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Leadership in small online collaborative learning groups: A distributed perspective

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Abstract We service mathematics and science teachers. Groups worked primarily online in an asynchronous discussion environment on a 6-week task in which they applied learning-science ideas acquired from an educational psychology course to design interdisciplinary instructional units. We employed an adapted coding system previously developed by Li et al. (*Cognition and Instruction*, *25*(1), 75–111, 2007) to determine that group leadership was highly distributed among participants (Spillane 2007). We illustrated that leadership emerged through different forms of participation described in this paper and that, in some cases, individuals specialized in specific leadership roles within groups. Findings helped validate the theoretical concept of group cognition and led us to suggest an approach to online asynchronous learning for college students that depends more on students' emergent leadership skills than on prescriptive assignment or scripting of participant roles.

Keywords Group cognition · Leadership · Online collaboration · Problem-based learning

Introduction

The nature and quality of leadership in small groups and its effects on group outcomes has been studied for many years by researchers in different disciplines and across many varied contexts and age levels (e.g., Chemers 2000; Eby 2003; Hare 2000; Kozlowski and Ilgen 2006; Li et al. 2007; Mumford et al. 2000; Scribner et al. 2007). However, the role of leadership within small collaborative-learning groups in authentic instructional settings has explicitly been examined very infrequently (Kim et al. 2007; Hmelo-Silver et al. 2007). That there is little leadership research in small-group instruction, despite an enormous literature on peer learning in small groups (O'Donnell et al. 2007), is not surprising, because small-group instruction is typically scaffolded or scripted (O'Donnell et al. 2007;

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Dillenbourg 2002), designed so that students achieve goals without relying on the emergent leadership skills of group members. Yet as emphasis on group cognition increases in the larger world (Stahl 2006), it becomes increasingly important to understand and develop students' small-group leadership skills as preparation for later life. Moreover, as the need for Web-based collaboration accelerates, it becomes increasingly important to understand small-group leadership in *online* environments. Accordingly, this study examined the emergence of leadership within five small math-science interdisciplinary teams who collaborated for two months to complete an instructional design assignment made in a learning-science course for advanced pre-service secondary teachers. The teams conducted a large percentage of their work online using a collaborative whiteboard. The whiteboard was not unlike many commercial tools available today, and could easily be duplicated in a wiki. These groups were randomly constituted, received the same general design assignment, used identical technological tools, and were minimally scaffolded as needed by instructors. This setup provided an excellent "natural experiment" enabling us to observe emergence of leadership in small learning groups that experienced varying degrees of success.

Theories of leadership in corporate (Northouse 2007) and school–administrative contexts (Spillane 2007) provide useful frameworks for understanding leadership's essential role in small collaborative-learning groups. While leadership can be emergent or assigned (Northouse 2007), it can also be thought of as trait based (Eby et al. 2003) or as a set of skills that can be learned (Northouse 2007). Some perspectives emphasize its situatedness and underline the fact that some people are more effective leaders in certain contexts (Northouse 2007). Spillane (2007) proposed a framework of "distributed leadership" that places leadership not in discrete actions of, and reactions to, particular leaders, but in the spread of interactions across group members and tools over time—a definition in which some elements of leadership are not clearly distinguished from active participation. Leadership is a process reliant not only on leaders but also on followers. Leaders are responsible for initiating action, but it is the followers who determine the success of leadership contributions (Hollander 1978).

In this paper, our emphasis is on leadership initiation within the interactions of small collaborative groups. Where leadership has often been conceptualized as residing in one or two people (Li et al. 2007; Spillane 2006) and as being assigned (Li et al. 2007; O'Donnell et al. 2007; Dillenbourg 2002), in this study, we hypothesized that leadership would emerge as a distributed and self-organizing entity across group members (Li et al. 2007; Northouse 2007). We further postulated that patterns in the distribution of leadership behavior would differ for successful versus less successful teams. Because we speculated that good leadership would be a distributed, reciprocal social process (Li et al. 2007; Spillane 2006), we hypothesized that a more balanced distribution of leadership involvement would be observed in more successful groups. We also postulated that more than one pattern of distribution might lead to group success. Because instructors are an integral part of the small-group collaborative process, we were also interested in defining the leadership roles of the instructor in the small collaborative groups: in what ways might they afford or constrain emergence of student leadership and how might they compensate for leadership weaknesses in groups that struggled?

Methodology

We combined quantitative and qualitative methods (Barron 2003; Kumpulainen and Mutanen 1999). First, data were coded using an adapted framework developed by Li et al. (2007) to categorize group members' interactions related to leadership contributions. We employed statistical analyses and graphical representations derived from the quantification of codes to explore patterns of distribution of leadership and to make comparisons between more and less successful groups (Chi 1997).

Qualitative methods were used to further mine online discourse to shed light on the nature of distributed leadership and to create illustrative cases of social and cognitive interaction related to leadership in groups (Barron 2003). Specifically, contrasting cases (George and Bennett 2005; Scholz and Tietje 2002; Stake 1995; Firestone 1993) were developed to illustrate how specific forms of leadership were distributed and how role specializations within groups emerged. Through this approach, we were able to describe leadership phenomena that were not immediately apparent through quantifications of coded leadership contributions. Using distinctively different cases to exploit the variability between groups and among individuals allowed us to discover possible explanations of the fundamental differences influencing group outcomes (Firestone 1993).

Data source

Data analyzed in this study were collected with the STELLAR online course development system (e.g., Derry et al. 2005). STELLAR is a system for building and researching online courses and activities that contains configurable instructional tools. Within the system are tools for high-level scripting of learning activity, multimedia hypertext resources, and an interactive group whiteboard. STELLAR contains both data collection and research tools that allowed us to collect and organize online discourse for analysis as well as collect descriptive statistics, students' feedback, and satisfaction scores online as the instruction unfolded.

We examined five interdisciplinary math and science collaborative groups from a learning-science course taught within the past 5 years for pre-service teachers at a large Midwestern university. There were a total of 25 students in the class, 8 males and 17 females. Of the male students, 3 were science majors and 5 were math, while 11 of the female students were science majors, 5 were math and one was a math and science major. All groups included both majors and both male and female members. Individuals were blocked by gender and major and randomly assigned to groups by the instructor. Because the instructor participated in varying levels of direct interaction with each group throughout the project, we count the instructor as part of the group and view him as an inherent part of the group leadership process. The same instructor participated in all five groups.

The groups interacted primarily through an asynchronous whiteboard where they collaborated for much of one academic semester to design an instructional unit for a topic and grade level chosen by their group (see Fig. 1). This whiteboard, which could be configured in almost any of today's wiki environments, allowed any member of a group to post a design proposal for their project. In our instructional procedure, which had evolved from previous experience with this course as the most expeditious format, only the poster could edit his or her contribution, although all group members could comment, suggest edits, and rate all proposals. The groups also met face-to-face several times during the activity, but the whiteboard supported most of their work, which occurred largely online between meetings. While we did not collect data from the face-to-face sessions, we believe our incomplete data is adequate for our analysis. We base this claim on widely accepted research and theory from cognitive science arguing that a complete trace of any cognitive activity is impossible to obtain and that it is valid to draw inferences about the complete trace from a reasonable subset of data (Ericsson and Simon 1980). Hence, we make the assumption that data from online sessions is the major portion of an incomplete trace that is reflective of major leadership trends in the entire trace. The whiteboard posts varied widely in length, but a significant percentage of proposals and comments were lengthy and thoughtful.

