develop content expertise.

To investigate the issue of resolution of incorrect claims, the original claim for each episode without peer leader intervention was identified as being correct or incorrect. For the episodes initiated by an incorrect claim, careful analysis of the transcript and video provided a basis for determining whether or not the incorrect claim was resolved by the end of the episode. Phrases such as, “I understand now,” “I agree,” “that makes sense,” given by students after a lengthy discussion that included reasoning with a presentation of the correct claim were also used as indicators for resolution of wrong claims through argumentation.
As described previously, in some cases, the ChemActivity contained prompts for explanations that supported the resolution of initially incorrect claims. In most cases, however, the students independently addressed the incorrect claim. When one student presented an incorrect claim, one or more other group members offered a rebuttal and provided reasoning as support for their rebuttal. Through this type of interaction, the group was able to not only arrive at a correct resolution but also helped each other better understand the underlying chemistry concepts. An example of this process is demonstrated in the following excerpt from a Level C3 argument from Group A, dealing with part of the “Atomic Size” ChemActivity described earlier. Here the students are working on the question, “Predict which is larger: the $O^2-$ ion or the $F^-$ ion?” given in the activity.

**Ionic Size Argument**

[00:31:17.26] Joe: Which is bigger? They're equal. Right? (CLAIM-incorrect)

[00:31:26.07] Scott: No. (REBUTTAL)

[00:31:27.10] Joe: Yeah. Eight and 2 would be 10 and then F is 9 and 1. (DATA)

[00:31:31.27] Scott: Um... Oxygen would be larger. (REBUTTAL)


[00:31:35.23] Scott: They can have the same, like, electrons but um...fluorine has more protons (DATA) so it's going hold its electrons closer. (WARRANT)

-----------

[00:32:02.00] Mike: They can't be the same as equal.

[00:32:06.17] Joe: Oh. So then...
[00:32:11.00] Mike: Let's find the core charge.

[00:32:15.19] Scott: ________. [inaudible]

[00:32:17.18] Joe: Isn't that what I'm saying? It's the same thing, right?

[00:32:19.24] Scott: Um...

[00:32:19.07] Joe: So they would both have 10.

[00:32:20.18] Scott: So the core charge for fluorine is going to be greater because it' has more protons. (BACKING…) So you'll have oxygen only has 8…

[00:32:26.15] Joe: How do you know it has more protons?

[00:32:29.19] Scott: Because see 8 and 9, that's the number of protons it has. (DATA)


[00:32:31.25] Scott: Since this has 9 that means it's going to be a greater charge in the center so they're going to have...pretty much they're going to have the same number of electrons. (DATA) But since its core charge is greater it's going to pull 'em in closer so it's going to make it smaller. (…BACKING)


Joe begins this argument by making the incorrect claim that the sizes of the oxide and fluoride ions are the same. After Scott disagrees by saying “No,” Joe provides some data for his claim by correctly calculating that both ions are 10 (referring to the total number of electrons). Scott rebuts Joe’s claim at 31:27 and then provides both data (same number of electrons, different number of protons) and warrant (since fluorine has more protons, it would make the radius of the fluoride ion smaller) at 31:35. Mike suggests that
the group consider the core charge as a possible way of approaching the issue. Joe does not appear to understand the concept of core charge, as is evident from his statements, “Isn't that what I'm saying? It's the same thing, right?” (32:17) and “So they would both have 10” (32:19). Scott helps Joe understand the difference between the core charge and the total number of electrons by again referring to the concept of protons at 32:20. This reference is the beginning of the backing, which Scott continues at 32:31, after Joe asks him how he knows that fluorine has more protons than oxygen. Scott explains the meaning of the atomic number, and can be seen pointing at the atomic numbers of oxygen and fluorine on the periodic table when he says, “Because see 8 and 9, that is the number of protons it has.” This statement is labeled as data since it is some of the evidence that was used for the explanation (warrant) Scott gave above. At the end of the argumentation, (32:31) Scott includes the data that Joe originally provided – that oxide and fluoride ions have the same number of electrons – and then concludes by continuing the backing related to core charge that he began earlier. This statement validates the reasoning (“pull them in closer”) for his rebuttal that oxide is the larger ion; therefore, it is labeled as a backing. This example demonstrates how the students resolved an incorrect claim through argumentation and also helped each other understand an important and challenging chemistry concept.

Examining the accuracy of all the claims provided by students during the 105 arguments without peer leader intervention in Group A, 22 were initially inaccurate. The students were able to resolve 20 out of these 22 inaccurate claims (91%) by engaging in argumentation without peer leader intervention. For Group B, 23 initially inaccurate claims were made during a total of 96 arguments. The students were able to resolve 20
out of these 23 inaccurate claims (87%) by engaging in argumentation without peer leader intervention. Overall, out of 201 arguments without peer leader intervention produced by these two groups, 196 of them (97.5%) ended with a correct claim being accepted by the group. Not only are relatively few incorrect claims generated, but the vast majority that do arise are resolved within the groups without intervention. These outcomes demonstrate the favorable impact of argumentation and small group interactions on students’ independence in this cooperative learning environment.

Conclusions and Implications

We have presented a modification of the TAP framework for analyzing student discourse involving argumentation in small group settings based on both the strength of the argument and the extent of participation. This framework is a useful tool because it enables observation of group processes and individual participation patterns within cooperative groups, and thus can be applied in any context or discipline in which small group discussion is involved.

There are some limitations of the findings from our study. First, our findings are based on the argumentation analysis of only two groups of students. Our current and future work involves analyzing more groups in different peer-led sessions from different academic years. In addition, our analysis is limited to one type of cooperative class setting led by student peer-leaders, and is based on discourse concerning the specific chemistry topics covered in the peer-led sessions. Therefore, it is not certain that these findings can be generalized to any type of cooperative educational setting with different types of instructors and students or content.
Previous researchers have warned that the benefits of group work are not universal (Bianchini, 1997, 1999; Cohen, 1984; Veenman et al., 2005). Our analytical framework is a useful device for considering student participation patterns in a small group learning environment. Our results reveal that students are not contributing equally in the construction of arguments, and that interactions among group members varied between the two groups. In one case, one of the students dominated in the construction of both individual and co-constructed arguments, while in the other instance two students participated more equally as leaders of individual arguments, and a third joined in substantially contributing to collective argumentation. The large difference in the percentage of arguments with rebuttals between the two groups reflects differences in student participation patterns.

Most of the argumentation that occurs in these small groups was co-constructed, suggesting that students are working cooperatively in this group setting. In addition, students provided a greater percentage of higher-level arguments with validations when co-constructing arguments rather than doing so individually. Our findings add to the literature that has examined the impact of collaboration on constructing arguments such as a study by Samson & Clark (2009a) who found that even though groups did not produce better arguments than students who worked individually on initial tasks, students who had collaborated earlier did better on the mastery and transfer tasks. Previous studies have shown that students often do not support their claims with data (McNeill & Krajcik, 2007; Sandoval & Millwood, 2005). There are also reports that students often do not provide reasoning (warrants) for justifying their claims (Kuhn & Reiser, 2005; McNeill & Krajcik, 2007). However, in this PLGI context, students support most of their claims
with data and warrants. This is a promising finding because it shows that students do provide evidence for their claims and can explain how that evidence connects to those claims.

Another significant finding here is that students infrequently provided backings as part of their arguments. This finding is consistent with Bell’s (2000) work, in which middle school students rarely offered backings. Even though students in our study generally provided warrants, they did not often go beyond that step to validate the argument further. The ChemActivity curricular material used by students in our study contained scaffolds that promoted explanations. This structure is consistent with previous research showing that instructional frameworks with scaffolding promote student argumentation (Berland & Reiser, 2009). However, argumentation may be further enhanced by providing students with prompts based on the Toulmin’s scheme itself (Chin & Osborne, 2010a, 2010b; Kaya, 2013; Weinberger et al., 2010) for eliciting data, warrants, and backings. This higher level of scaffolding would be likely to help students construct better and stronger arguments more frequently. Research in how teachers implement argumentation in the classroom is an area that needs much further investigation (McNeill & Krajcik, 2008), especially since incorporation of argumentation into the instructional practice has found to be a slow and challenging process for teachers (Osborne et al., 2013). Our future studies entail examining peer leader intervention with student groups, including the role of different peer leader verbal behaviors (Gillies 2004, 2006) on eliciting student arguments.

Finally, this study demonstrates that students were able to resolve their incorrect claims through argumentation without the peer leader providing them with the correct
answer, or even intervening in any way. This is an important finding because many chemistry instructors may feel that they must provide students with correct answers in order for them to understand concepts and solve chemistry problems. This lends further credence to the effectiveness of cooperative learning environments where students work on their own without much direct assistance from the instructors (Slavin, 1990). In this PLGI setting, students were able to resolve almost all of the inaccurate claims by engaging in collective argumentation without peer leader intervention. Previous work has shown that engaging in argumentation could improve understanding of science concepts (Jimenez-Aleixandre et al., 2000; Mason, 1996; Zohar & Nemet, 2002) and improve reasoning skills (Mercer et al., 2004; Simon & Maloney, 2007). This study demonstrates that students were able to resolve inaccurate claims via argumentation, an indication of independent learning.

