Emergent Leadership in Children's Cooperative Problem Solving Groups

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Keywords: emergent leadership; problem solving; collaborative reasoning; small group

Abstract

Social skills involved in leadership were examined in a problem solving activity in which children worked in small groups and cooperatively searched for solutions to a spatial reasoning puzzle. Participants were 252 fifth-graders from four classes in a city in Mideast China. Prior to the cooperative problem solving activity, students from two classes had five concurrent, open-format, peer-managed, small-group discussions of stories while two control classes continued regular instruction. Results showed that students who had discussions produced significantly better problem solutions than comparable control peers and had more positive feelings toward the problem solving experience. Analysis of problem solving transcripts indicated that, compared with control students, discussion students initiated significantly more effective leadership moves, and significantly fewer ineffective leadership moves, including allocating tasks, proposing and justifying solutions, planning and organizing, and seeking group consensus. A qualitative analysis identified attributes of effective leadership that included appropriate timing, open-mindedness, inclusive tone, and respectful attitude.

Keywords: emergent leadership; problem solving; collaborative reasoning; small groups

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The emergence of leadership is an important but often ignored component of successful collaborative and cooperative learning groups. Studies of leaderless groups date back to the 1950s when leadership was observed in groups in which no leaders were assigned. Although leadership is a perennial topic of research in domains such as business, military, and youth extracurricular activities (Borg, 1957; Chemers, 2000; Hart, Donnelly, Youniss, & Atkins, 2007; Rouse, 2012), research on children's leadership, particularly emergent leadership in collaborative learning groups, is limited (Edwards, 1994; French & Stright, 1991; Li et al., 2007; Mercier, Higgins, & da Costa, 2014; Miller, Sun, Wu & Anderson, 2013; Yamaguchi, 2001, 2004).

With the wide application of collaborative and cooperative learning in school settings, it becomes increasingly important to understand the mechanisms by which children develop the skills and knowledge to work productively with others (Barron, 2003), and whether the skills and knowledge are generalizable over a range of situations. The current study, therefore, aims to examine whether children will employ leadership skills in a cooperative problem solving activity after having the opportunity to improve their leadership skills during several collaborative discussions.

A foundational assumption of collaborative and cooperative learning is that successful group work depends upon *positive interdependence* (Johnson & Johnson, 1989, 2009), when members of a group "perceive that they can attain their goals, if and only if, the other individuals with whom they are cooperatively linked attain their goals" (Choi, Johnson & Johnson, 2011, p. 977). We further assume that high status, or socially centered, children are

likely to emerge as group leaders and will be the key to whether or not positive interdependence is established. However, research indicates that sometimes socially centered children have a positive influence, sometimes a negative influence. For example, Ellis and her colleagues (2012) found that adolescents with high social status interacted with their peers in more dominant and controlling ways than adolescents with lower status. One possible reason for the inconsistent findings is that group norms moderate the influence of socially centered students (Lin et al, 2015). Socially centered children may be more sensitive to norms and, if and when adapted to prosocial norms, may play an important role in establishing positive interdependence. Mercier et al. (2014) found that leadership is not stable across content areas, suggesting that emergent leadership is not based solely on a single form of social status.

Characteristics of emergent leadership

Leadership is a more specific construct than positive interdependence. It means taking responsibility and initiative for the functions that must be fulfilled for a group to achieve its goals (Miller et al., 2013). An *emergent leader* is someone who is neither appointed nor elected, but spontaneously performs leadership functions. A *leadership move* is a specific action to help a group accomplish its goals. Examples of leadership moves are: Inviting a contribution from a group member; proposing an agenda for orderly completion of work; seeking consensus about a solution to a problem.

In this article, we adopt the view of leadership as a reciprocal social process based on the *leadership schema theory* proposed by Li and her colleagues (2007) in the context of collaborative discussions. A leadership schema incorporates knowledge about the overall group structure including the “roles played by members, the functions served by leadership moves,

the contingencies under which moves may be useful, the complementary relationships between leading and following, problems that may arise and possible remedies, and the temporal-causal flow of group activities" (Li et al., 2007, p. 79).

The idea that leadership must be a *reciprocal process* is implied by the fact that attempts to lead are fruitless unless others follow. Hollander (1978) described leadership as "a process of influence between a leader and those who are followers. A leadership process usually involves a two-way influence relationship aimed primarily at attaining mutual goals. . . Thus, leadership is not just the job of the leader but also requires the cooperative efforts of others" (p. 4). Leadership may be widely distributed among the members of a group, and there may be no sharp boundary between leaders and followers. By focusing on the reciprocal process between leading and following, the current study moves beyond the question of what makes a children emerge as the leader, to what makes the emergent leadership sustainable.