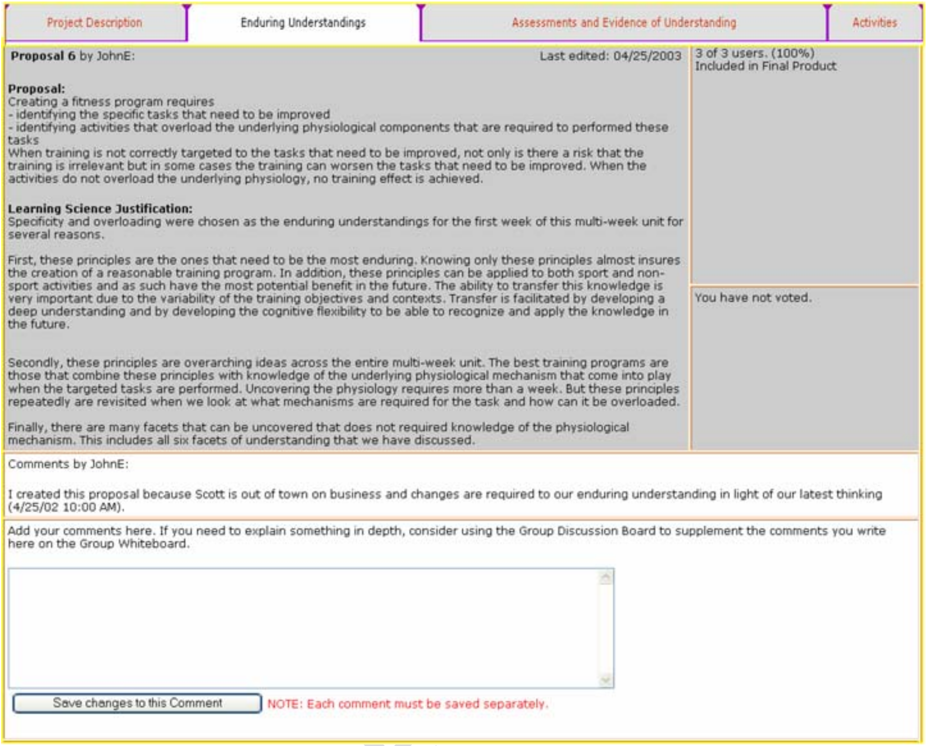


Fig. 1 Illustration of whiteboard where groups interacted online

The online course environment provided deadlines, and the setup of the whiteboard interface reminded students to justify their instructional designs with learning-sciences concepts, the main topics of the course. The activity that students participated in was a modified problem-based learning (PBL) activity in which much of the scripting or modeling capabilities were built into the tool as macroscripts rather than supplied directly by the instructor (Steinkuehler et al. 2002). For example, the major steps, sub-goals, and deadlines within the activity were illustrated for students as steps they took on a sidewalk. No other interventions were implemented to scaffold leadership in groups other than the instructors' (primarily one teaching assistant) interacting with groups to guide them as needed. Groups completed an instructional-unit design problem-based learning activity that required them to design an interdisciplinary instructional unit on a topic of the group's choice. Some example topics selected by students included understanding the four seasons and planning a vacation. The design activity comprised three iterations, each lasting 2–3 weeks and focusing on a different step of the backward design approach (Wiggins and McTighe 2005): 1. define instructional goals, 2. develop assessments, and 3. design instructional activities.

Descriptive data for groups

While all groups were successful in meeting the collaborative goals of the PBL activity, some groups demonstrated a higher degree of success than others. In Table 1, we approximately organize groups from high (Group 1) to low (Group 5) based on instructors' nomination, average (across iterations) score given for their instructional design projects (a rubric-based PBL score), and average of the group members' satisfaction with the PBL assignment (on a scale of 1–5, with a rating of 1 indicating high satisfaction). Satisfaction ratings were based on a group average of individual student responses to end-of-PBL reflection questions. The questions that we based this rating on were: How much did you learn from the overall PBL activity? How much did you learn from interacting with group members? How much did you learn from reflecting on the PBL activity? How well did the group whiteboard work for you? Table 1 also supplies the total number of valid posts for each group, including comments and proposals, made within each group. "Valid posts" eliminate entries that were made only as a result of a student's repeatedly "saving" work being composed online.

Coding

All valid posts to the whiteboard were coded with a set of leadership roles based on a well-explicated framework developed and vetted by Li et al. (2007) to study the emergence of leadership in children's face-to-face discussion groups. We adopted the coding scheme used by Li et al. (2007) because of its emphasis on group leadership phenomena independent of specific topics of discussion. Additionally, their framework was also guided by previous research in leadership behaviors (Halpin and Winer 1957). Although their subjects interacted face-to-face, their coding scheme focused primarily on group members' verbal interactions. Because of this, its application is well suited to an asynchronous online learning environment. Similar to our study, Li et al. (2007) viewed leadership as a "reciprocal social process" rather than as residing in individuals.

Building on this framework, we adapted the coding categories to better capture the distinct patterns that emerged in this online data and context. Table 2 describes each coded role and provides an example of a coded post. Entire posts by individual group members were coded as a contribution; a single post could receive multiple codes. One successful group and one weaker group were first coded and codes were found to have 94% reliability between coders (the authors) working independently. The refined framework was then applied by the first author to all valid posts for all five groups.

To insure that our codes recognized the importance of followers and the reciprocal nature of the leadership process, we then further examined each coded contribution to determine whether it was influential or non-influential to the course of the group project. Influential posts were those that evoked a response from other group members or an observable change in the group project. Non-influential posts were attempts at leadership based on our coding scheme, which did not influence the group process. Even though these contributions fit within our definition of leadership, because they did not influence or transform the group process in some way, these posts were disregarded and not taken into

Table 1 Group ranked from most successful (1) to least successful (5) by grades and satisfaction ratings

	Group 1	Group 2	Group 3	Group 4	Group 5
Average satisfaction rating	1.4	2.0	1.5	1.8	2.5
Average PBL score	97	97	92	90	88
Total number of group whiteboard posts	71	105	65	40	40

t2.1 **Table 2** Description and examples of framework for coding instances of leadership online

	Code	Description	Example
t2.2	Code	Description	Example
t2.3	Acknowledgement/ Affective (A/A)	Positive: Using language in a way likely to motivate or inspire and encourage group members; encourage positive group interactions	- *I liked your expanded explanation—it was considerably clearer than mine! Thanks.*
t2.4		Negative: Using language in a negative or critical way that may inhibit group success	- *That sounds whimpy...*
t2.5	Argument Development (AD)	Soliciting reasons, evidence, and clarification from others; extending others' arguments through elaborating on them or making comments about them. Holding group accountable for justifying their reasons.	*Are these final reports done completely individually? What kind of guidelines will the students be receiving-a list of questions that they will answer in essay form? Or something else?*
t2.6	Seeking Input (SI)	Looking for general input from other members of the group; seeking help, advice, ideas on the work	*I've tried to clarify the graphic organizer part. If anyone has any other ideas about how to do it, let me know.*
t2.7	Knowledge contribution (KC)	Contributing academic knowledge—working toward the academic goal of the project by contributing new ideas and extending meaning (i.e., from personal reading or research)	*Graphic organizers are a type of assessment that evoke and require student initiative and explicit reasoning...The graphic organizers are also beneficial in having students demonstrating self-knowledge… Wiggins and McTighe point out that "A student who really understands reveals self-knowledge..."*
t2.8	Organizational Moves (OM)	Planning, organizing, monitoring—both whiteboard space and ideas; statements and other moves that provide structure to the situation	*We also might want to split the goals up... assessment and enduring understanding. So specific and general type of [stuff].*
t2.9	Topic Control (TC)	Statements that influence the topic of discussion or direction of work (looking at another side of an issue, getting back to original topic, taking up new topic)	*My only comment is regarding what we have seen in the class of teaching to diverse learners... How could we expand the assessment to include a larger diversity of students?*

Framework adapted from Li, et al. (2007)

account as part of the leadership process in these analyses. However, the only posts that were eliminated in this process were 14 contributions across groups that were affective responses (e.g., "We did great!").

Results/Discussion

We explored these primary research questions:

- Was emergent leadership distributed? Was a distributed model (as opposed to other models) appropriate?
- Was successful group performance related to patterns of leadership distribution?
- Which leadership roles were distributed?
- What leadership roles did an instructor play?

Distribution of leadership

Leadership was highly distributed, with *all* members of *every* group participating in multiple leadership roles. Tables 3, 4, 5, 6 and 7 illustrate the distributions of influential leadership contributions within groups. Further, Figs. 2, 3, 4, 5, 6, 7, 8 and 9 characterize leadership distribution patterns between groups and across specific contributions. Even in a group (Group 1) where a particular leader (1A) was essentially elected and remained in that position throughout, leadership was shared among group members. However, group members participated in leadership in very different ways, with some group members avoiding some roles entirely while embracing others. This pattern is highly evident in Tables 3 and 7, which show the distribution of influential leadership contributions among group members, including the instructor, for the highest and lowest performing groups. These tables indicate trends in the data that were observed across groups. In examining these tables, we see that certain group members, like 1A and 5B, made well over half of the leadership initiations of a certain type within their group while other group members avoided or made minimal contributions in these areas. Different aspects of leadership had different characteristic patterns of distribution, with some functions (e.g., knowledge contribution, see Fig. 6) being shared fairly evenly across all group members in all groups, but with other functions (e.g., topic control, see Fig. 7) being dominated by fewer members. Evidence for these differences can be examined in detail in Tables 3, 4, 5, 6 and 7 and Figs 4, 5, 6, 7, 8 and 9.

As illustrated by comparing Tables 3, 4, 5, 6 and 7, the instructor shared in specific leadership roles but avoided others, and participated to different degrees with different groups. In the highest and lowest groups (Tables 3 and 7), the instructor was a key contributor to topic control, argument development, and acknowledgment/affective roles. In the weaker group, the instructor also played a primary role in organizational management and was responsible for more than half of the group's acknowledgment/affective contributions. The characteristic trend for the instructor's contributions is verified also in Groups 2, 3, and 4 (see Tables 4, 5 and 6).

Is successful group performance related to patterns of leadership distribution?