**References**


IV. Exploration of peer leader verbal behaviors as they intervene with small groups in college general chemistry

Introduction

Cooperative learning is a student-centered instructional reform that began in the 1960s and is currently prevalent at the college level (Johnson, Johnson and Smith, 1998, 2007). Cooperative learning is achieved when students work together in groups to accomplish shared learning goals (Johnson and Johnson, 2002). Cooperative learning has shown to be an effective student-centered pedagogical approach that promotes positive student learning outcomes (Johnson and Johnson, 2002; Kirik and Boz, 2012; Kose et al., 2010; Slavin, 1996; Webb 1989). Peer-Led Team Learning (PLTL) (Gosser, Kampmeier, and Varma-Nelson, 2010; Mitchell, Ippolito, and Lewis, 2012), Process Oriented Guided Inquiry Learning (POGIL) (Lewis and Lewis, 2005; Moog and Farrell, 2008), and Problem-Based Learning (PBL) (White, 2007) are some of the currently popular cooperative learning instructional approaches at college level (Eberlein et al., 2008).

In spite of these college instructional reform methods, research has demonstrated that one of the main barriers to the implementation of such student-centered instructional reforms is the inadequate training in pedagogy for college science and mathematics faculty (Al-Amoush, Markic, and Eilks, 2012; Walczyk, Ramsey, and Zha, 2007; Wright and Sunal, 2004). A study conducted by Walczyk et al. (2007) also found that college faculty who did receive training were more likely to consult instructional innovation
resources as support for teaching; therefore, professional development regarding teaching is vital for the sustainable implementation of cooperative learning at the college level.

For the successful implementation of cooperative learning, the teacher must be equipped with the necessary skills (Sharan, 2010; Sharan, Sharan, & Tan, 2013). The teacher must employ effective group monitoring (Johnson and Johnson 1990) and intervention (Brodie, 2001; Hamm and Adams, 2002) strategies for cooperative learning to be effective. An evaluation (Cohen et al., 2004) of teacher training programs, however, found that teachers learned more about routine administrative tasks (e.g. composing groups, assigning roles) than about group intervention strategies (e.g. when and how to intervene, use scaffolds, promote interaction, or otherwise guide the group process).

Group monitoring and intervention requires the teacher to engage in productive discourse, e.g., questioning and exploratory talk, that help students reason (Mercer et al., 1999; Webb et al., 2004; Ding et al., 2007). Studies have also demonstrated that students do not provide explanations for conclusions (Meloth and Deering, 1999: Chinn, O’Donnell, and Jinks, 2000), elaborate on responses or ask high-level questions (King, 2002) without teacher guidance or explicit instructions to provide justifications. In a study conducted over a 20-year period on teacher interactions by Galton et al. (1999), however, the percentage of time teachers spent on directly providing students facts and procedural directions increased from 57% to over 80% of total teacher discourse. This finding is disconcerting, since research suggests that teacher discourse should comprise strategies such as scaffolding, probing, questioning, and challenging student ideas, rather than direct teaching, in order to help students attain higher level cognitive processing for successful learning (King, 2002). Recent research (Kennedy, 2004) also has
demonstrated that instructional approaches have not changed despite many reform efforts. Teacher-centered beliefs are still dominant among teachers (Al-Amoush et al., 2012) and scaffolding practices are rare (Van de Pol, 2011). Therefore, examining the range of verbal behaviors exhibited by teachers continues to be important. It is also important that professional development programs focus on teacher discourse that can guide students to supply reasoning and explanations, such as the development of skills for prompting, questioning, and otherwise scaffolding student group work.

In order to provide professional development programs focused on teacher discourse, it is important to understand the current state of the art of teacher discourse during cooperative learning. Previous studies have investigated teacher discourse in cooperative learning environments at primary, middle, and high school levels. A study that examined teacher discourse in middle school cooperative learning found that instructional practice was mostly recitation and procedural (Webb, Nemer & Ing, 2006). On the other hand, a study that explored high school teacher discourse during cooperative learning found that teachers used an array of mediated-learning behaviors such as asking cognitive metacognitive questions, challenging students’ perspectives, and scaffolding student learning (Gillies & Boyle, 2008). Research has also shown that teachers who received training in specific communication skills and questioning strategies used more challenging and scaffolding behaviors, resulting in improved reasoning and problem-solving skills of primary school children (Gillies & Khan, 2008, 2009). All of these studies investigated teacher discourse during cooperative learning with K-12 students, and there is a lack of research on teacher discourse on this topic at the college level. Literature has also suggested that there is a general lack of research on teacher discourse
during cooperative learning (Hertz-Lazarowitz & Schar, 1990; Gillies & Boyle, 2008; Webb 2009). Our study begins to address this literature gap by investigating teacher discourse during group intervention in a cooperative-learning-based teaching reform at the college level.

Peer-led Process Oriented Guided Inquiry Learning (peer-led POGIL) is a cooperative small-group teaching reform conducted in a college general chemistry course (Lewis & Lewis, 2005, 2008). In weekly peer-led POGIL sessions students work in small groups on targeted chemistry concepts through especially structured paper-and-pencil activities (known as ChemActivities). Peer leaders, who facilitate these POGIL sessions in lieu of faculty, are upper-level undergraduate students who have done well in the general chemistry course or chemistry graduate students. This study explores peer leader discourse by examining the verbal behaviors of peer leaders during group intervention. As others have demonstrated (Gillies & Khan, 2008, 2009), in order to understand the role of teacher discourse, researchers first need insight into student discourse. Collectively examining both the teacher and the student discourse can help researchers understand better how instructors are interacting with students during group intervention. For our setting, an argumentation framework was used to analyze the student discourse in conjunction with the verbal behaviors of the peer leader.

The role of argumentation in science discourse has been gaining recognition recently. Research has shown that student argumentation has resulted in improved understanding of science concepts and better reasoning skills in elementary school children (Simon & Maloney, 2007), high school students (Jimenez-Aleixandre, Rodríguez & Duschl, 2000; Zohar & Nemet, 2002) and college students (Nussbaum,
Sinatra, & Poliquin, 2008). However, studies on argumentation have found that students have difficulty explaining phenomena based on data (McNeill & Krajcik, 2007; Sandoval & Millwood, 2005). Students also often do not provide scientific explanations to support claims (Kuhn & Reiser 2005; McNeill & Krajcik, 2007). Teacher intervention strategies can impact students’ scientific explanations (McNeill & Krajcik, 2008) and argumentation (Kaya, 2013; Mork, 2012). Findings of a study conducted by Evagorou and Osborne (2013) on collaborative argumentation suggest that teachers should be aware of the challenges students face when constructing arguments and come up with the appropriate scaffolding strategies to promote argumentation. It is important, therefore, to investigate whether instructors can prompt students to provide data and scientific reasoning as the students work in groups to construct chemistry knowledge. Combining the verbal behavior categories for teacher discourse with an argumentation framework for student discourse allows the investigation of the relationship between instructor verbal behaviors and student argumentation in our setting.

Recent studies have used argumentation as a tool to investigate student discourse specifically in college chemistry courses. Toulmin’s argumentation scheme (Toulmin, 1958) has been used to analyze physical chemistry students’ conceptual progress and normative classroom practices in POGIL classrooms (Becker et al., 2013; Cole et al., 2011). Becker et al. focused on students’ development of particulate-level justifications for claims in thermodynamics. Cole et al. analyzed more general conceptual progress of students studying thermodynamics. Even though the findings of both of these studies revealed that the instructor’s role was important in scaffolding student arguments during whole class discussions, the research focus was not on the interactive discourse between
the teacher and the students during small group intervention. One interesting finding from Cole et al.’s study, that the quality of student discourse varied on different days, led to these researchers calling specifically for research into which “discourse interaction patterns” between teacher and students would support productive argumentation. Our work answers this call.

In our study, peer leader discourse during group intervention was coded with verbal behavior categories established by Gillies (2004, 2006) and Eagan (2002), and student discourse was coded with Toulmin’s argumentation scheme (1958). We address the following specific research questions:

1. What types of verbal behaviors do peer leaders exhibit as they intervene with small student groups?
2. What is the relationship, if any, between student argumentation and peer leader verbal behaviors?
3. How do the peer leaders use verbal behaviors to help students build chemistry knowledge?

**Method**

**Peer-led Process Oriented Guided Inquiry Learning (peer-led POGIL) Setting**

The peer-led POGIL sessions were held for General Chemistry I course at a large public university in the southeastern United States. The students worked in small groups of 3-4 on targeted chemistry concepts presented via published guided inquiry materials, ChemActivities, (Moog & Farrell, 2008) in weekly (50-minute) peer-led POGIL sessions. The class sizes ranged from 20-24 students, comprising a total of 5-6 groups per class.
The student groups were mixed ability based on prior achievement in mathematics as represented by SAT or ACT scores. The instructors facilitating these sessions were peer leaders, undergraduate or graduate students who received weekly training and support. During the first hour of each training session, peer leaders worked in small groups on that week’s assigned ChemActivity as students. In this way peer leaders experienced cooperative learning as modeled by the trainer, a learning method that research has shown to be effective (Koutselini, 2009). During the second hour, peer leaders developed their plans for facilitation of that week’s ChemActivity with their own students, including group monitoring and intervention strategies associated with the specific lesson and their experiences with students. Neither information on the specific verbal behavior categories used in this study nor information about Toulmin’s argumentation scheme was provided to the peer leaders.