Previous Research on Emergent Leadership of Children and Youth

Prior research indicates that child leaders do emerge in groups both inside and outside of school and that both peers and adults perceive the emergent leaders as helping groups to successfully reach goals. French and Stright (1991) described emergent leadership in groups of second, fourth and sixth graders, examining how task facilitation supported goal completion. Across two studies they found that children's task facilitation, solicitation of feedback, and recording the group's activities were associated with nominations as leaders by peers and adults. Edwards (1994) conducted a nine-month longitudinal study of fourth to sixth grade girls in Girl Scout troops, finding that emergent leaders took actions to help groups reach goals, and that compared to the elected or assigned leaders, emergent leaders were more consistent over

the course of the study, indicating that emergent leaders continued to lead once they had developed organizational skills.

Goal orientation appears to influence children's emergent leadership. Yamaguchi (2001, 2004) found that children were more likely to demonstrate emergent leadership and reported better collaborative experiences given a mastery goal instead of a performance goal. Although neither task-focused nor relationship-focused leadership led to better task performance, both aspects of leadership increased group cohesion.

Emergent leadership of children and youth have been examined in computer-supported collaborative learning contexts. Interestingly, despite the distinctive challenges that computer supported collaborative learning might bring, research shows similar characteristics of emergent leadership in a computer supported environment and other settings. Mercier et al. (2014) compared groups that used paper and pencil to solve a history or math puzzle with groups that worked on multi-touch tables, and obtained a similar distribution of leadership in the two conditions. Under both conditions, about half of the groups had two different students that emerged as the intellectual and the organizational leader. In a study involving 3,062 adolescents from 139 countries, Cassell and her colleagues examined the discourse patterns of the large online community of Junior Summit, and discovered that young adolescents who emerged as leaders focused more on the goals and needs of the group instead of themselves. The particular characteristics of these youth leaders included using plural forms to address the group, asking many WH questions, initiating interpersonal communication, and synthesizing the posts of others (Cassell, Huffaker, Tversky, & Ferriman, 2006).

There is a dearth of research that looks specifically into the development of children's leadership. However, because social skills establish the foundation for leadership, it is useful to look at how social skills develop. According to Ladd and Mize (1983), children go through three stages in successful social skills acquisition and future generalization. The first step is to help children develop a conception of what the skill is and is not; the second step involves assisting children to translate the skill ideas or images into actual behavior and the provision of feedback by teachers or other adults to improve skill performance; and the final step asks children to internalize and generalize the learned skills to different situations, so they can initiate the skills automatically and continuously evaluate their performance on their own.

The cognitive-social learning approach to social skill training described by Ladd and Mize (1983) has been mainly applied to help low-status or socially isolated children obtain peer acceptance (Asher, Parker, & Walker, 1996; Mize & Ladd, 1990), and has shown significant positive effects. Using similar approaches, many cooperative learning researchers have argued that some key social skills must be explicitly taught if children are to benefit from small-group experiences (Cohen, 1994; Gilles & Ashman, 1996; Johnson & Johnson, 2003). Such skills training usually uses a direct teacher-led instructional method, where skills are explicitly taught and students are then given the opportunity to practice. Research has shown that the training of social skills leads to increases in the quality of group interactions and to positive relationships among group members (Johnson & Johnson, 2003). Furthermore, positive relationships have been shown to generalize to other situations not directly linked to the instructional setting and may persist for two years or more (Gillies, 2002). Although we are unaware of any research on leadership skills training with children, there are studies of leadership training with adolescents

and young adults. For example, Posner (2009) applied the direct social skills training approach to encourage leadership development in college students, and found in a longitudinal study that students' leadership improved significantly from freshman to senior years.

Under the assumption that leadership is a process instead of a set of skills, there is an alternative to the direct instruction of social skills, where children develop leadership skills through experience in working with one another. In a close examination of 12 discussion groups over 10 collaborative peer-managed discussions, Li and her colleagues (2007) found that children's leadership developed dramatically, and there was a wide distribution of leadership functions among group members. They found that even without teachers' specific instruction of leadership moves, children spontaneously succeeded in leading discussions, both intellectually and socially. Once children emerged as leaders, they continued to lead in later discussions despite variation in topics and other specific circumstances. Li et al.'s (2007) explanation in terms of leadership schema theory was that the children had abstracted effective leadership elements from recurrent patterns of successful behavior that were common across different situations.