When the groups were viewed as the unit of cognition without regard to individuals, the distribution of influential leadership behaviors represented as a percentage of the total

Table 3 Distribution of leadership contributions in Group 1 across leadership categories and individuals

Group 1		Leadership Contribution					
		A/A	AD	SI	KC	OM	TC
Group Member	1A[a]	.33	.20	.72	.24	.66	.17
	1B	0	.27	0	.33	0	.17
	1C	.27	0	0	.12	.14	0
	1D	.07	.20	0	.15	.03	.17
	1E*	0	0	.27	.12	.14	0
	Instr.	.33	.33	0	.03	.03	.50
	Total Group Moves	15 (13%)	15 (13%)	15 (13%)	33 (29%)	29 (26%)	6 (5%)

[a] Indicates a female participant

Table 4 Distribution of leadership contributions in Group 2 across leadership categories and individuals

Group 2		Leadership Contribution					
		A/A	AD	SI	KC	OM	TC
Group Member	2A[a]	.11	.14	.09	.20	.61	0
	2B	.29	.36	.27	.35	.17	.11
	2C	.18	.19	.27	.18	.06	0
	2D[a]	.11	.05	.27	.10	.06	0
	2E	.18	.17	.09	.18	.06	.33
	Instr.	.14	.10	0	0	.06	.56
	Total Group Moves	28 (19%)	42 (28%)	11 (7%)	40 (27%)	18 (12%)	9 (6%)

[a] Indicates a female participant

number of posts was not obviously different for successful versus less successful teams (see Fig. 2). As shown in Fig. 2, there was a tendency for all teams to devote relatively less time to seeking input from others and to topic control, and relatively more time to providing affective statements, contributing knowledge, developing arguments, and handling organizational management. Through using a chi-square test, we did not find evidence that differences in distributional leadership patterns were associated with differences in quality of group product.

Based on previous research on distributed leadership models (Spillane 2006; Northouse 2007) and on input from the instructor, we hypothesized that leadership contributions would be distributed in significantly different patterns when comparing the most successful group, Group 1, to each other group. A chi-square test was used to test the differences in overall group distributions ($\chi_5{}^2(.95)=11.0705$). It was found that Group 1's distribution did, in fact, differ significantly ($p<.01$) from each of the other groups with the exception of the lowest group, Group 5. This finding led us to look further at the distribution of contributions and to conclude that the instructor's elevated level of participation in the leadership structure of these two groups could have been responsible for the similarities in the patterns observed. It was also noted that in Group 5 the instructor assumed many of the

Table 5 Distribution of leadership contributions in Group 3 across leadership categories and individuals

Group 3		Leadership Contribution					
		A/A	AD	SI	KC	OM	TC
Group Member	3A[a]	.17	.18	.22	.22	.08	.09
	3B	.04	.05	0	.30	0	.09
	3C[a]	.17	.18	.33	.13	.31	0
	3D[a]	.13	.18	.11	0	0	.18
	3E[a]	.04	.09	0	.09	.15	.09
	3F[a]	.22	.09	.33	.22	.38	.09
	Instr.	.22	.23	0	.04	.08	.45
	Total Group Moves	23 (23%)	22 (22%)	9 (9%)	23 (23%)	13 (13%)	11 (11%)

[a] Indicates a female participant

Table 6 Distribution of leadership contributions in Group 4 across leadership categories and individuals

Group 4		Leadership Contribution					
		A/A	AD	SI	KC	OM	TC
Group Member	4A[a]	.13	.25	.38	.33	0	0
	4B[a]	.17	.17	.13	0	0	0
	4C[a]	.13	.17	.25	.25	.17	0
	4D[a]	.13	.08	0	.25	.50	.25
	4E	.17	0	.25	.17	.33	0
	Instr.	.26	.33	0	0	0	.75
	Total Group Moves	23 (35%)	12 (18%)	8 (12%)	12 (19%)	6 (9%)	4 (6%)

[a] Indicates a female participant

same leadership functions that 1A, a strong individual leader in Group 1, assumed. Because of 1A's strong presence in Group 1 and the instructor assuming the roles that 1A contributed to Group 1 in Group 5, we speculated that the distributions might, in fact, be significantly different between the two groups when compared without including the instructor. A second chi-square test was conducted between all groups after omitting the instructor's contributions. Again, with the absence of the instructor, the results were the same as with the instructor included (see Fig. 3). The distribution of leadership contributions in Group 1 differed significantly (p<.01) from Groups 2, 3, and 4 but not from Group 5 (see Tables 8, 9). Overall, through comparing group distributions of leadership activity, it can be concluded that the quantification of the patterns of distribution alone was not a significant indicator of group success.

However, while the instructor's presence in Groups 1 and 5 was elevated and the patterns of distribution in the groups were similar, the instructor assumed qualitatively contrasting roles when Groups 1 and 5 were compared. Where in Group 5, the lowest group, the instructor added additional support, the structure that Group 1 internally created encouraged interaction with the instructor. This case is discussed in more detail in a later section.

Table 7 Distribution of leadership contributions in Group 5 across leadership categories and individuals

Group 5		Leadership Contribution					
		A/A	AD	SI	KC	OM	TC
Group Member	5A[a]	0	.06	0	.18	0	0
	5B[a]	0	.06	.75	.14	.12	0
	5C[a]	.22	.29	0	.23	.35	.11
	5D	.11	.06	0	.09	.06	0
	5E[a]	.11	.12	.25	.27	.12	.11
	Instr.	.56	.41	0	.09	.35	.78
	Total Group Moves	9 (12%)	17 (22%)	4 (5%)	22 (28%)	17 (22%)	9 (12%)

[a] Indicates a female participant

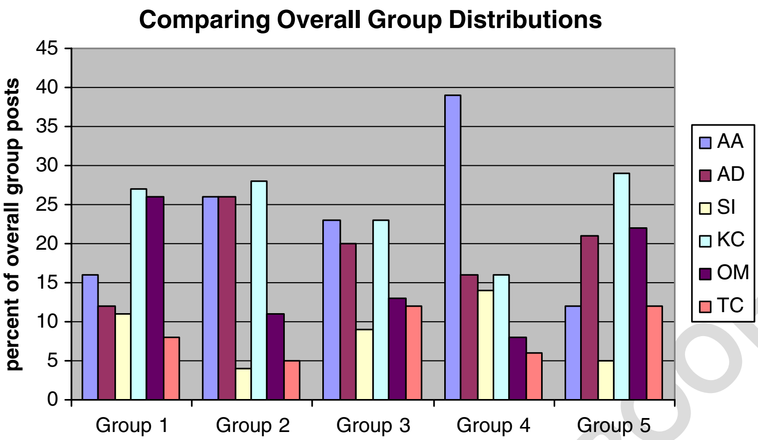


Fig. 2 Comparing within-group distributions of leadership contribution patterns across the 5 participating groups

Which forms of leadership were distributed?

When we focused on each specific form of contribution within our leadership framework, it was evident that, while all forms of leadership contribution were distributed, there were different degrees of distribution across different forms. Some types of leadership contributions were more evenly distributed than others and more frequently used by group members, while other types were dominated by individuals within their groups.

Table 10 and Figs 4, 5, 6, 7, 8 and 9 provide contrasting cases showing how each type of leadership was more or less distributed. In Figs. 4, 5, 6, 7, 8 and 9, each pie represents the total number of codes given to a particular form of leadership across the entire class with all groups combined. Each slice of the pie represents one student's contribution to that particular type of leadership initiative. Pie charts with many small slices illustrate wide and fairly even involvement by many class members in that particular form of leadership. Pie

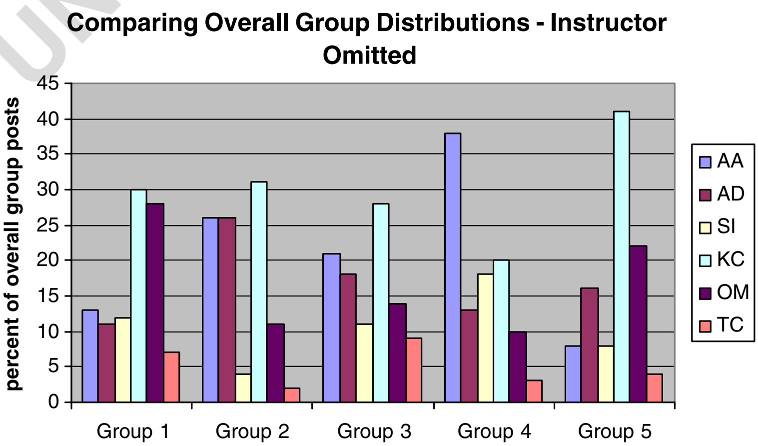


Fig. 3 Comparing within-group distributions of leadership contribution patterns across the 5 participating groups with instructor omitted