Each weekly peer-led POGIL session began with a quiz and a brief introduction by the peer leader. The students then worked on the ChemActivities within small groups, typically for 20-35 minutes. Each student had their own copy of the activity, but one group member (a different person each week) was responsible for recording the official group answers for the eyes of the peer leader to assist with group monitoring. Typically during a session the peer leader facilitated one or two whole-class discussions to address difficult concepts, although the majority of class time was spent in small group discussion, with the peer leading moving around the room to monitor and intervene with each small group as needed.
Data Source

A semester (Spring 2008) of video data on two small student groups in the General Chemistry I was used. Maximum diversity sampling (Daniel, 2012) guided the selection of the peer leaders and the groups. Peer Leader 1 was a chemistry doctoral student with three years of teaching experience as a graduate teaching assistant. Peer Leader 2 was a senior undergraduate student with several years of chemistry coursework, including general chemistry, but this was her first experience in a teaching role. Both peer leaders are female. The diversity of the larger group of peer leaders is such that revealing racial/ethnic information would insufficiently mask identity, but the two peer leaders also did not have race/ethnicity in common.

The two student groups were selected to represent two different group compositions with respect to sex and race/ethnicity to achieve maximum diversity, since literature (Webb, 1984) suggests that group composition in terms of sex and race/ethnicity can impact group interactions. The student group in Peer Leader 1’s class was composed of three females (two Asian, one Black) and one male (Black). The student group in Peer Leader 2’s class was composed of four White male students. Both groups were mixed ability with respect to incoming mathematics preparation. Student group composition remained constant throughout the semester. All students and peer leaders gave informed consent for video recording during class time.

A total of 20 videos, 10 from each class, were used for the analysis and comprise the entire semester of group work. All videos were transcribed; transcripts were coded while watching the videos. During the coding of transcripts, peer-led episodes were identified. A peer-led episode began when the peer leader was in close proximity to the
student group and started interacting with the group. The episode ended when the peer leader left that group. Student discourse during these peer-led episodes was coded with the analytic framework based on Toulmin’s argumentation scheme. If the student discourse during the peer-led episode contained at least a claim, data, and warrant (argument core), the episode was coded as a “peer-led argument.” For the data collected over the semester, a total of 23 peer-led episodes were observed for Peer Leader 1, and 65% of these episodes were peer-led arguments. For Peer leader 2, a total of 34 peer-led episodes were observed, and 67% of these episodes were peer-led arguments. Each statement (utterance) by the peer leader during a peer-led argument was coded with a verbal behavior category.

**Coding**

The coding comprised two frameworks for this study, verbal behavior categories for peer leader discourse analysis and Toulmin’s argumentation scheme for student discourse analysis. Verbal behavior categories proposed by Gillies (2006) and effective communication skills that have shown to promote student group learning (Gillies, 2004, 2006) were combined and adapted to this study, resulting in eight verbal behavior categories (Table 4.1) to fit our college-level peer-led POGIL setting. For example, the category “disciplines” was not used, since it is more suitable for younger students. The category “teacher control” was modified to direct teaching to indicate instances where the peer leader lectured to the students instead of facilitating. The category “mediates” was expanded to four different communication skills (probing & clarifying, acknowledging & validating, confronting discrepancies & clarifying options, offering suggestions) that have shown to mediate learning (Gillies, 2004, 2006), Table 4.1
presents examples from the data set coded under each verbal behavior category. One of the coders was the first author. The second coder was a chemical education doctoral student who coded 20% of the transcripts with peer-led episodes. Cohen’s kappa for the inter-rater reliability on verbal behavior categories was 0.8, which is substantial agreement (Landis & Koch, 1977).

Table 4.1

*Peer Leader Verbal Behavior Categories*

<table>
<thead>
<tr>
<th>Category</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct teaching</td>
<td>Electrons in the outermost shell are referred to as valence electrons.</td>
</tr>
<tr>
<td></td>
<td>Cl is very electronegative. Na isn't. This is an ionic bond.</td>
</tr>
<tr>
<td>Short questions</td>
<td>How many electrons?</td>
</tr>
<tr>
<td></td>
<td>How many molecules do you have of carbon dioxide?</td>
</tr>
<tr>
<td></td>
<td>What is the q for the nucleus of a carbon atom?</td>
</tr>
<tr>
<td>Encouraging</td>
<td>Good! Fully confident.</td>
</tr>
<tr>
<td></td>
<td>This will be a good learning experience.</td>
</tr>
<tr>
<td>Maintaining</td>
<td>Are you done with your homework?</td>
</tr>
<tr>
<td></td>
<td>Go put that on the board so everyone will know.</td>
</tr>
<tr>
<td>Probing &amp; clarifying</td>
<td>So why did you answer that for 10?</td>
</tr>
<tr>
<td></td>
<td>What can you tell me about resonance?</td>
</tr>
<tr>
<td></td>
<td>So how did you all know that alkanes were nonpolar?</td>
</tr>
<tr>
<td>Acknowledging &amp; validating</td>
<td>Okay, so it’s the smallest.</td>
</tr>
<tr>
<td></td>
<td>That's right.</td>
</tr>
<tr>
<td>Confronting discrepancies &amp;</td>
<td>But I just don't see how those variables are going to work out.</td>
</tr>
<tr>
<td>clarifying options</td>
<td>So just use...use that...and have it...</td>
</tr>
<tr>
<td></td>
<td>So what you're saying is that the largest effect on the melting point</td>
</tr>
<tr>
<td></td>
<td>is the size. But I've just showed you that these sizes are the same.</td>
</tr>
<tr>
<td></td>
<td>And they're very different.</td>
</tr>
</tbody>
</table>
Toulmin’s argumentation scheme (Toulmin, 1958) was used as the analytic framework for analyzing student arguments. In Toulmin’s model of argumentation, an argument has specific components. The claim is the conclusion at which one arrives upon considering the data. The data consists of evidence, information, facts or procedures that lead to the claim. The warrant explains how the data or evidence leads to the claim. These three fundamental components (claim, data, warrant) comprise the core of the argument. Higher quality arguments may contain a backing (authority for the warrant) or a rebuttal (counter claim or a refutation of an argument component) (Evagorou & Osborne, 2013).

Although some authors have referred to the potential difficulty of identifying the separate components of an argument in Toulmin’s argumentation scheme (Kaya, 2013), this study involved two independent coders in identifying the student argument components. The first author was one of the coders. The second was a chemistry education doctoral student from another institution who had used Toulmin’s framework in her own research. Cohen’s kappa for the inter-rater reliability on the argument components of the student discourse on 10% of the transcripts was 0.64, which is substantial agreement (Landis & Koch, 1977).

Since previous research (Kuhn & Reiser 2005; McNeill & Krajcik, 2007) has shown that students can have difficulty supporting their conclusions with data and explanations, we were interested in examining whether the students provided these supports when generating responses for chemistry questions in this study. Therefore, for
examining the relationship between peer leader verbal behaviors and student argumentation, verbal behaviors that elicited data (evidence) and warrants (explanations) specifically were examined.

**Results and Discussion**

Findings with respect to the first research question, “What types of verbal behaviors do peer leaders exhibit as they intervene with small student groups?” are presented here. The analysis revealed that all eight verbal behavior categories were present for both peer leaders. The distribution of the verbal behavior categories with respect to each peer leader for the data from the whole semester is presented in Table 4.2. Peer Leader 1 engaged in 15 peer-led arguments (across the 10 peer-led sessions) in which a total of 153 coded utterances emerged. Peer Leader 2 engaged in 23 peer-led arguments over the same time period, in which a total of 250 coded utterances emerged.

**Table 4.2**

*Distribution of Peer Leader Verbal Behaviors*

<table>
<thead>
<tr>
<th>Verbal Behavior Category</th>
<th>Percentage of Verbal Utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peer Leader 1 (N= 153)</td>
</tr>
<tr>
<td>Short questions</td>
<td>38%</td>
</tr>
<tr>
<td>Probing &amp; clarifying</td>
<td>20%</td>
</tr>
<tr>
<td>Maintaining</td>
<td>16%</td>
</tr>
<tr>
<td>Acknowledging &amp; validating</td>
<td>10%</td>
</tr>
</tbody>
</table>
As can be seen from Table 4.2, the distribution of the different verbal behaviors was similar for both peer leaders. A chi-square test of independence revealed no statistically significant difference in the distribution pattern of the verbal behavior categories for the two peer leaders (n= 403, d=7, $\chi^2 = 4.78$, p = 0.687). Short questions, probing and clarifying, and *maintaining* were the most commonly observed behaviors for both peer leaders. It was promising to find that peer leaders more often used short questions, probing and clarifying, and suggestions to guide students instead of direct instruction, in alignment with the peer-led POGIL objectives. For both peer leaders, short questions were exhibited about twice as often as probing and clarifying. All four types of specific communication skills, probing & clarifying, acknowledging & validating, confronting discrepancies, and offering suggestions, that literature has shown to mediate learning (Gillis, 2004) are exhibited by both peer leaders.

The second research question, “What is the relationship, if any, between student argumentation and peer leader verbal behaviors?” also led to meaningful findings. In order to address this research question, data and warrant components of the arguments were examined to see which peer leader verbal behaviors elicited these argument components. The analysis of all the data components elicited for the total peer-led arguments constructed during the semester revealed that for Peer Leader 1, 64% and for
Peer Leader 2, 61% of the data components emerged from short questions. The analysis of all the warrants revealed that for Peer Leader 1, 61% and for Peer Leader 2, 62% of the total warrants emerged from probing & clarifying verbal behaviors (Table 4.3).