Questions Addressed in This Study

Few if any studies of children's leadership have addressed the following issues: First, is leadership context specific? Li and her colleagues (2007) found that children cumulatively developed leadership skills across a series of collaborative story discussions. But what if children were placed into a very different type of collaborative activity after participating in story discussions, say, a cooperative problem solving activity involving a mathematics problem. Would they continue to employ the social skills involved in leadership? Second, is emergent

leadership group specific; that is, does it involve learning to work with particular classmates? If children were shuffled into new groups, would they be able to adapt leadership skills to this different group of classmates whom they have not collaborated with before? Third, assuming positive answers to the first two questions, would leadership in the new group with a new task facilitate group processes so that the group is more productive, achieves better results, and increases enjoyment of the collaborative activity? The current study aimed to answer these questions by looking at whether children were more likely to display leadership in a small-group activity, called Cooperative Problem Solving, after their participation in a different type of small-group activity called Collaborative Reasoning.

Collaborative Reasoning (CR) is a free-flowing, peer-managed approach to discussion intended to stimulate critical reading and thinking and to be personally engaging (Anderson, Chinn, Waggoner, & Nguyen, 1998). Children read stories about controversial issues that cover ethical or practical dilemmas or child-friendly public policy or scientific issues. They take positions on the *big question* raised by a story, present reasons and evidence for and against these positions, with the goal of collaboratively coming up with the best answer to the big question. In a CR discussion, teachers are encouraged to step back and reduce their talk, making more room for students to decide when to speak and what to say. Students' independent control of discussions is fostered by open participation. That is, students speak without raising their hands and without being nominated by the teacher. Students' rate of talking almost doubles during CR discussions as compared to conventional discussions in the same classrooms, and the quality of their talk improves as well (Chinn, Anderson, & Waggoner, 2001; Jadallah et al, 2011; Lin et al., 2012; Morris et al., 2013).

Teachers have a role to play in CR, even though the rate of teacher instructional moves is low by ordinary standards (Jadallah et al., 2011). One essential role of teachers is to assure that students understand and honor CR norms, which emphasize openness to diverse viewpoints, providing social support for others, thinking critically, and expressing ideas clearly. Besides providing scaffolding occasionally during CR, before each discussion teachers review norms, and after each discussion lead children in a debriefing about this day's discussion and what can be done to make the next discussion better.

Cooperative Problem Solving (CPS) is a subcategory of collaborative learning in which students work together to find the answer to a specific problem (Chiu, 2000a). It is similar to CR discussions in the way that students take charge of the activity independently from the teacher. But different from CR discussions, where there is no definite right answer and discussions typically end without a consensus, during CPS students need to reach a consensus about the best solution. CPS requires group members to support each other and collaborate efficiently so that the value of different knowledge and perspectives can be maximized. Diverse viewpoints enable a group to create multiple ideas, combine the ideas together, and interpret them creatively (Chiu, 2000b). Individual comments, requests for clarifications, or questions may inspire other group members and move the group forward intellectually. Furthermore, group members can split the work into stages and put partial solutions together for the final answer. They can also provide emotional support for each other to continue working even though problems are difficult (Chiu, 2000a).

Method

Participants

252 students from four fifth-grade classrooms in two elementary schools in Mideast China took part in this study. Among the participants, there were 105 girls (41.5%) and 147 boys (58.5%), with an average age of 11.07 years old (*SD* = .71). One school was in an urban neighborhood while the other was in an adjoining suburb. The two schools were within the same school district, followed the same curriculum, and completed the same final achievement tests. The average class size in the urban school was 80 students; the exceptionally large classes are attributable to the superior reputation of the school and an open enrollment policy that allowed students to flock to the school. The two suburban classes each enrolled 44 students. According to the school principals, parents of students in the urban school have a middle-high annual income and the suburban school parents have a low-middle income. Within each school, one class was randomly assigned to be the treatment class and the other to be the control class.

Children in these two schools stay with the same cohort of classmates throughout their six-year elementary education. Teachers are assigned to teach either lower elementary classes from the first through the third grade or upper elementary classes from the fourth through the sixth grade. In either case, teachers stay with the assigned class for the full three years until their students graduate to the next level. The current study was conducted during the last month of the fifth grade; therefore, participating students were very familiar with both their classmates and teachers.