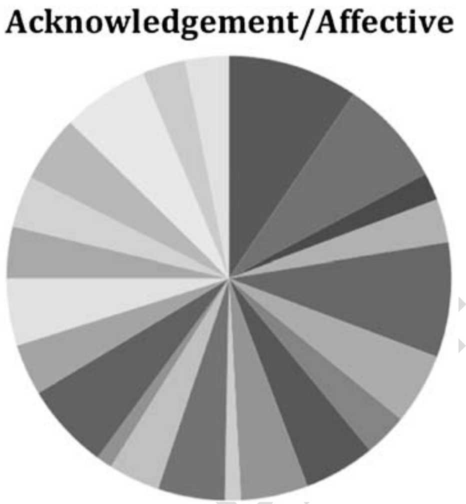


Fig. 4 Comparison of individual Acknowledgment/Affective leadership contributions across the entire class. Each slice represents an individual student

charts with uneven and/or fewer slices illustrate that some forms of leadership were assumed unevenly by particular students. Acknowledgment and affective contributions were highly distributed. Twenty-two of the 26 course participants made these contributions at some point during their group project (see Table 10). In addition, the proportion of participation in acknowledgment and affective (A/A) contributions for individuals within their groups was fairly balanced across individuals and groups. However, distribution alone did not tell the entire story for the contributions coded as A/A. All of the affective contributions by individuals were positive and encouraging, except for within the lowest performing group. In Group 5, where there were statements of a negative nature, there was a stronger instructor participation in this type of leadership. This may indicate an effort by the instructor to compensate for the students' negative affect.

A similar pattern of high, even distribution was found for argument development (where 23 participants contributed) and knowledge contribution (which was the most highly

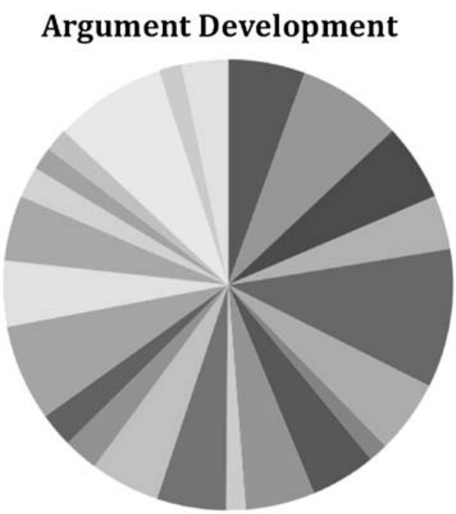
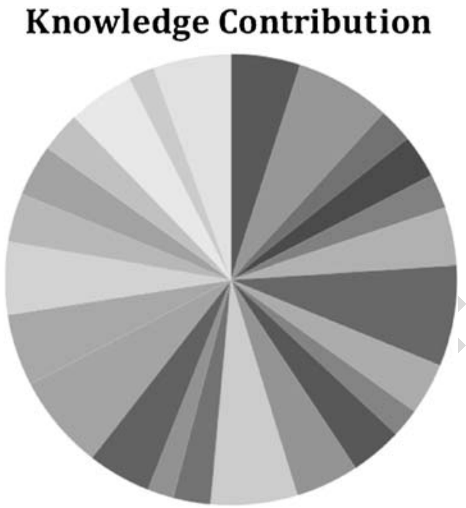


Fig. 5 Comparison of individual Argument Development leadership contributions across the entire class. Each slice represents an individual student

Fig. 6 Comparison of individual Knowledge Contributions across the entire class. Each slice represents an individual student



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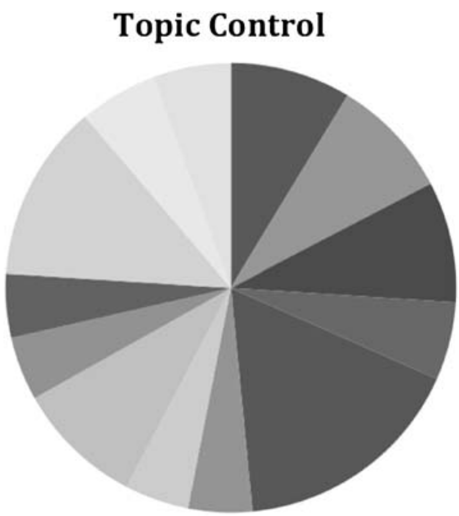
distributed leadership contribution, with 24 of the 26 participants playing a role). The patterns of distribution for these contributions are illustrated in Figs. 5 and 6. Argument development was typically demonstrated by the instructor and a few (1–3) members of each team, so not all students actively participated in argument development. The instructor's role ranged from 11% to 50% of a group's overall contributions, with fewer contributions being made in more successful groups.

In contrast to the distributions of the aforementioned leadership contributions, others were less evenly distributed among participants. Topic control, for example, was a contribution only half of the class made (see Table 10). In addition to being less distributed, the contributions were less even between students. Figure 7 illustrates this distribution and shows that some individuals played a much larger role in this facet of leadership than others. Similarly, seeking input was less well distributed, with 17 participants taking part and with certain individuals playing larger roles in this contribution (see Fig. 8). Females

Fig. 7 Comparison of individual Topic Control leadership contributions across the entire class. Each slice represents an individual student



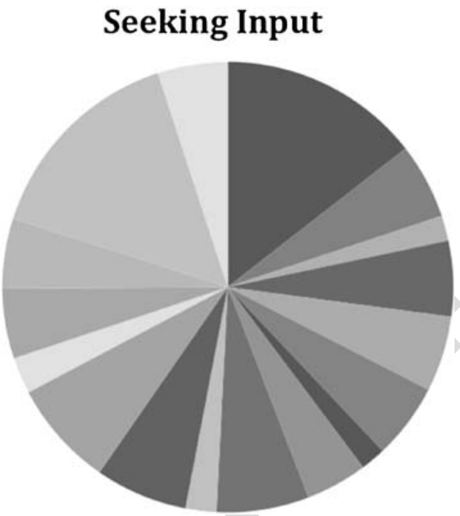


Fig. 8 Comparison of individual Seeking Input leadership contributions across the entire class. Each slice represents an individual student

more actively sought input than males; this was the only obvious gender difference when we examined specific roles and was statistically significant (Mann-Whitney U=98.5, $p<0.05$).

While organizational moves were made by 20 participants, a pattern similar to topic control and seeking input was found where certain group members made more contributions in this area of their group's leadership (Fig. 9). A primary student organizational manager emerged in all groups, except in Group 5, the weakest group, where the instructor took over as the main organizer. In sum, the higher levels of individual contributions that we found for topic control, seeking input, and organizational moves may have indicated specializations within their group's leadership. Specific cases demonstrating this are explored qualitatively in additional detail in the following section.

Along with the variation in distributions and balance of leadership contributions, we found that some forms of leadership were more likely to happen together than others.

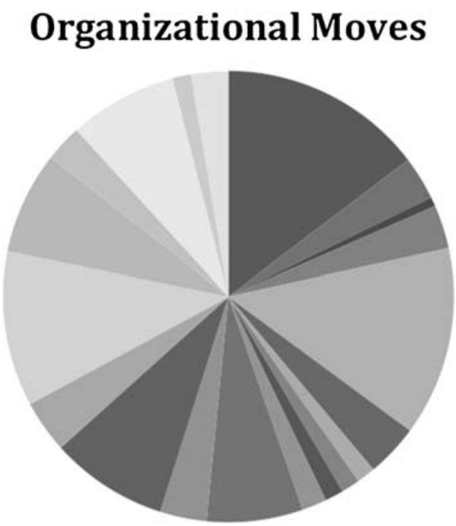


Fig. 9 Comparison of individual Organizational Moves across the entire class. Each slice represents an individual student

Table 8 Comparison of distribution patterns of Groups 2, 3, 4, and 5 to Group 1 using chi-square values

Comparison	Pearson's Chi Square
Group 1 vs 2	15.94*
Group 1 vs 3	11.54*
Group 1 vs 4	15.33*
Group 1 vs 5	6.44

*p<.01

Argument development was significantly correlated with knowledge contribution (r=.43, p<.05), indicating a relationship between these facets of group leadership. Similarly, the correlation between acknowledgment/affective moves and organizational moves approached statistical significance (r=.39, p<.05).

Features of distributed leadership: Suggestive findings of qualitative case analyses

Although leadership was distributed among group members, the data we have presented suggested that different forms of leadership had varying distributions. Some forms were more evenly distributed with nearly all participants taking part—most notably knowledge contribution and acknowledgment/affective contributions. Other forms like topic control and organizational moves, however, were not as evenly distributed. To increase our knowledge of what participating in these leadership roles entailed and what motivated different students to participate, we inspected the online discourse in search of student cases that illustrated leadership specialization, and used a contrasting-cases approach to examine them in detail. As noted by George and Bennett (2005), Scholz and Tietje (2002), and Stake (1995), contrasting-case analyses serve to highlight potentially important dimensions of difference that can be further investigated.