Table 4.3

*Verbal Behavior Categories and Argument Components*

<table>
<thead>
<tr>
<th>Verbal Behavior</th>
<th>Data</th>
<th>Warrants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peer Leader 1 (N=42)</td>
<td>Peer Leader 2 (N=33)</td>
</tr>
<tr>
<td>Short questions</td>
<td>64%</td>
<td>61%</td>
</tr>
<tr>
<td>Probing &amp; clarifying</td>
<td>21%</td>
<td>24%</td>
</tr>
</tbody>
</table>

These findings, that most of the data emerged from short questions and most of the warrants emerged from probing & clarifying, make sense in terms of the argumentation framework. Since data mostly comprises information (e.g. molecular weights, number of protons, electrons) that students use to arrive at a claim, short questions posed by the peer leaders tend to elicit the missing data. Since peer leader probing with prompts such as “why”, “how”, or “explain” and peer leader requests for clarification both tend to elicit explanations, which are the warrants of arguments, probing & clarifying behaviors mostly allow students to express missing warrants.

To move beyond a simple relationship between discrete prompt - response pairs, it was important to examine both the student and peer leader discourse throughout an intervention episode to understand the cumulative process of peer-leader-assisted argumentation. An example of a peer-led argument is presented in Figure 1 to illustrate the relationship between the peer leader verbal behaviors and argument components. For
context, this argument occurred in the POGIL session on the ChemActivity “Atomic Size” while the students were working on the question, “What trend in atomic radius is observed as one moves from left to right across a period?” While this particular interchange involves only one student directly interacting with the peer leader, the others, based on the video, are listening. In this peer-led argument the peer leader intervenes with the small group by first determining the student’s belief about what the current task is, a maintaining verbal behavior, followed by a short question to start the process of determining whether the student is able to fully express an argument for the previous task. The student replies to the short question with the answer (claim), that the atomic radius decreases and provides the information, “because the core charge increases”, (data) that was used to arrive at the answer. The peer leader continues with probing and clarifying verbal behavior by asking, “Why does that happen? ” and is rewarded with an explanation of the link between the data and the claim, “there’s a greater charge pulling the electrons inward”, which serves as the warrant. Finally, the peer leader acknowledges and validates the student’s answer, as can be seen in the final statement in Figure 4.1.

Peer Leader: What number are you guys on? (maintenance)
Student: Four.
Peer Leader: What's your number three? (short questions)
Student: It decreases (CLAIM) because the core charge increases. (DATA) The core charge is increasing, I guess.
Peer Leader: Okay. Why? Why does that happen? (probing & clarifying)
Student: Because there's a greater charge pulling the electrons inward? (WARRANT)
Peer Leader: Right. There's a greater magnitude charge going from +3 to +4. (acknowledging & validating)

Figure 4.1. Peer-led argument, from Atomic Size activity, with a single student in which peer leader verbal behavior codes are shown in bold italics and student argument component codes are shown in all capital letters
Although this episode demonstrates that the student was able to supply an argument, a peer leader’s strategy of using a series of verbal behaviors to see whether an argument can be produced can also reveal problems with student reasoning. The two vignettes that follow demonstrate peer leader use of a variety of verbal behaviors to guide students to build a correct argument.

For context, the first of these vignettes is from the ChemActivity “The Ionic Bond”, and Figure 4.2 presents the student discourse prior to peer leader intervention. The students are trying to answer the question, “Which would be expected to have stronger ionic bonds: NaCl or NaF? Explain your reasoning.”

S1: What'd you say for b)?
S2: I put the NaF. (CLAIM)
S1: I said NaF because it has a stronger hold on its electrons. Which is not a very scientific explanation but...(DATA)
S2: Well, because it's closer...(DATA)
S1: It's got a stronger pull. Yeah. It's a tighter...together. It's smaller, can keep a... It's easier to keep track of...(DATA)

Figure 4.2. Student argument, from The Ionic Bond activity, in which student argument component codes are shown in all capital letters

As illustrated in Figure 4.2, the students are providing some evidence (data) to support their claim that NaF has stronger ionic bonding than NaCl. However, they have not explained how the evidence connects to the claim and are aware that their explanation is not “very scientific”. In other words, the students have not provided a warrant to build a complete argument. When the peer leader intervenes, as shown in Figure 4.3, she begins with a short question (1), followed by probing and clarifying (3), as before, but this time the student she has asked does not succeed in supplying a warrant (4).
(1) Peer leader: Okay. And what about 7 b)? *(short questions)*
(2) S1: NaF. *(CLAIM)*
(3) Peer leader: Why? *(probing & clarifying)*
(4) S1: Because F has a stronger attractive force, its outer electrons. *(DATA)*
(5) Peer leader: Okay. What... Can you explain it using that equation? *(offering suggestions)*
(6) S1: Um...
(7) Peer leader: I know you can but I am asking him. *(maintaining)*
(8) S3: Heh...heh...
(9) S2: The distance from the nuclear...the nucleus...
(10) Peer leader: Okay.
(11) S2: ...and to the valence electron is closer. *(DATA)*
(12) Peer leader: Okay. So it's... It's a shorter distance, is what you're saying. *(acknowledging & validating)*
(13) S2: [Nods, yes.]
(14) Peer leader: So if you have a smaller number on the denominator what does that mean for the force? *(probing & clarifying)*
(15) S2: It's larger. *(WARRANT)*
(16) Peer leader: It's larger. So smaller distance, greater force. *(acknowledging & validating)*
(17) Peer leader: Are we understanding this relationship? *(short questions)*
(18) S3: Smaller distance, greater force. Got ya.
(19) Peer leader: It makes sense, right? *(short questions)*
(20) S1: Yeah.
(21) S2: Distance, smaller force. Here.

*Figure 4.3.* Peer-led argument, from The Ionic Bond activity, in which peer leader verbal behavior codes are shown in *bold italics* and student argument component codes are shown in all capital letters.

When the student has difficulty supplying a warrant, the peer leader offers the suggestion (5) to use the Coulomb’s Law equation *(Force α − [(q₁ x q₂)/d²])* provided at the beginning of the activity. Student 1 attempts to answer; however, the peer leader specifies that Student 2 should answer (7), which is coded as “maintaining” since she is requiring the student who was originally asked to address the question to do so. Student 2 provides a piece of evidence (data) that the “distance from the nucleus to the valence electron is closer” *(9-11)* but does not fully connects this new data to the claim that NaF has stronger ionic bonding. The peer leader acknowledges this answer *(12)* and proceeds.
to focus the students’ attention on the mathematical relationship between two variables in the equation by probing the meaning of that relationship (14). The students need to correctly interpret the relationship between the variables, the Coulombic force (Force) and the distance between the two centers of the ions (d), in order to provide the justification that connects the evidence to the claim (15). In other words, the peer leader’s probing & clarifying verbal behavior is eliciting the warrant to complete the student argument that was incomplete prior to the intervention. Once the warrant has been expressed, the peer leader acknowledges and validates the response (16) and checks in with a short question to see if the other students agree.

Similar guidance from a peer leader can assist when students are missing both the warrant and the data. The second vignette (Figure 4.4) illustrates a peer leader guiding students to provide the data to build an argument where initially the students only have a claim. For context, the students are working on the ChemActivity “Lewis Structures”, and addressing the question, “Predict the C-C bond length for a molecule with a C-C bond order of 1.5.” A table comprising the molecular structure, C-C bond order and C-C bond length for the organic compounds ethane, ethene, ethyne, and benzene is provided in the activity.

(1) Peer leader: Okay. Five. So what was your answer for 4 then? *(short questions)*
(2) S2: 140...1. *(CLAIM)*
(3) Peer leader: 140.
(4) Peer leader: ...41.
(5) S2: Approximately.
(6) Peer leader: And how did you decide that? *(probing & clarifying)*
(7) S2: It's between...
(8) S1: I just added 'em together and divided by two. That's all I did. *(DATA)*
(9) Peer leader: You added what together? *(short questions)*
(10) S1: 150 and 133. *(DATA)*
Peer leader: So what is that? What are those numbers? *(short questions)*
S3: One
S1: The...
Peer leader: I mean, like where did you get those numbers from? *(short questions)* Heh...heh... I’m math oriented. He’s like I got this. I can do this math. *(encourages)*
S3: Yeah, I can do it now. I was practicin' all week.
Peer leader: But where did you get those numbers from? *(short questions)*
S3: From the bond-length, from the table. *(DATA)*
Peer leader: Ethane and ethene? *(short questions)*
S3: Yeah.
S1: Yeah. Si’ si’.
Peer leader: So why . . . Why do you think they told you to look at those things? *(probing & clarifying)*

Figure 4.4. Segment of peer-led argument, from Lewis Structures activity, in which peer leader verbal behavior codes are shown in *bold italics* and student argument component codes are shown in capital letters.