Chinese elementary classes are taught by different subject matter teachers and

managed by a head teacher. The head teacher usually teaches a core subject like Chinese or math and shoulders responsibility for managing student behavior, hosting parent-teacher conferences, and organizing classroom- and school-level events. The head teachers of the four participating classrooms were all experienced teachers. Three had taught over 15 years and one had taught for eight years. The head teachers of the CR classrooms were both teachers of Chinese and the two head teachers of the Control classrooms were both teachers of mathematics. All of them had a bachelor's degree in the subject that they specialized in teaching and an endorsement in elementary education.

An informal interview with the teachers at the end of the study revealed that the principal method of teaching for each of the four teachers was whole-class direct instruction. None of them reported using many small group activities in their teaching. They said that they occasionally asked two children sitting at the same desk to turn to each other, or asked them to turn back to the desk behind and form a group of four, to talk about a question for 2 to 5 minutes. Usually students would simply state their opinions about the question and the discussion was over. Then the teacher would wrap up by selecting one or two students in the class to stand up and state their answers. There was one item in the pre-survey that asked children specifically about collaboration experience: "In my class, I have many changes to work with my classmates in small groups." On a four-point scale where 1 indicates not true at all and 4 indicates completely true, children from CR classes averaged 1.69 on this item and children from control classes averaged 1.82 ($t = -1.20$, $df = 250$, $p = .23$). Evidently, extended group discussions in an open format were rare or non-occurring in these classrooms.

Procedure

The two treatment classes received a 45-minute whole-class lesson to introduce them to the Collaborative Reasoning (CR) approach to discussion. The lesson was modeled after the one successfully used by Dong and her colleagues (2009) in a city about 150 miles south of the one where the present study was carried out. In the lesson, the researcher introduced the procedures for CR discussions, and highlighted the six norms, which are (1) talking freely without raising hands; (2) making sure only one person talks at a time and not interrupting; (3) listening respectfully to each others' opinions; (4) encouraging everyone to be part of the discussion; (5) considering different sides of the issues discussed, and (6) thinking critically about the ideas rather than people. The researcher gave examples of each norm, and involved children until they demonstrated understanding.

Meanwhile, the two control classes were given a 45-minute informal lecture by the same researcher about college life in America. The children were curious about the United States, but had never had the chance to visit, and therefore were very interested in the topic. Children were encouraged to ask questions about anything that they might want to know about America. The purpose of the control lesson was to minimize any difference in control and treatment students' rapport with the researcher or motivation for participating in the project.

With help from the teachers, the treatment classrooms were divided into CR discussion groups, with 6-8 students per group, that were a balanced cross-section of the class in gender, talkativeness, and reading ability. Because of differences in class size, there were 11 CR groups in the urban class and 6 CR groups in the suburban class. In the following two weeks, the two treatment classes had five CR discussions while the two control classes continued their normal

school lessons, which presumably continued to involve teacher-directed whole-class instruction. Copies of the story to be discussed were given to students to read one day prior to the discussion. To help insure that their conversation during the CR discussion was fresh and spontaneous, students were encouraged to read the story carefully but not to talk about it with others before the discussion. Groups had discussions concurrently. Before discussions, the desks and chairs were rearranged so the students within each group could face each other while talking.

In the order in which they were discussed, the five stories that served as the basis for the CR discussions were Chinese translations of *Dr. DeSoto* (Steig, 1982), *What Should Kelly Do?* (Weiner, 1980), *A Trip to the Zoo* (Reznitskaya & Clark, 2001), *Marco's Vote* (Nguyen-Jahiel, 1996), and *Amy's Goose* (Holmes, 1992). These stories have been used many times before in the United States and have proved to lead to good discussions. Except for the fourth story, the others had been successfully used in previous studies of Chinese children participating in CR discussions (Dong, Anderson, Kim, & Li, 2008; Dong, Anderson, Lin, & Wu, 2009).

During discussions, the researcher walked around, stood next to groups listening for a while, but never sat with any group. After 20 minutes, the students were asked to stop their discussions and have a debriefing on their own within their small groups, followed by a whole-class debriefing session led by the researcher. The researcher used three prompts to help organize the small group and whole-class debriefing, which included 1] "please share what you think worked in your discussion," 2] "please share what did not work in today's discussion," and 3] "what can you do to improve the next discussion?" The debriefing sessions varied in length between 10 and 15 minutes. The purpose of the debriefing was to get students to reflect on

their performance during the discussion, share with each other what needed to be improved, and set goals for the next discussion. The debriefing could be about the social dynamics of the discussion or the quality of their ideas about the topic.