The first two cases we describe are male students, 1B and 2E. Their stories relate to how each similarly used topic control and argument development to influence their group's product, but with different motivations. The second set of cases are 1A and 5E, two female students who demonstrate strongly contrasting roles within their groups; 1A was a strong and positive contributor in all categories of leadership while 5E demonstrates how an individual group member assuming leadership had a negative influence on the overall group outcome. An additional pair of contrasting cases explores the instructor's interactions with Groups 1 versus 5, arguably the strongest and weakest groups.

The discussion of these three case sets refers to posts shown in Tables 11, 12, 13, 14, 15, 16 and 17, which are located in an appendix. To understand these data, it is necessary to realize that they represent two possible kinds of posts that students were able to make: 1. Proposals (with justifications) and 2. Comments on Proposals. All students could post and edit proposals, although students were only allowed to edit a proposal they had personally posted. However, students could comment on any member's proposal. All groups worked on their projects in three consecutive phases: 1. Defining goals, 2. Developing assessments, and 3.

Table 9 Comparison of distribution patterns of Groups 2, 3, 4, and 5 to Group 1 using chi-square values, instructor omitted

Comparison	Pearson's Chi Square
Group 1 vs 2	17.86*
Group 1 vs 3	11.20*
Group 1 vs 4	13.17*
Group 1 vs 5	4.55

*p<.01

Table 10 Number of individual students participating in each type of leadership contribution

	Leadership contribution					
	A/A	AD	SI	KC	OM	TC
Number of contributing participants (26 total)	22	23	17	24	20	13

Designing activities. During each phase, most groups selected a "best" proposal for further development, with the author of that proposal taking responsibility for further editing that proposal until it became the final group product. The editing process involved incorporating input from other students. Students provided their input to the ongoing proposal through the comments tool. However, as is common in most wiki environments, the person editing the proposal would sometimes communicate by incorporating comments directly into the proposal itself. These would show up temporarily and then be edited out prior to the final submission. The data in Tables 11, 12, 13, 14, 15, 16 and 17 represent both kinds of posts. They are displayed in the order in which the posts occurred. Developing proposals thus "grow" or are "pruned" by subsequent posts, which represent developing versions of a product. Comment posts are interspersed throughout the development of the proposal. We have indicated the type of post made by an individual in Tables 11, 12, 13, 14, 15, 16 and 17.

Case set 1: Using topic control and argument development to "advocate." In the two groups that we characterized as more successful, a similar pattern of leadership behavior was noticed in one member of each group, 1B in Group 1 and 2E in Group 2. In Group 1, 1B used argument development and topic control to guide the assignment in the direction of his area of expertise, math. Through making 27% of the group's argument-development contributions and 17% of their topic-control contributions, 1B extended the group's initial proposal and contributed new topics to the group's plan that integrated more mathematical content. The initial project proposed by the group, to develop a middle-school unit to teach understanding the seasons, included primarily learning goals related to science. By using topic control and argument development to advocate for his discipline, 1B insured that a math-rich lesson evolved. This example demonstrates important mechanisms of inter-disciplinary collaboration wherein argument and topic control are used to incorporate a disciplinary perspective being left out. Individual members negotiated with each other through this form of interactive leadership contribution to reach agreements that influenced the final outcome of the group product.

Table 11 exemplifies the interactional nature of this leadership process in Group 1. The interaction in example 1 took place between two group members as they negotiated the topic for their instructional unit. This group was developing their product on a single whiteboard Web page that all were commenting on but only 1A was editing. The interchange began with 1A, a science major, posting an initial idea for this phase of the project, likely organizing ideas from conversation that happened in a face-to-face meeting. This was followed by a post by 1B, a math major, who advocated for the inclusion of ideas that would allow more math standards to be addressed in the unit. In response to 1B's argument development as he advocates for his content area, 1A acknowledged his idea, but was not sure how to integrate the idea herself into the group's plan. So she invited other group members to respond by redirecting the idea to the entire group as a question. While the question was posed to the entire group, 1B continued to advocate for the topic by supplying supporting resources in the form of mathematical academic standards that relate

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t11.1 **Table 11** Examples of 1B's use of Argument Development in Group 1 on whiteboard

t11.2 **Example 1**

t11.3 ***Proposal by 1A:*** *... The topic of our lesson is: What causes the seasons? (Why are some months hotter and some months cooler?)*

t11.4 *For this, should we include something from WI science standards?—like, why should we be teaching this topic?*

t11.5 ***Comment by 1B:*** *I also think that we should teach topics like orbit and other properties of the earth and sun to help the students better understand. We can then combine some more math activities in. Here is a standard that might help…*

t11.6 I'm sure there has to be more. E.12.3 Using the science themes*, describe* theories of the origins and evolution* of the universe and solar system, including the earth system* as a part of the solar system, and relate* these theories and their implications to geologic time on earth

t11.7 ***Proposal by 1A:*** *Context: As a collaborative group of math and science educators, we intend to prepare an earth science lesson for 10th graders in a rural high school in Wisconsin.*

t11.8 *The topic of our lesson is: What causes the seasons? (Why are some months hotter and some months cooler?) How does the earth interact with the sun? (What are some properties of earth?)*

t11.9 ** Regarding the topic of the lesson—I like [1B's] idea in comments, but I'm having problems with forming a cohesive sentence—any ideas? Thanks.*

t11.10 *Applicable standards:*

t11.11 *E.12.3: Using the science themes, describe theories of the origins and evolution of the universe and solar system, including the earth system as a part of the solar system, and relate these theories and their implications to geologic time on earth.*

t11.12 ***Comment by 1B:*** *Math Standards:*

t11.13 *C.12.2 Use geometric models* to solve mathematical and real-world problems*

t11.14 *C.12.1 Identify, describe, and analyze properties of figures, relationships among figures, and relationships among their parts by:*

t11.15 *constructing physical models*

t11.16 *drawing precisely with paper-and-pencil, hand calculators, and computer software*

t11.17 *using appropriate transformations** (e.g., *translations, rotations, reflections, enlargements)*

t11.18 *using reason and logic*

t11.19 ***Resulting proposal by 1A:***

t11.20 *Context: As a collaborative group of math and science educators, we intend to prepare an earth science lesson for 10th graders in a rural high school in Wisconsin.*

t11.21 *The topic of our lesson is: What causes the seasons? (Why are some months hotter and some months cooler?) How does the earth interact with the sun? (What are some properties of earth?)*

t11.22 *Applicable standards:*

t11.23 *Science Standards:*

t11.24 *E.12.3: Using the science themes, describe theories of the origins and evolution of the universe and solar system, including the earth system as a part of the solar system, and relate these theories and their implications to geologic time on earth.*

t11.25 *G.12.2 Design, build, evaluate, and revise models and explanations related to the earth and space, life and environmental, and physical sciences.*

t11.26 *A.12.7 Re-examine the evidence and reasoning that led to conclusions drawn from investigations, using the science themes.*

t11.27 *Math Standards:*

t11.28 *C.12.2 Use geometric models to solve mathematical and real-world problems.*

t11.29 *C.12.1 Identify, describe, and analyze properties of figures, relationships among figures, and relationships among their parts by constructing physical models, drawing precisely with paper-and-pencil, hand calculators, and computer software using appropriate transformations (e.g. translations, rotations, reflections, enlargements), using reason and logic.*

t11.30 *National Council of Teachers of Mathematics (NCTM): In grades 9–12 all students should develop a deeper understanding of very large and very small numbers and of various representations of them.*

Table 11 (continued)