This peer-led episode begins in the same way, with the peer leader asking a short question to find out the group’s answer to a specific question (1). Student 2 provides the claim, the answer to the posed question (2), after which the peer leader probes the students to find out how they arrived at that answer (6). Student 1 provides some evidence (data) by referring to taking an average (8). In order to move the students toward a fuller explanation of the data, the peer leader asks a series of short questions (9, 14, 16, 18), and provides some encouragement (14). This pattern of questioning demonstrates the way in which, when an expected scientific justification is not received for a probing & clarifying verbal behavior, the peer leader can focus on ensuring the students understand the data before moving to the rest of the argument. This combination of probing & clarifying followed by short questions was very common, particularly when students were not recognizing that relevant data could be found earlier in an activity.
(1) Peer leader: How does the core charge change going down a group? (*probing and clarifying*)
(2) S?: Yeah. I thought you [audio breaking up]...
(3) S1: Look, man. Okay, look...
(4) S2: Yeah, like increases... (wrong CLAIM)
(5) S1: ...see it...
(6) Peer leader: What is the core charge of hydrogen? (*short questions*)
(7) S1: I don't even know.
(8) S2: One. (DATA)
(9) Peer leader: What is the core charge of Li? (*short questions*)
(10) S1: Seven. (wrong DATA)
(11) S2: Lithium? It has one. Two.
(12) Peer leader: No. No. No. No. Don't change... Don't change it. (*maintaining*) So what is the core charge of H? (*short questions*)
(13) S2: One. (DATA)
(14) S1: One. (DATA)
(15) Peer leader: What is the core charge of Li? (*short questions*)
(16) S2: Two. (wrong DATA)
(17) Peer leader:...going to one is increasing? (*short questions*)
(18) S1: Ha...ha...
(19) S2: You know what?
(20) S?: Three. (wrong DATA)
(21) S2: The core charge in the same group does the same... (WARRANT)
(22) S?: They... They increase. (wrong REBUTTAL)
(23) S2: No, in the same... In whatever [looking at an earlier question], it was 1 (DATA), they're the same. (CLAIM)
(24) S?: They... Really?
(25) S1: That's what I said.
(26) S2: Really.
(27) Peer leader: Go put that on the board so everybody'll know. (*maintaining*)

*Figure 4.5.* Segment of peer-led argument, from Atomic Size activity, in which peer leader verbal behavior codes are shown in *bold italics* and student argument component codes are shown in capital letters

For example in Figure 4.5, the peer leader again begins with probing and clarifying (1) and then switches to short questions (6) to elicit the data after hearing an incorrect claim (4). The ensuing confusion is resolved only when the peer leader’s continued short questions result in the students finding the relevant data (23) themselves.
After ensuring that the students can articulate the data clearly, the peer leader can move back to probing and clarifying to elicit the warrant, again using short questions as needed until the students are able to produce this final component of the core of an argument.

Argumentation, while an important goal in this setting, is not the only goal; in addition to building arguments, students are expected to build chemistry knowledge. The findings for the third research question shed light on how peer leaders use verbal behaviors to help students build chemistry knowledge, for example to fix an incorrect claim. The vignette in Figure 4.6 is a peer-led episode in which the peer leader helps the students to recognize that they have made a mistake, and to correct it. For context, the students are working on a series of questions from the ChemActivity “Coulombic Potential Energy” about determining the potential energy of a hypothetical atom when the peer leader intervenes.

(1) Peer leader: [Reading the students’ written answer.] “Positive potential energy is always a positive number.” So why is the...is it always a positive number? (probing & clarifying)
(2) S4: Because potential energy cannot be negative. Like it can be zero or it can be positive potential energy. (wrong CLAIM)
(3) Peer leader: So it can't be negative? (short questions)
(4) S4: No.
(5) Peer leader: Hm! Well,...
(6) Peer leader: ...why don't we look at the equation for V (offering suggestions)
(7) S4: Okay.
(8) Peer leader: ...here and see if we can solve the equation for this. Because... At least for the charges. Because we know, what, k is always what? (short questions)
(9) S2: Positive?
(10) Peer leader: Okay. Distance is always...
(11) S2: Positive. (part of WARRANT)
(12) Peer leader: Okay. q1 and q2, what is... What is q? (short questions)
(13) S2: Charge.
(14) Peer leader: Okay. The charge on the particles. We have two particles. The top of Table of 1, this is what we're talking about. What are we talking about? What two particles? (short questions)
Figure 4.6. Peer-led argument segment, from Coulombic Potential Energy activity, in which peer leader verbal behavior codes are shown in bold italics and student argument component codes are shown in all capital letter.

As can be seen in Figure 4.6, the peer leader begins the intervention by probing and clarifying, asking the students to explain their answer (1-3). Student 4 provides a wrong claim, that the potential energy cannot be negative, as a response to her question (2). Based on student responses, the peer leader then offers a suggestion that students should look at the provided Coulombic potential energy equation in order to solve this problem (6) and guides them through each variable in the equation with a series of short questions (7-13). With her suggestion, the peer leader is bringing in a piece of key information (the Coulombic equation) that students had missed. The short questions continue as the peer leader draws attention to the types of particles in a hypothetical atom (14-22). She acknowledges the students’ responses (23) and helps them build the full warrant by helping them put the different pieces of information together, asking another short question (23) and receiving the final piece of the puzzle (24-25), allowing her to point out the discrepancy between the students’ new knowledge and their original
incorrect claim. Functionally, the peer leader was able to use a combination of verbal behaviors to engage the students in challenging their own previous response.

This peer-led episode illustrates how a peer leader can help a group to correct an incorrect claim by using verbal behaviors to uncover and correct a misunderstanding. This episode is focused on resolving an incorrect understanding of the relationships among variables in an equation, which may appear to be a basic concept. The students, however, need to be able to correctly interpret the Coulombic potential energy equation to build relationships between multiple course concepts, such as ionization energy, atomic radius, and potential energy, a set of ideas that students find very challenging. The student discourse following this peer-led episode revealed that students were able to construct arguments with correct scientific justification and articulate relationships among these difficult concepts. The students would not have been able to achieve this if the peer leader had not initially helped them to resolve their misinterpretation of the equation and to understand that potential energy can be positive or negative.

In these intervention episodes the peer leader used some short questions that elicited expected responses, which may seem trivial if taken alone. Peer leader discourse, however, is better thought of as a collection of mediated-learning behaviors (probing & clarifying, offering suggestions, acknowledging & validating, and confronting discrepancies) accompanied by short questions. Research has demonstrated that the combination of short questions with mediating behaviors promotes instructional scaffolding (Turner et al., 2002), creates a series of reciprocal discourse that helps students focus on the activity and produce explanations (Gillies & Khan, 2008), and fuels
engagement and triggers more student questions (Zuckerman, et al, 1998), all of which help students learn.

As seen in these episodes, the data analysis revealed some common scaffolding strategies the peer leaders used to guide students to build chemistry knowledge via argumentation. With the use of these strategies, peer leader helped students locate relevant data, build justifications (warrants) for their claims, and correct incorrect claims in the process of building chemistry knowledge. These strategies are consistent with verbal behaviors that have been observed by researchers studying teacher discourse in cooperative learning environments (Gillies & Boyle, 2008; Gillies & Khan, 2008). Suggesting the use of a relevant mathematical equation or guiding students through equations to help resolve incorrect understanding of relationships among variables are other unique strategies observed in our college chemistry POGIL setting where use of equations is prominent. Ultimately, it is a collective of verbal behaviors that seems to help students to build chemistry concepts without the peer leader having to provide direct instruction.

Conclusions

Combining Toulmin’s argumentation scheme with the verbal behavior categories provided a fruitful framework for examining peer leader interventions with small student groups. Focusing on verbal behaviors, understanding their relationship with student argumentation components, and noting their incorporation into guiding strategies provides a way to examine the functions of teacher discourse in group interventions. In this study, peer leaders employed a variety of verbal behaviors, including behaviors that
previous literature has shown to mediate student learning in cooperative learning environments (Gillies & Khan, 2008, 2009). Most of the existing literature investigating teacher discourse is at the K-12 level and focuses on classroom teachers (Gillies, 2006; Gillies & Boyle, 2008; Webb & Nemer, 2006). The findings from this study add to this body of literature by demonstrating that similar verbal behavior categories are useful for understanding the ways in which college chemistry instructors can work with small groups.

The findings revealed a relationship between peer leader verbal behaviors and student argumentation. A combination of short questions and probing & clarifying behaviors elicited scientific evidence (data) and scientific justifications (warrants) from the students. Peer leaders scaffolded students with a range of verbal behaviors to help them build more challenging argument components, such as warrants. Prior research has demonstrated not only the difficulties students face when having to support claims (Kuhn & Reiser 2005; McNeill & Krajcik, 2007), but also that (McNeill & Krajcik, 2008) students may not receive much support from teachers for building scientific reasoning. Since literature (Jimenez-Aleixandre, Rodríguez & Duschl, 2000; Nussbaum, Sinatra, & Poliquin, 2008; Zohar & Nemet, 2002) has demonstrated that student argumentation leads to better understanding of science concepts and reasoning skills, effective teacher discourse resulting in student argumentation is crucial to students’ learning of science. The simple scaffolding strategies used by the peer leaders in this study to help students build scientific evidence and justifications therefore have the potential to be of use in helping to improve science learning.
Overall, this study revealed that peer leaders guide students to build chemistry knowledge through scaffolding strategies instead of via direct instruction, which is in alignment with the peer-led POGIL objectives and consistent with effective group intervention strategies that help students reason (Mercer et al., 1999; Webb et al., 2004; Ding et al., 2007). The scaffolding strategies that have emerged from this study are resonant with prior work suggesting that teachers should engage in strategies such as probing, questioning student perspectives, and challenging students to promote higher level cognitive processes of students (King, 2002). A limitation of this study is that it is small and focused, encompassing only two peer leaders and their interventions with one small group each over the course of a semester; however, two very different peer leaders (based on experience) and two very different groups (based on demography) were selected in an attempt to mitigate this limitation. Certainly in the future, the discourse of more student groups and peer leaders could be collected and analyzed to get a broader understanding of this particular cooperative learning environment. It is also the case that this study used only video and audio data with transcripts as a data source. Additional data sources, such as students’ written work, student interviews, and real-time classroom observations, could shed more light on the nature of interactive discourse and student learning in the group environment.