Although the Chinese students in this study had never had CR discussions before, the discussions got underway without any problem and the students were very engaged even in the first discussion. Many times the students were talking loudly as they became excited about the issues facing story characters, and the researcher had to remind students to lower the volume of their voices. The dynamics were similar to that described in previous studies of CR in China and South Korea (Dong et al., 2008, 2009; Kim et al., 2011).

Despite the high engagement that most CR groups demonstrated, some groups faced difficulties in adapting to the open-format, self-managed discussions. In the first debriefing session, several groups commented on how chaotic the discussion quickly became as everyone started to feel emotional and sometimes cut off each other's talk to argue for or against different perspectives. The researcher had to remind children of the six norms for successful CR discussions, which included one-at-a-time turn-taking and showing respect towards each other's opinions. She also used the debriefings to offer strategies to the groups in need. For instance, to help one group that complained about unequal participation, she suggested going around the group at the beginning of the discussion to share a quick thought without lengthy explanations, to make sure everyone got involved in the discussion early. When another group expressed concern about the discussion drifting away from the big question, the researcher emphasized that it was the group's own responsibility to manage the discussion, so group members needed to redirect the conversation back to the main topic.

After the five CR discussions, students were shuffled into new balanced, heterogeneous groups based on mathematical ability, talkativeness, and gender for the cooperative problem solving activity, so that they were now grouped with different students, but only students who had previously participated in CR discussions. Regrouping the students served two purposes. The first was to eliminate the effects of learning to work with a particular set of children. The second purpose was to make sure that the CPS groups had the same average mathematical competence.

Like the experimental CPS groups, students from control classrooms were divided into CPS groups that were balanced and heterogeneous with respect to mathematical ability, talkativeness, and gender. Students in the control classrooms had regular school lessons during the period the CR students were having story discussions. In the interview at the end of the project, control teachers were asked about class activities during the intervention period. They said lessons continued as they usually did.

There were a total of 33 CPS groups, 21 from the two urban classes (11 experimental groups, 10 control groups) and 12 groups (six experimental groups, six control groups) from the suburban classes. Within each of the two schools, both CR and control classrooms participated in the CPS activity on the same day, to minimize the chances that students would learn about solutions to the problems before solving them with their assigned groups.

During the CPS activity, groups were asked to solve three problems (see Appendix): move two matchsticks from a number composed of matchsticks to get the maximum and minimum number; solve an equation and make up a word problem to represent the equation; and solve a word problem about dividing buns into three piles without dividing a single bun into

halves. Every student was provided with a piece of scratch paper but each group had only one Q&A sheet to share. Each group's Q&A sheet and scratch papers were collected after the activity for later analysis. Students were asked to achieve two goals: generating as many good solutions as possible; and making sure everyone in the group understood the best solution before moving on to the next problem.

Due to variation in class schedules, the time available for the CPS activity ranged from 9 minutes to 16.67 minutes with an average of 12.78 minutes for experimental groups and 13.92 minutes for control groups. To decrease time pressure, the researcher emphasized that groups should complete as many problems as they could but that it was okay if they did not finish all the problems. Two groups met at a time and were videotaped as they completed the CPS activity. Despite the short amount of time available, children from both CR and Control classes were eagerly involved in figuring out the problems, particularly the first matchstick problem.

Measures of Student Characteristics

A survey assessing students' social relationships with classmates, daily classroom activities, and attitudes toward school was administrated at the beginning of the project. Included were four questions that asked students to nominate classmates who usually had lots of good ideas, who demonstrated good leadership, who were most talkative in classroom discussions, as well as ones who were most quiet. Taking varying class size into consideration, students from the large urban classrooms were asked to name up to eight classmates for each of the nomination questions, Students were allowed to nominate themselves for all of the questions. A hybrid measure of talkativeness was created by subtracting quietness nominations from the nominations for talking most in classroom discussions. Each of the nomination scores

was divided by number of children in the class to adjust for differences in class size, yielding peer-perceived measures of talkativeness, having good ideas, and leadership.

Each student was asked to nominate their best friends in their classroom, up to eight in the urban classes and up to five in the suburban classes. Based on the friendship nominations, three measures of social status were derived — indegree centrality, betweenness centrality, and information centrality — calculated for individual students using a social network analysis program in R (Butts, 2008).