t11.31	**Example 2**
t11.32	***Proposal by 1A:*** *Regarding our proposal, specific goals for enduring understanding that we have include:*
t11.33	...
t11.34	*1. Students understand that seasons on earth are caused by the tilt of earth's axis. Students measure an angle from an axis.*
t11.35	*2. Students understand the inquiry cycle.*
t11.36	...
t11.37	*8. Students understand properties of the earth's elyptic revolution.*
t11.38	*9. Students understand geometrical concepts, such as radius, circumference, diameter, distances, etc.*
t11.39	*10. Students understand mathematical/scientific notation when talking about huge distances.*
t11.40	*11. Students understand the concept of "radiative balance" and can explain it.*
t11.41	***Comment by 1C:*** *....We also might want to split the goals up...assessment and enduring understanding. So specific and general type of sh*t.*
t11.42	***Proposal by 1A:***
t11.43	Regarding our proposal, specific goals for enduring understanding that we have include:
t11.44	* [1C] has a good suggestion regarding splitting the goals into more manageable groups—He recommends assessment and enduring understanding—This makes me wonder if we're being too specific in our enduring understandings? Or, in other words, are we going into another section of the PBL? I don't know. What do you guys think?
t11.45	1. Students understand that seasons on earth are caused by the tilt of earth's axis. Students measure an angle from an axis.
t11.46	2. Students understand the inquiry cycle.
t11.47	…
t11.48	8. Students understand properties of the earth's elyptic revolution.
t11.49	9. Students understand geometrical concepts, such as radius, circumference, diameter, distances, *etc.*
t11.50	10. Students understand mathematical/scientific notation when talking about huge distances.
t11.51	11. Students understand the concept of "radiative balance" and can explain it.
t11.52	***Comment by 1B:*** *I do agree with [1C]—that we may have too many goals for enduring understanding for only a two-week lesson. But I feel the math goals are very important and should be included in enduring understanding not just assessment. Especially number 9 and 10!!!*
t11.53	***Proposal by 1A (final group submission for this iteration):***
t11.54	Regarding our proposal, specific goals for enduring understanding that we have include:
t11.55	1. Students adapt geometrical concepts in new contexts.
t11.56	- elyptic revolution
t11.57	- radius, diameter
t11.58	- circumference
t11.59	- distance
t11.60	- 2- and 3-dimensional diagrams/models
t11.61	- angles
t11.62	- axes
t11.63	2. Students can explain how mathematical/scientific notation can make numbers more manageable. (Students understand the importance of magnitude.)
t11.64	3. Students reassess their prior knowledge by using and applying the inquiry cycle.
t11.65	4. Students can identify the factors that cause the earth to have seasons.
t11.66	- tilt of earth's axis
t11.67	- location on earth (geographical—N./S. hemisphere, altitude, latitude, near/far ocean)
t11.68	- earth's revolution and rotation
t11.69	- earth's radiative balance

t12.1 **Table 12** Examples of 2E's use of topic control in Group 2 on whiteboard

t12.2 **Example 1**

t12.3 ***Proposal by 2C:*** *We will begin this unit on "Velocity" with an assessment of students' prior knowledge. The unit will be introduced with the presentation of a scenario. The teacher will ask the students to imagine that their family was planning a vacation to take during spring break. One of the main components of vacation planning is …*

t12.4 ***Comment by 2A:*** *…The teacher will be a mentor in this case in a COGNITIVE APPRENTICESHIP. Students will need the teacher to coach them along so that their ideas remain on track towards the final goal of discovering what the actual relationship is…*

t12.5 ***Comment by 2E:*** *My only comment is regarding what we have seen in the class of teaching to diverse learners. We want to tap on students' prior knowledge and connect the assignment with their life, is it good to assume all of our students take spring-break vacations? How could we expand the assessment to include a larger diversity of students?*

t12.6 *I do not think this assessment falls under [the topic of] cognitive apprenticeship. Students share what they think they need for the trip, but I do not see this as a task that students could not handled by themselves, or a guided effort directed for students proficiency on a particular skill.*

t12.7 ***Comment by 2A:*** *Nice. Maybe talk about how this is formative because the info the students provide will be used to inform further instruction and motivate the inquiry cycle to determine exactly how velocity works to be able to fully plan the trip.*

t12.8 *This is also a good example of Cognitive Apprenticeship and the development of a schema to understand velocity. We are providing a meaningful context to help the students understand velocity. This helps them develop a web of knowledge surrounding velocity that is meaningful to them. This is probably also Cognitive Flexibility Theory since the students will talking about many complicated features involved in trip planning that are considerations (such as traffic lights and construction). The more understanding, the more flexible their ability to imagine these different situations and how this connects to trip planning.*

t12.9 *What I mean about cognitive apprenticeship is more about how this beginning question/assessment frames the rest of the unit (including the abstractions of formulas and the such) into something most students have some grasp of. Thus, they have an organizing principle for the rest of the unit: How does velocity figure into trip planning?*

t12.10 ***Final proposal by 2A:***

t12.11 *We will begin this unit on "Velocity" with an assessment of students' prior knowledge. The unit will be introduced with the presentation of a scenario. The teacher will ask the students to imagine that they are taking a trip of some sort; for example to visit a distant relative or friend, to take a family vacation, or to explore a college or technical school that they are interested in. One of the main components of trip planning is to outline and design the actual travel to the destination. The teacher will pose the following question to the whole class and record responses on the board: "What do we need to consider when planning a trip?" By introducing this unit in the context of trip planning, which is more familiar to the students than the concept of velocity, we hope to receive more student participation in the discussion and determine students' current understanding of velocity. This is an informal, whole-class, formative assessment. Because this assessment is formative, it will be used by the teacher to inform further instruction. Students will receive feedback in the form of questioning by the teacher. The teacher might ask them to elaborate on a response in order to learn more about the students' current knowledge. In this way, the teacher is also accessing any misconceptions that may need to be addressed in future instruction. This assessment is also a great way to begin the inquiry cycle because we are posing a question that will lead to further questions such as "what is velocity", which will lead to hypothesizing and further investigation on this concept and why it is important to trip planning…*

t12.12 **Example 2**

t12.13 ***Proposal by 2A:****…Activity 6 (I'm going off of what we have written in the assessment):*

t12.14 *This activity is helping to SCAFFOLD students into the final formative assessment. They will be basically using the same format as the final assessment, however, all of the information will be given to them instead of them having to figure everything out. TOOLS AND ARTIFACTS will be used when students are using real to life scenarios and modes of transportation that they are already familiar with. (okay, so I stopped here to look back at the assessment. It seems like I'm using the exact same logic to justify it, is that okay, or do they want something totally different?)*

t12.15 ***Comment by 2E:*** *For all of us, this activity is meant to provide support to students (scaffold) for their final assessment, but I believe they should be less similar. I think of the final assessment as a problem solving*

Table 12 (continued)

	activity in which students need to transfer what they have learned. I would like the activity to be something new, not just an assessment in which students repeat a previously seen activity. Am I missing something here?
t12.16	***Comment by 2A:*** *I think what I was trying to portray is not that the final assessment is exactly the same format rather we are giving them an example of how they might organize and complete their final assessment with this assessment. In my mind, I agree that this is very much a scaffolding activity.*
t12.17	***Final Proposal by 2A:*** *Activity #6: Problem-Solving Using the Velocity Model*
t12.18	*Students use information about a trip that has already been planned. They will need to calculate velocity, distances, and times for various portions of the trip with the information given. The trip will consist of different forms of transportation and use many different velocities, distances and times so that students get a lot of work solving for different variables. They will also then have to graph the different portions of the trip, including time when they had no velocity and describe why the graph appears the way it does. Students will also have to write the equation of the line for each consecutive portion of the graph. This activity serves as assessment #4 and will be done individually. The teacher will answer questions and act as a guide-on-the-side.*
t12.19	*Justification:*
t12.20	*This activity is helping to SCAFFOLD students into the final formative assessment. They will be basically using the same format as the final assessment, however, all of the information will be given to them instead of them having to figure everything out. TOOLS AND ARTIFACTS will be used when students are using real to life scenarios and modes of transportation that they are already familiar with. While using these tools and artifacts they will also be activating their PRIOR KNOWLEDGE USE because they are already familiar with the modes of transportation and what velocities or distances they can cover in a certain amount of time. They will also be using the prior knowledge that they have used throughout the week in order to complete the project. Without that prior knowledge from earlier in the week, the project would be too hard for students. Because they should already know what velocity, distance and time are, they will also be using PROCEDURAL KNOWLEDGE because they will need to know the steps necessary to calculate for velocity, distance or time. Finally students will be using COGNITIVE APPRENTICESHIP in order to complete the task because they are doing an authentic assignment that is real to life. The mentor in this apprenticeship will be the teacher because he/she will guide them towards the correct procedures and calculations through formal and informal feedback.*

to the topic of their instructional unit, understanding the four seasons. 1A ultimately integrated these standards into the final group proposal, which the entire group voted in favor of. In this interchange, both 1A and 1B demonstrated successful group leadership actions. 1A, who was in control of the group's physical space, invited other group members to share in this process through asking questions. In another way, 1B leveraged argument development to advocate for his content area by suggesting an additional approach to the topic and then supplying the necessary supporting resources needed for the group to accept his idea. This interchange demonstrates the importance of the interactional nature of leadership. If, for example, 1B had advocated for his content area but his attempt went unnoticed or failed to transform the final group product, the contribution would not be considered part of the group's leadership process.