The findings from this study have implications for professional development, specifically for those engaged in implementation of cooperative learning or other pedagogical approaches based on small groups. The two instructors in this study received the same weekly training and exhibited similar verbal behavior patterns. Previous research also has shown that teachers who are trained with specific communication skills
(Gillies & Khan, 2008, 2009) and argumentation strategies (Kaya, 2013) tend to use more challenging and scaffolding strategies to support student learning. Since effective group monitoring and intervention strategies are vital for the successful implementation of cooperative learning (Johnson & Johnson 1990; Brodie, 2001; Hamm & Adams, 2002), explicit tools for professional development are valuable. The verbal behaviors that were shown to be effective for different tasks during group work in this study can be presented as tools. For example, teachers can be provided with the type of verbal behaviors that can be used to maintain the student activity, to promote argumentation, and to encourage students during group activity. Demonstrating that a range of verbal behaviors is necessary to support groups work may help teachers to reflect on and to improve their own practice.

The findings from this study can be used by teachers (K-12) and college instructors to understand what effective discourse can look like when implementing cooperative learning. The combination of two analytic frameworks characterizing students and instructor discourse separately that is presented in this study may also be helpful in future studies of group learning environments.

**Acknowledgments**

We would like to thank Janelle Arjoon and Nicole Becker for their contributions to this work. This material is based upon work supported by the National Science Foundation under Grant No. DUE-1044111. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.
References


Kennedy M. M., (2004, April 7), Reform Ideals and Teachers Practical Intentions.


V. Use of Toulmin’s Argumentation Scheme for Student Discourse to Gain Insight About Guided Inquiry Activities in College Chemistry¹

Introduction

The use of inquiry-based activities in college chemistry, physics, and biology has been shown to enhance student outcomes such as increased achievement, knowledge gains, and understanding of scientific concepts (Bryant, 2006; Ingram et al., 2004). While the definition of “inquiry” may be debated (Fay et al., 2007), there is general agreement that inquiry-based approaches help students develop the scientific thinking and process skills that help them to understand the nature of science and to act like scientists (Handelsman et al., 2004; Kuhn & Dean, 2005). Argumentation is one of those necessary skills, and research has shown that inquiry-based instruction promotes argumentation (Wilson et al., 2010).

Educational researchers have also emphasized the importance of group learning. Group learning allows student interactions, feedback, and sharing of ideas that help reformulate concepts and construct new knowledge (Slavin, 1990). Recent studies have shown that allowing students to engage in group argumentation promotes students’ scientific reasoning (Osborne, 2010), as well as students’ understanding of science concepts (Jimenez-Aleixandre, Bugallo Rodriguez, & Duschl, 2000; Mason, 1996; Zohar & Nemet, 2002). In addition, other studies (Linden & Wittrock, 1981; Nussbaum, 2008) have suggested that verbal elaboration during group argumentation is a key element in developing content knowledge.

¹This chapter has been accepted in the Journal of College Science Teaching.
This study explored student discourse in a small group learning setting to gain insight about the relationship of various features of general chemistry guided inquiry activities (ChemActivities) to the production and sophistication of arguments produced by student groups. These published materials (Moog & Farrell, 2008) are influenced by the Learning Cycle and are designed for use in groups. The Learning Cycle, described in more detail below, is a pedagogic strategy derived from constructivism (Bodner, 1986) and developmental theory (Piaget, 1970) and is aligned with the way most students learn effectively (Abraham, 1986; Lawson, 1995). Although previous studies have shown that the Learning Cycle approach leads to higher science achievement, improved retention, and better reasoning abilities (Lawson et al., 1989; McComas III, 1992), they have not explicitly explored how to create Learning Cycle experiences that are particularly effective in prompting student argumentation. The purpose of our study was to explore the relationship of the structure of the ChemActivities to the production of argumentation by general chemistry students.

**Toulmin’s Argumentation Scheme**

Toulmin’s argumentation scheme (1958) forms the initial analytic framework for this work. This scheme has been widely used by science educators to define and examine arguments. It has been helpful in understanding argumentation in a broad spectrum of subjects including mathematics (Stephan & Rasmussen, 2002; Weber, Maher, Powell, & Lee, 2008), science (Cole et al., 2012; Jimenez-Aleixandre et al., 2000; Zohar & Nemet, 2002; Sampson & Clark, 2009), and English (Mitchell, 1996). In Toulmin’s model (Figure 5.1), there are several specific components of an argument. The claim is the conclusion at which one arrives upon considering the data. The data consists of evidence,
information, facts or procedures that lead to the claim. The warrant explains how the data or evidence leads to the claim. These three components (claim, data, warrant) are essential, and constitute the core of the argument. In this study, arguments containing only this core were labeled “Basic Arguments”. Stronger arguments that were labeled “Higher Level Arguments” contain a backing or a rebuttal. A backing explains why the warrant has authority and provides further validity for the argument. A rebuttal is a counter claim or a refutation of one or more components of the argument.

Figure 5.1. Toulmin’s model of argumentation

Types of Questions

A well-scaffolded classroom activity provides students with questions and prompts that encourage discussion of difficult concepts. In our context, prompts are cues
that are intended to elicit explanations and scientific evidence from students. Prompts have been shown to be important in scaffolding arguments in science (Cavagnetto, 2010; Cavagnetto & Hand, 2012), guiding students to provide scientific evidence and to construct better arguments. Questions also play a vital role in promoting students’ critical thinking and construction of conceptual knowledge (Chin & Osborne, 2010). Having a mixture of different types of questions can be important in eliciting arguments (Russell, 1983) and improving students’ problem solving skills (Cashin, Brock & Owens, 1976).

The materials in this study contain questions that can be broadly separated into two categories. Directed questions can be answered directly from provided information or previous knowledge. For example: “How many protons are in a carbon atom?” Or “How many electrons are in the valence shell of H?” Convergent questions generally require more than one piece of information and some synthesis or analysis of provided information. For example: “Which would be expected to have stronger ionic bonds: NaCl or NaF? Explain your reasoning.” These two types of questions can play an important role in helping students analyze scientific evidence and have a better understanding of scientific concepts (Hanson, 2006).

**Process Oriented Guided Inquiry Learning (POGIL) ChemActivities and the Learning Cycle**

POGIL is a student-centered instructional method that promotes both content mastery and the development of process skills such as problem-solving and critical thinking in a small group cooperative setting. POGIL activities are focused on the development of higher-order thinking skills with an emphasis on deep conceptual understanding of the course material (www.POGIL.org).
POGIL ChemActivities are paper-and-pencil materials designed to be used by students in groups of three or four, with the instructor (or peer leader) serving as a facilitator. The activities are structured to guide students through an exploration of data, figures, or verbal descriptions to build chemical concepts. Many of the guiding questions contain prompts, such as “why” or “explain”, that explicitly elicit explanations for the answers. The ChemActivities are specifically structured to promote analysis and interpretation, discussion, and student articulation of reasoning. Thus, these materials are different than typical worksheets in which students would instead practice applying what they have been taught to new exercises or problems.

There are two general types of activity structures within these ChemActivities, both based on the concept of the Learning Cycle. The Learning Cycle promotes student engagement, allows restructuring of knowledge, and helps students understand concepts (Hansen, 2006). The first type of activity structure contains a full Learning Cycle, which guides the students to construct content knowledge through a structure of exploration, concept invention/term introduction, and application. These structures generally begin with a model that provides information for students to draw inferences or conclusions. Exploration questions lead students to explore the model and develop the appropriate conclusion. Concept invention questions introduce the central concept. For the application phase, there is at least one question that requires the use of this introduced concept. For example, the activity pertaining to atomic and ionic radii begins with periodic trends in first ionization energy. (The concept of first ionization energy has been addressed previously.) Next, a data table indicating the valence shell, core charge, and atomic radius of numerous atoms is presented. The students are guided to recognize the
trends in atomic radii across a period and down a column through guiding questions, and they are cued to provide explanations for these trends in terms of the atom’s core charge and valence shell. The students are then asked to apply these concepts by predicting the radii of three atoms not listed in the table, and explaining how they arrived at their estimates.

The second type of activity structure contains only the application phase of the Learning Cycle and is referred to as a Stand-alone Application. A Stand-alone Application structure deepens, refines, and/or integrates the understanding of one or more previously developed or presented concepts through application or relevant process skills. In this type of structure, an equation (such as the ideal gas law) or concept is presented, and the questions that follow lead students to examine the implications of the equation or concept more fully and deeply.

In order to investigate the relationship between the structure of the ChemActivities and student discourse, the following research question was asked: How does the structure of the ChemActivities affect argumentation? In particular, we analyzed the impact of prompts and question type on eliciting elements of arguments from students, and also examined the relationship between the Learning Cycle Components and argumentation.

Method

Peer-Led Guided Inquiry Setting

Peer-Led Guided Inquiry (PLGI) (Lewis & Lewis, 2005, 2008) sessions of 20 – 24 students were held for a General Chemistry I course at a large public university in the
southeastern United States. These weekly 50-minute sessions were facilitated by graduate or undergraduate students who received weekly training on peer leading. Students worked in small groups of 3-4 on ChemActivities that focused on content they had not yet seen in lecture. Each session began with a quiz and a brief procedural introduction by the peer leader. The students then worked on one or two specific activities in their small groups. During a typical session, the peer leader facilitated one or two whole-class discussions of important or difficult questions or concepts, asking the students to present their answers to reinforce individual accountability. Sessions typically ended with a written group report including some self-reflection on the group’s performance. The time spent in small group work each week ranged from 20 to 35 minutes, where students spent much time working without peer leader intervention.

Data Source and Analysis

One group of four male students was video recorded during 12 weekly peer-led sessions (50 minutes) in Spring 2008. Informed consent was obtained from all students and the peer leader prior to videotaping the sessions. Group composition remained consistent throughout the semester. All videos were transcribed; transcripts were coded while watching the videos. Toulmin’s argumentation scheme described above was used to track the frequency of arguments and student participation patterns. The arguments analyzed in this study were student arguments without any peer leader intervention. The analysis of the quality of arguments and student participation is discussed in detail in another manuscript currently under review, “Level of Argumentation and Participation Patterns in General Chemistry I Peer-Led Sessions.”
Discourse related to the 15 ChemActivities used during the 12 weekly sessions was analyzed. Three chemistry faculty members from different institutions who are POGIL experts (including one author of the ChemActivity book) conducted coding of the directed vs. convergent questions. The inter-rater reliability among the three coders was 76% overall agreement. Fleiss’ kappa, the appropriate statistic for more than two raters (Fleiss, 1971) is 0.5, indicating moderate agreement (Green, 1997). Two of the faculty members indicated the presence of Learning Cycles with 100% agreement. The 15 ChemActivities comprised a total of 78 directed and 111 convergent questions; however, only the questions with student responses are considered as the data set. The ChemActivity data set contained 24 Learning Cycles and 13 Stand-alone Applications comprising 48 directed and 65 convergent questions with student responses (Table 5.1). After the coding, three types of relationships were analyzed: (1) presence of arguments and the questions with and without prompts; (2) level of arguments and the type of questions (directed vs. convergent); and (3) frequency of arguments and the segmented structure of the Learning Cycle.

Findings

Effectiveness of Prompts

Questions with prompts (such as “explain”, “why”, “predict”, and “show”) were analyzed to see their effect on building arguments. The distribution of student responses to questions with prompts is given in Table 5.2; 94% of questions with prompts produced full arguments, and more than a third of these were higher-level arguments, indicating that prompts guide students to go beyond merely providing an answer (claim). Of the
Table 5.1

**Description of Structure Components of ChemActivities**

<table>
<thead>
<tr>
<th>ChemActivity*</th>
<th>Number of Learning Cycles</th>
<th>Number of Stand-alone Applications</th>
<th>Directed Questions</th>
<th>Convergent Questions</th>
<th>Directed with Prompts</th>
<th>Convergent with Prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>27</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>34</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>34A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>13</td>
<td>48</td>
<td>65</td>
<td>7</td>
<td>28</td>
</tr>
</tbody>
</table>

* Numbers refer to ChemActivity numbers in Reference (Moog & Farrell, 2008).
Chemactivity 34A was created for the institution of the study and is not available publicly.

Questions with prompts that elicited higher-level arguments, 64% were convergent. Thus, the prompts seemed to be functioning as intended, eliciting evidence and reasoning from students to support their answers.

Table 5.2

**Characterization of Student Group Responses for Questions with Prompts**

<table>
<thead>
<tr>
<th>Student response type</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claim</td>
<td>0</td>
</tr>
<tr>
<td>Claim &amp; Data</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>Basic Arguments</td>
<td>21 (60%)</td>
</tr>
<tr>
<td>Higher Level Arguments</td>
<td>12 (34%)</td>
</tr>
<tr>
<td>Total Questions with Prompts</td>
<td>35</td>
</tr>
</tbody>
</table>
A sample argument that was elicited by a *convergent* question with a prompt is shown in Figure 5.2. Student responses for each coded argument component are shown inside the ovals. Note that the previously learned concept of core charge is mentioned to validate the argument on the size of ions; this utterance is thus considered a backing. Therefore, this argument has the three basic components (claim, data, and warrant) plus a backing, and is a higher-level argument. This example shows that having the prompt “predict” in a *convergent* question on the size of oxide and fluoride ions helped produce a higher-level argument.

**Directed vs. Convergent Questions**

The detailed results of the *directed* and *convergent* question analysis are shown in Figure 5.3. For the 48 *directed* and 65 *convergent* questions with student responses, the frequency of each student response type was obtained. The percentage of question type (y-axis) was calculated by taking into account the number of questions producing each response type with respect to the total number of each type of questions. For example, 13 *directed* questions out of a total of 48 *directed* questions produced “claims” response type, therefore, 27% of the *directed* questions produced claims as shown on the y-axis. The relationship between the type of question and the student response type is illustrated in Figure 5.3. As can be seen in the figure, a high percentage of *convergent* questions produced more complex student responses with respect to argumentation in comparison to the *directed* questions. In fact, 78% of the *convergent* questions produced arguments in comparison with only 40% of the *directed* questions. Sixty percent of the *directed* questions only produced claims and claims & data, not complete arguments. However, *directed* questions that preceded a *convergent* question in a clear sequence of
development frequently elicited the data component of the argument with the following *convergent* question eliciting an explanation that led to completion of the argument. This pattern (Figure 5.4) was observed in seven out of nine sets of such sequences of questions. Figure 5.4 illustrates the way in which *directed* questions (b & c) in the *exploration* phase elicited the data and the *convergent* question (d) in the *concept invention* phase of the Learning Cycle elicited the warrant allowing the construction of a complete argument. The letters (b, c, d) in the student responses correspond to the (b, c, d) questions. Directed questions b and c prompted the responses (*data*) that HCl has a shorter bond and that F is more electronegative than Cl. The *claim* is made that the partial charge is more important in determining dipole moment, supported by the *warrant* that the partial charges are larger in HF than in HCl, also prompted by directed question c. In this way, directed questions can play an important role as part of a learning cycle sequence that produces a full, and often higher-level, argument.

**Learning Cycle Components and Arguments**

Of the 24 Learning Cycles and 13 Stand-alone Applications in the studied activities (see Table 5.1), arguments were produced in 83% and 77% of the cases, respectively. Thus, both types of structures were approximately equally effective in prompting arguments. Because our interest was in the effects of the Learning Cycle on argumentation, only the Learning Cycle structures were examined.

A clear pattern emerged when each phase of the Learning Cycle was analyzed for the presence of arguments (Table 5.3). Questions within the *application* phase produced the largest ratio of arguments to non-arguments (only claim and/or data), and questions within the *exploration* phase produced the smallest ratio. Even though the frequency of
Figure 5.2. Sample argument illustrating the argument components elicited by a convergent question with a prompt. Student responses for each coded argument component are shown inside the ovals.
Figure 5.3. Relationship between the type of questions and student response type arguments for the exploration phase is low; those questions served as cues to elicit claims and/or data, leading to arguments when presented in a sequence of directed questions preceding convergent questions as discussed in the previous section (Figure 5.4).

Table 5.3

Relationship between Learning Cycle Phase and Presence of Full Arguments

<table>
<thead>
<tr>
<th>Exploration</th>
<th>Non-Argument</th>
<th>18</th>
<th>5</th>
<th>1</th>
<th>21</th>
<th>33%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept invention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concept invention</th>
<th>Argument</th>
<th>24</th>
<th>13</th>
<th>12</th>
<th>49</th>
<th>67%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 5.4. Sample argument illustrating the argument components elicited by directed and convergent questions in the different phases of the Learning Cycle. Student responses for each coded argument component are shown inside the ovals.
Conclusions and Implications

This study has demonstrated that Toulmin’s Argumentation Scheme is a useful tool for examining and analyzing student discourse in group settings, the level of argumentation produced by that discourse, and the relationship between that discourse and the structure of the written activities.

This study also revealed that prompts within questions were effective in eliciting scientific evidence from students in small groups and in building arguments without instructor intervention. The use of prompts frequently led to higher-level arguments containing a backing and/or a rebuttal. The guided inquiry ChemActivities studied here were very effective in promoting argumentation as a very high percentage of questions produced arguments. Not surprisingly, *convergent* questions produced more arguments than *directed* questions, indicating that the questions are functioning as intended. This study also shows the importance of having a combination of *directed* and *convergent* questions in the right sequence to promote argumentation. Therefore, both the type and the order of the questions are important to promote student discourse with all of the elements of a full argument. These insights can be used as guidance for instructors who are writing guided inquiry activities or are selecting questions from a textbook or activity for conducting group work.

Although the Learning Cycle approach has been shown to lead to higher science achievement, improved retention, and better reasoning abilities (Lawson et al 1989; McComas III 1992), previous studies have not examined the details of a particular set of Learning Cycle materials and the relationship of those materials to the production of student argumentation. Our findings demonstrate how the different phases of the
Learning Cycle, *exploration, concept invention*, and *application*, provide a scaffolding structure for students to construct arguments when developing chemistry concepts.