Example 2 in Table 11 portrays another example of a leadership interchange in Group 1. This example involved three group members and demonstrates the intricacies of the various facets of the leadership process. 1C responded to 1A's initial post of the goals for the unit by suggesting the goals be split into categories to help organize the group project. 1A took up this organizational move but sought input from the group on how precisely to make the change (rather than just making the change herself). In this redirection to the group, 1B responded in agreement with 1C's organizational suggestion and, once again, asserted the importance of keeping the math standards in the project. The result was that the math goals were kept in the unit and the unit became transformed from a heavily science unit to having a distinct focus on math. Through his leadership contributions, 1B shaped the course of the group project. 1C t13.1 **Table 13** Examples of 1A's communicative contributions in Group 1

t13.2 ***Example 1***

t13.3 ***Comment by 1A:*** *[1C] has a good suggestion regarding splitting the goals into more manageable groups… This makes me wonder if we're being too specific in our enduring understanding? Or, in other words, are we going into another section of the PBL? I don't know. What do you guys think?"*

t13.4 ***Example 2***

t13.5 ***Comment by 1A:*** ** Ok—Please let me know how you guys would like to modify these assessments. I've tried to explain the activity and how it's done. I may have delved into the justifications or been insufficient in describing them so let me know what you think can be done to improve them. [lists names with specific assignments on whiteboard]*

t13.6 ***Example 3***

t13.7 ***Proposal by 1A:*** *Assessment Plan:*

t13.8 *Formative Assessments:*

t13.9 *1. Initially, in small groups …*

t13.10 *2. Daily, students will …*

t13.11 *Summative Assessments:*

t13.12 *3. At the end of the lesson, students will …*

t13.13 *4. At the end of the lesson, small groups of students will …*

t13.14 ** Ok—Please let me know how you guys would like to modify these assessments. I've tried to explain the activity and how it's done. I may have delved into the justifications or been insufficient in describing them so let me know what you think can be done to improve them.*

t13.15 *Justifications:*

t13.16 *1. 1B*

t13.17 *2. 1C*

t13.18 *3. 1D*

t13.19 *4. 1E*

t13.20 ***Comment by1C:*** *Justification #2*

t13.21 *Journal Entries are very helpful over a period of time for the teacher to assess the knowledge construction over time. If the students write a journal entry before the unit starts completely, the teacher can observe what knowledge students already have, and as students add to their journals, the teacher can observe what knowledge is built up onto the old knowledge. This can also be very helpful for the students to help them build on their knowledge. Another thing that will be useful for the students in these journals is metacognition. Through their journal entries, they will be thinking a lot about what they know and writing it down on paper. Some things they might be thinking about are: why are they learning this, what are they learning, and maybe what they think they will learn next. Other questions could be given to the students also to help them think about what they have learned and apply it to a new problem. This would involve the students using transfer which would show the students how the activity is important for real life situations.*

t13.22 ***Proposal by 1A (Integrating 1C's comment):*** *Assessment Plan:*

t13.23 *Formative Assessments:*

t13.24 *1. Initially, in small groups …*

t13.25 *2. Daily, students will …*

t13.26 *Summative Assessments:*

t13.27 *3. At the end of the lesson, students will …*

t13.28 *4. At the end of the lesson, small groups of students will …* Ok—Please let me know how you guys would like to modify these assessments. I've tried to explain the activity and how it's done. I may have delved into the justifications or been insufficient in describing them so let me know what you think can be done to improve them.*

t13.29 *Justifications:*

t13.30 *1. 1B*

t13.31 *2. Journal Entries that occur over a period of time are very helpful so that the teacher can assess students' knowledge construction over time. If the students write a journal entry before the unit starts completely, the teacher can observe the students' prior knowledge, and as students add to their journals, the teacher can*

Table 13 (continued)

	observe what knowledge is built up onto the old knowledge. This can also be very helpful for the students to help them build on their knowledge. Another way that journaling will be useful for the students is by increasing metacognition. Through their journal entries, they will be thinking a lot about what they know and writing it down on paper. Some things they might be thinking about are: why are they learning this, what are they learning, and maybe what they think they will learn next. Other questions could be given to the students also to help them think about what they have learned and apply it to a new problem. This would involve the students using transfer which would show the students how the activity is important for real life situations.
t13.32	*3. 1D*
t13.33	*4. 1E*

demonstrated how making a suggestion can be considered a leadership move in that group members took up his suggestion. In this example, 1B continued to advocate for math concepts in the project and 1A continued to demonstrate a soft style of leadership in her group through the use of questions. 1A's case will be described in further detail later in this paper.

Table 12 shows the work from another group (Group 2) in which 2E similarly used topic control to influence the direction of the group's final product. Taking on 33% of the topic control in his group (shared primarily with the instructor), 2E repeatedly pushed the group to draw links between the design of the project and the concepts being taught in the course (such as cognitive apprenticeship, scaffolding, transfer), while advocating for equity issues that the group members had taken up in another course on inclusive schooling. Table 12 contains an example where we observe 2E using leadership moves to advocate for both recognition of cultural diversity of learners and learning-sciences concepts. The first example shows how he, a minority student, calls the group's attention to a possible flaw in the unit design related to being sensitive to student diversity. 2C proposes a project that involves students planning a family vacation. 2E points out to the group that this might not be an appropriate context for all learners because they might not be able to relate to taking a family vacation. Thus, through posing a question to the group, he transforms the group project. In a following post, the context of the project was changed to include a broader range of scenarios, to which learners will likely find something to relate.

t14.1 **Table 14** Examples of 5E's contributions to Group 5

t14.2	"the science component of 11th grade" sounds overly complicated and wordy...why don't we just say "Our math/science interdisciplinary unit is designed for use in an 11th grade physics class at an urban high school"
t14.3	**Interchange between 5E and 5C**
t14.4	***Comment by 5E:*** *OK...so this is my idea of how this unit would be assessed...let me know if you think anything should be added, deleted or changed...and if anyone knows what kind of supporting research we could use here that would be really helpful*
t14.5	***Comment by 5C:*** *When you say "There will also be smaller assessments...", does what follows pertain to that statement, or do you mean OTHER smaller assessments? If you mean OTHER smaller assessments, then I think they need to be defined here.*
t14.6	*When you say "...and the teacher should observe this happening", I think this sounds a bit "wimpy". What if the teacher DOESN'T observe it. There needs to be some way for the teacher to assess this without necessarily observing it first hand.*
t14.7	*Also, you say "the student will be expected". Of course, the student will be expected to do these things! We need to assess them on how well they do them. Maybe it would be better to say "the student will be assessed on the written plan made... which will include... the student will be assessed on how they test their variables and represent the data... the student will be assessed on how they use the data to modify the rocket... etc.*

t15.1 **Table 15** Examples of positive affect and argument development from the instructor

t15.2	***Positive Affect***
t15.3	*Group 1: "Those standards seem excellent considering your topic."*
t15.4	*Group 5: "You have outlined an excellent list of learning science issues."*
t15.5	***Argument development***
t15.6	*To group 1: I also see that you use "understand" in most of your goals. Think about what types of understanding you mean by this. There are the 6 facets that Wiggins and McTighe talk about, as an example. Do you want the students to be able to explain, or apply the knowledge, etc.?*
t15.7	*To group 5: For the first paragraph, the learning science ideas you mention-metacognition, prior knowledge, and socio-cultural knowledge formation are good ones, but they need to have more elaboration. Go into more depth as to what these concepts really mean, and how these concepts relate to your assessments.*

In addition to advocating for diversity in the unit design, 2E also challenged whether something is truly cognitive apprenticeship that has been described as such. He provided support for this argument and transformed the final post by leading group members to question this use of the concept, and thus it was omitted from the final learning-sciences justification. In example 2 of Table 12, 2E challenged the proposed unit plan and supports his argument with the learning-sciences concept of transfer. He asserted that the assessment is too similar to the activity and suggests it should be different so as to promote transfer of knowledge. In response, 2A offers a clarification of his thinking. Ultimately, however, the final post that 2A made is modified taking 2E's suggestion into account, making 2E's suggesting a part of the group leadership process. Both examples were typical of 2E's constant redirecting of the group's thinking toward the learning-science ideas.

Case set 2: Dominant members within groups In describing the leadership of 1A in Group 1, we illustrate the nature of strong leadership in a distributed environment. 1A was a strong, active leader who structured the whiteboard space to establish individual accountability for contributions. In addition to organizing information (66% of total group contributions), 1A played an active role in seeking input (72%), acknowledgment and affective contributions (33%), knowledge contribution (24%), argument development (20%), and topic control (17%). Examples of 1A's communication and organizational contributions are in Table 13. Example 1 demonstrates how 1A, a science major, took up an idea from another group member, expanded on it, linked it to other facets of the project, and directed it back to the group. In example 2, 1A communicated her initial ideas about assessment with group members and involved them in improving the ideas. 1A's contributions demonstrated her horizontal role in her group's leadership as she worked to guide the group toward their goal without overpowering other members of her group. Example 3 shows how 1A used a numbered system to establish accountability among group members. The first post of her system shows how she used group member names to create a general understanding of who was responsible for which contributions. The second post shows a contribution made by 1C followed by the third in which 1A has synthesized this contribution into the group's final product.