All of the arguments presented in this study were produced by a group of students working by themselves without instructor intervention. Therefore, the findings of this study also suggest that the structure of these guided inquiry ChemActivities provides sufficient external motivation for the students to construct arguments when addressing chemistry questions in a group. Further, these findings show that students can produce productive discourse on their own when using carefully crafted written activities with prompts, a mixture of different types of questions, and the scaffolding provided by the segmented structure of the Learning Cycle. Therefore, such activities can be a useful component of student-centered instruction in the classroom, especially in group settings, to promote learning of science. One limitation of our study, however, is that the discourse of a single student group was examined. More student groups should be analyzed for our future work.

This study has shown the importance of having a mixture of different types of questions, the right sequence of questions, use of prompts, and the significance of having a scaffolded Learning Cycle structure to promote student discussions. These strategies are valuable for educators who are writing or modifying guided inquiry activities to promote verbal elaboration and argumentation.

**References**


Cavagnetto, A. R., & Hand, B. (2012). The Importance of Embedding Argument Within Science Classrooms. In M. S. Khine (Ed.), *Perspectives on Scientific Argumentation: Springer Science + Business Media*


VI. Conclusions

The work presented in this dissertation examined small group discourse in General Chemistry I Peer-Led Guided Inquiry sessions through a lens of argumentation. Discourse with respect to three central elements, students, peer leader, and the published ChemActivities that affect the dynamics of the peer-led classroom were studied to gain a better understanding of group learning. The findings from this dissertation contribute to science education by providing a valuable framework for analyzing group processes and student discourse in cooperative learning. This dissertation work illuminates important characteristics of student arguments, participation patterns, verbal behaviors of peer leaders, and the structural components of the ChemActivities that promote argumentation.

Studying in detail all three pivotal elements in the PLGI classroom helped shed light on the overall dynamics of the classroom. The analysis of student-student interactions within the small groups, peer leader-student interactions during peer leader intervention, and the relationship between the student discourse and the structure of the ChemActivities revealed the significant relationships among these three elements. For example, by evaluating student arguments first and peer leader verbal behaviors second, we were able to see how peer leaders guided students to correct initially incorrect claims and build chemistry knowledge with an array of verbal behaviors. By specifically examining the relationship between peer leader verbal behaviors and student arguments, we were also able to see how some verbal behaviors were more effective in eliciting
student argument components than others. Conducting both of these studies revealed how peer leaders were able to elicit data, warrants, and backings from the students with the use of different verbal behaviors. In other words, the peer leaders were able to help students bring in the scientific evidence and construct the justification for their claims in instances students struggled with chemistry concepts. If the study had only focused only on student arguments, such a connection would have not been revealed. Analyzing the relationship between student discourse without peer leader intervention and the structure of ChemActivities was fruitful in revealing that the structure of the ChemActivities scaffolded arguments, serving as a secondary support in the absence of the peer leader. The prompts, questions, and the segmented Learning Cycle of the ChemActivities helped students construct arguments on their own and build chemistry concepts. It was also promising to find that students were able to resolve most of the incorrect claims on their own without peer leader intervention, which lends support to the autonomy of students in cooperative learning environments.

The analytic framework based on Toulmin’s argumentation scheme combined with the extent of student participation was a useful tool for analyzing discourse with respect to student-student interactions and peer leader student interaction. It was also an effective framework for analyzing the relationship between student discourse and the structure of the ChemActivities. Therefore, it can be concluded that the analytic framework based on Toulmin’s argumentation scheme is a useful framework for analyzing group processes and student discourse in cooperative learning.

The teacher plays a key role in implementing innovative student-centered instruction (Blanchard, Southerland, & Granger, 2009). Research has shown the
challenges teachers face due to the lack of understanding of effective strategies to conduct group learning (Al-Amoush, Markic, & Eilks, 2012; Sharon, Shachar, & Levin, 1999) and insufficient pedagogical knowledge to engage students in argumentation (Simon et al., 2006). A recent study by Osborne et al. (2013) also found that the incorporation of argumentation into the instructional practice was a difficult and slow process for teachers. Therefore, training science teachers both at the secondary school and college level with specific strategies to overcome such obstacles is crucial to the success of implementing student-centered argumentation embedded instruction. Findings from this study have provided valuable specific strategies teachers can use to effectively conduct group learning and promote student argumentation.

The findings from the first study *Argumentation and participation patterns in general chemistry peer-led sessions* and the second study *Exploration of peer leader verbal behaviors as they intervene with small groups in general chemistry* produced effective group monitoring and intervention strategies for the professional development of the teachers. This is a great contribution since research has shown the difficulties teachers face when monitoring groups within the classroom and finding effective intervention methods (Cohen et al., 2004; Hertz-Lazarowitz & Schar, 1990; Gillies & Boyle, 2008). The teachers can be made more aware of what to expect in group settings through these findings. Professional development programs can include specific training with the Toulmin’s argumentation scheme. Teachers can be shown how the specific components of the Toulmin’s argumentation scheme can be used to examine whether students are providing evidence and explanations when they solve science problems. Teachers can also be provided the rationale for using this argumentation scheme and state
the importance of explicitly discussing the Toulmin’s argumentation components with students to promote argumentation. In order to get students to contribute more equally to constructing arguments and also to provide the more challenging components such as warrants and backings, teachers can be trained to address specific students in a group for an explicit component of an argument. For example, during a teacher intervention of the student group, the teacher can use explicit questions such as “Can you tell me the backing for your explanation.”

Peer leader verbal behaviors that were shown to be effective from this dissertation can be explicitly provided to teachers during professional development. Training can explicitly focus on the use of different verbal behaviors to maintain group activity, guide students to solve problems, and elicit argument components. The common scaffolding strategies that emerged from the peer leader verbal behaviors study such as probing, challenging students’ perspectives, bringing in missing key information, and compiling pieces of information together that helped students resolve incorrect claims and build chemistry knowledge can be used in the training for group intervention. The teachers can also be provided with information on how the right combination of short questions and probing & clarifying verbal behaviors elicit the evidence (data) and justification (warrants), of the student arguments. The right sequence of the short questions and probing & clarifying verbal behaviors that revealed to be effective for scaffolding when the students did not provide the expected answer for an initial probing question is also an important strategy the teachers can use during group intervention.

Findings from this third study, *Use of Toulmin’s Argumentation Scheme for student discourse to gain insight about guided inquiry activities in college chemistry*, are
beneficial for instructors who write or modify group activities and helpful for teachers selecting questions or written activities for group work in the training phase. This is an important contribution to professional development of teachers since literature has shown the need for more support in constructing small group activities (Rolheiser & Anderson 2004). Teachers can be provided with the information from the findings about how prompts, the type of questions, and Learning Cycle structure help students build arguments. Teachers can also be provided with strategies to help select questions from textbooks or published group activities that would enhance collaboration and promote productive student discourse in cooperative learning. Teachers can be given explicit directions on having a combination of directed and convergent questions in a particular order to promote student engagement in argumentation.

This dissertation work has some limitations since the student discourse of only two small student groups were examined. However, selecting two very different groups based on sex and ethnicity was also an attempt to mitigate the limitation of having only two groups for the study. The ability level of the students in these two groups were similar to other groups in the PLGI setting since all the groups were mixed ability groups based on prior achievement and they appeared to be functioning similarly according to the video data. Student discourse with the elements of argumentation can be analyzed in the future with more student groups to investigate further the findings from this study. Even though video data of student discourse was analyzed with respect to three pivotal elements (students, peer leader, ChemActivities) in the PLGI classroom, there are other factors that could also be considered. Students’ written work for the ChemActivities,
quizzes, and test scores could also be analyzed in the future to get a more complete understanding of the dynamics of the PLGI classroom.

Overall, this dissertation work contributes to science education by providing critical strategies for teacher training for conducting effective cooperative learning and promoting student argumentation. Since teachers both at the secondary (Yeany & Padilla 1986) and tertiary levels (Walczyk, Ramsey, & Zha, 2007) need intensive training to be furnished with the essential skills to implement student-centered innovative approaches, contributions from this dissertation study are of great value.

Since this dissertation work focused only on the structure of the arguments in the student discourse, future studies can focus on the types of critical questioning and other student verbal behaviors that contribute to producing effective discourse in group learning. The questions probed by group members who necessarily do not contribute to constructing arguments still play a crucial role in driving the argument forward. Therefore, examining the role of questions would provide a more complete view of the argumentation process. Specific verbal behaviors peer leaders exhibit that elicit critical questions from the students can also be examined. Another interesting study that can be conducted in the future is to examine whether high quality oral argumentation skills translate to students producing high quality written arguments.

References


Appendix A:

IRB Approval Letter

July 6, 2012

Ushiri Kulatunga
Chemistry
4202 E Fowler Ave. CHE 205
Tampa, FL 33620

RE: Expedited Approval for Continuing Review
IRB#: Pro00004449
Title: Analysis of Argumentation and Participation Patterns in General Chemistry I Peer-led Sessions

Study Approval Period: 7/31/2012 to 7/31/2013

Dear Ushiri Kulatunga,

On 7/6/2012 the Institutional Review Board (IRB) reviewed and APPROVED the above protocol for the period indicated above. It was the determination of the IRB that your study qualified for expedited review based on the federal expedited category number:

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Protocol Document(s):
Kulatunga Study Protocol
PDF version of Kulatunga Study Protocol

Also approved was a waiver of the informed consent process.

Please reference the above IRB protocol number in all correspondence regarding this protocol with the IRB or the Division of Research Integrity and Compliance. It is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB.

We appreciate your dedication to the ethical conduct of human subject research at the University.
of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

[Signature]

John Schinka, PhD, Chairperson
USF Institutional Review Board