t16.1 **Table 16** Examples of inviting the instructor's participation through open-ended questions

t16.2	* *Also, for our topic, do we need to explicitly include math aspects or are including them in the enduring understandings sufficient?* (1A)
t16.3	*Those standards seem excellent considering your topic. I've commented more in regards to your goals.* (Instructor)

t17.1 **Table 17** Examples of instructor using the organizational system developed by Group 1 and instructor interaction with Group 5

t17.2	**Example 1**
t17.3	*1E, that is just the sort of thing that we are hoping to see in examining goals, and seeing how to use the learning sciences to inform and expand them.*
t17.4	*1B, I'd like to see more elaboration in what the learning science concepts are, and a more in depth analysis of how those concepts are useful in achieving your goals.*
t17.5	*1D -your justification is great as far as it goes, but it needs to be developed further. Expand on how learning science ideas inform this type of assessment.*
t17.6	*#3-say more about what you mean about a graphic organizer—I'm not sure what you mean*
t17.7	*#4 will need some elaboration as well—I'd like some sort of example, or also a statement of what new knowledge they will be applying and how.*
t17.8	**Example 2**
t17.9	*Hey Guys,...is the main idea that students are actually creating successful rockets, or are they showing that they understand the physics concepts behind rocket flight?*

Although overall leadership was distributed, this does not preclude the idea that one group member can make a noteworthy difference within a group with their leadership initiations. In the case of 1A in Group 1, this influence was of a positive nature that moved the entire group toward their goal. In Group 5, however, there was a group member that not only evoked negative affect from other group members but likely inhibited the group's overall success. This appeared to be the case of 5E in Group 5. The following examples indicate the inhibitive nature of 5E's contributions to Group 5.

5E made two contributions to the first iteration of her group's proposal. The first was a content-based contribution and the second was related to the phrasing of the group's proposal which was posted by another group member (see Table 14). This exemplifies the sentiment that 5E expressed in her end of project reflections in which she discusses how she wanted to be the main poster for her group. In the group's second iteration, she did have this leadership role (the "poster"), and, in response, other group members expressed negative affect toward her knowledge contributions. As shown in Table 14, when 5E asked for group input, another member, 5C, responded with negative affect, which indicated tension within the group. Group 5 was the only group to exhibit such tensions. Negative affect was not directed at any other members of the group. 5E also made organizational contributions that might have contributed to breakdowns in her group. During the second iteration of the project, she was responsible for posting the group's proposals to the whiteboard. While other students could post comments to the group, she was responsible for synthesizing their ideas into the final proposal. The whiteboard in STELLAR was set up with two separate entry fields for the project and learning-sciences justifications of the project design. 5E combined the two fields, making the plan and the justification behind the plan difficult to read because the amount of information in a single field was overwhelming, making it more difficult for her group members to collaborate effectively.

There were a number of potential repercussions from the tension that was evident within the group. For example, the one male member in the group, 5D, did not actively participate in the group's proposal development. Additionally, the group demonstrated limited use of the whiteboard space, making only 40 posts which could have been directly related to the within-group tensions. While 5E wanted to be a primary leader in the group, hers was a case where the plan backfired and contrasted strongly to 1A's role in Group 1. Where 1A guided the group through organization and positive affect, 5E sought to control the group's project by, as expressed in her reflection, wanting to take over as the lead poster for each iteration of the project. We characterize her as a case of a "toxic" group member.

Case set 3: What leadership roles did an instructor play? As discussed above, the patterns of overall distribution of leadership contributions differed between Group 1 and all other groups except for Group 5, the lowest performing group. A main factor that contributed to the similarity in the distribution of roles was the active role that the instructor played in both groups. There were some similarities in how the instructor interacted with both groups. For example, in both groups, the instructor made positive affective-leadership contributions. Additionally, in both groups, the instructor asked students to provide initial justifications of the learning-sciences content in their proposal. Examples of these contributions are illustrated in Table 15.

While the instructor was actively involved in both groups, the specific modes of involvement were considerably different between the two groups. As discussed above, we did not find a statistically significant difference between the groups' distribution of leadership when the instructor was omitted. We have, in turn, explored the differences qualitatively. These differences are discussed below with supporting examples.

Group 1 invited the instructor to participate in their group by asking open-ended questions monitoring the group's progress. For example, 1A provided a list of standards (being used as evidence to justify an instructional design) that she had compiled from individual group contributions, and posted them with questions about how to incorporate them into the group product. It was unclear if these questions were directed solely to other group members or toward the instructor as well, but the use of these questions impacted how the instructor interacted with the group (see Table 16). Questions like this were not asked by members of Group 5. In Group 1, the instructor also, in turn, asked questions back to the students.

There are things that Group 1 did that facilitated the instructor's ability to interact with individual team members. Through the organization of the whiteboard space established by 1A, Group 1 created a point of entry for the instructor's interaction with the group. 1A established individual accountability for components of the lesson that the group is designing. By including individual's names next to their agreed-upon task, the instructor knew who was responsible for which components of the project and could direct feedback specifically to individuals. 1A also established a numbered system for separate parts of the lesson plan. Having a consistent structure over time afforded ease of communication not only within the peer group itself but with the instructor as well. This internally developed structure invited the instructor to interact with the group and facilitated his point of access. The instructor took advantage of this structure by referring to specific numbers in the feedback that he provided. Examples of how the instructor complied with the organizational structure of the project are provided by Example 1 in Table 17. A similar system of organization and accountability was not seen in Group 5. Because of this, it was difficult at times to determine if the instructor was referencing the entire group or an individual member. Example 2 in Table 17 illustrates a case of this.

Conclusion

We conducted a study to examine emergent leadership in small online collaborative-learning groups of pre-service math and science teachers. Groups worked online to design interdisciplinary instructional units. We employed an adapted coding system previously developed by Li et al. (2007) that focused on leadership initiatives to determine that group leadership was highly distributed among participants (Spillane 2007). We additionally Q1 considered which posts generated "follower" responses. In five online groups, a distributed model of leadership was confirmed, with members of every group participating in multiple leadership roles. Thus, our findings indicate that leadership was a social process, with all members of all groups taking some part in their group's leadership. Adapting Spillane's (2007) definition of distributed leadership to the small group describes our findings. Therefore, we define leadership as distributed activities tied to the core work of groups that are designed by group members to influence the motivation, knowledge, affect, or practice of other members and that are likely understood by group members as intended to influence their motivation, knowledge, affect, or practices. Our study focused on influential leadership activity which, in all but one group, were positive and led the groups to success.

Even in a group where a particular leader was "elected" and remained throughout, leadership was intricately shared. However, group members participated in leadership in different ways, with some members avoiding certain roles entirely while embracing others. These differences may exhibit gender-related patterns in that females seemed to seek more input than males, although this must be further investigated. Different aspects of leadership had different patterns of distribution, with some leadership forms being shared more evenly across group members (e.g., knowledge contribution), while other forms (e.g., topic control) were dominated by fewer members. Moreover, different specific forms of leadership were more or less prominent as emergent aspects of leadership. The instructor shared in specific leadership roles (e.g., topic control) but avoided others (e.g., seeking input), and participated to different degrees with different groups, focusing primarily on the strongest and the weakest groups. Yet when groups were viewed as the unit of cognition without regard to individuals, the distributions of leadership behaviors represented as a percentage of total posts did not obviously differ for more- versus less-successful teams.

Based on the patterns we observed, leadership emerged as a distributed phenomenon that involved all members of all groups at some point as they interacted in the virtual space. We posit that this model of emergent leadership may suggest a form of instructional guidance appropriate for college students working in online collaborative groups. Merely creating awareness of these facets for students and allowing leadership to emerge could result in a robust quality of leadership within groups, with more group members taking part. Additionally, such a model's authenticity allows individuals to specialize within the model, lending personal strengths to the group. Because most college students have had prior experience working in collaborative groups, over-scripting (Dillenbourg 2002) might limit the benefits of an organically occurring emergent distributed model of leadership. Our data demonstrated multiple individuals taking part in ownership of group processes simultaneously; were specific roles assigned to individuals, this might not be evident.

Because, overall, groups were successful in their completion of the assignment and in satisfying the learning goal, leveraging the understanding of leadership as a distributed, interactive group process appears to be a feasible alternative to scripting experienced students into specific, discrete roles within groups. Furthermore, the patterns that we observed through this coding scheme serve as a basis on which to move toward the development of a diagnostic model to help guide instructors in scaffolding student participation rather than directly supplying the deficit roles themselves. It also focuses attention on phenomena like toxic group members so that instructors can detect such problems quickly and address them.

These findings support aspects of Stahl's (2006) theory of group cognition, in which he argues for more analytical and instructional approaches that treat the small group as a cognitive unit. Leadership, like problem solving in Stahl's online virtual math teams, was an emergent and distributed phenomenon best characterized at the small-group, rather than individual, level. It would be impossible to develop a theory of leadership by looking at individuals separately; focusing on leadership initiatives in this study has furthered our understanding of distributed leadership in small groups. These findings suggest the importance of investigating small-group collaboration as an emergent, distributed process and of exploring participation in such process as it relates to individual learning and group cognition.

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