The three measures are all indicators of social status but differ in important ways (Wasserman & Faust, 1994). *Indegree centrality* is the total number of friendship nominations a student receives. It considers only the student's immediate ties rather than indirect ties to the rest of the social network; it is the conventional measure of popularity. A student with a large indegree occupies a central location in the classroom social network while those with small indegrees are located in peripheral positions. *Betweenness centrality* is a measure of how often a student lies on the shortest path (geodesic) between two other nonadjacent students; hence a student with high betweenness centrality is positioned to mediate interactions among others in the social network. *Information centrality* is the harmonic average of all paths to other students originating from a specific individual. Informationally centered individuals are densely interconnected with others within the social network.

Following the CPS activity, students were given a final survey that asked for their attitudes toward the CPS activity. Two weeks after the study, students took the district-level standardized final exams for mathematics and Chinese. Their final test scores were collected from school files as indicators of math and language ability.

Transcription and Coding of Cooperative Problem Solving Videos

Of the 33 problem solving groups, the videos of 16 groups were randomly selected to be transcribed. Within the two large classrooms, 5 out of 10 or 11 groups were randomly selected, and within the two smaller classrooms, 3 out of 6 groups were randomly selected. Thus, the corpus of discussion transcripts included 8 groups that had CR before the CPS activity and 8 groups that had not. One of the researchers compared the beginning minute, the middle minute, and the last minute of all 33 videos, and found no evidence to suggest that the un-transcribed groups differed appreciably from the groups that were transcribed and analyzed in depth. Groups selected for transcription included 119 students, 51 girls and 68 boys, which reproduces the gender composition of the entire sample of 252 students. Comparison of the entire set of pre-intervention measures shown in Table 1 confirmed that the selected groups were comparable to the groups that were not transcribed. The correlation matrix of pre-intervention measures is presented in Table 2.

[Insert Table 1 about here]

[Insert Table 2 about here]

For easy communication among collaborators, the videos were directly transcribed into English using InqScribe (Garde, 2012) with the goal of a complete and faithful record of the talk and accurate identification of each speaker. The transcriber was a fluent Chinese-English bilingual who understood the local dialect of the children.

The corpus of 16 discussion transcripts was organized, searched, and coded using QSR NVivo8 for qualitative research (Richards, 2005). A complete utterance, or 'full speaking turn,' was the unit of analysis (see Chinn, Anderson, & Waggoner, 2001, for the definition of a 'full

turn'). The entire set of transcripts included 2,030 turns. Excluded from the analysis were 14 speaking turns in which students spoke to the researcher, and 52 turns in which the researcher spoke to students. The analysis included the remaining 1,964 turns where students spoke to each other. Although coding was based primarily on students' talk, gestures such as pointing and moving fingers to indicate matchstick moving were incorporated with speaking turns to pin down the referents in statements such as, "move this one over here."

The first step in coding was to establish the scheme for categorizing leadership moves. The starting point were Li et al.'s (2007) categories for analyzing leadership moves in story discussions, which consists of five categories — turn management, argument development, planning and organizing, topic control, and acknowledgement. This scheme was modified based on two randomly-picked videos and corresponding transcripts of cooperative problem solving from the current study, one from a control class, the other from a CR class. After repeatedly watching the videos and numerous discussions, Li et al.'s categories were adapted to fit the CPS activity. The four major leadership categories in the revised scheme are *allocating tasks, proposing and justifying solutions, planning and organizing,* and *seeking consensus*.

Allocating tasks refers to giving directions for what should be done by whom, including the assignment of speaking turns and 'behavior turns' [completing actions]. In the problem solving activity, students not only needed to brainstorm and discuss alternative ways to solve the problem, but also needed to do calculations and write down answers; therefore, assigning tasks to group members could increase efficiency and facilitate the problem solving process. A typical example of allocating a task is, "Write it down."

Proposing and justifying solutions refers to bringing up new ideas and reminding others

of problem constraints. Among solutions proposed, only those that embodied new ideas were credited, unless previously the same idea had been ignored. This leadership move helped to assure that the group explored different solutions as well as remaining on track to achieve the best answer.

Planning and organizing means taking charge of procedures, reminding others of time limits, regulating behavior, and shifting the topic. Although one goal of the activity was to explore multiple solutions, students still faced the 15-minute total time limit to finish as many problems as they could. Therefore it was important that some students took up the responsibility of reminding the group of problem constraints, saving the team from arguing over nuisance issues, and guiding the group to take steps likely to be productive. An example of a planning and organizing move is, “Let’s solve the equation first.”

Seeking consensus is about making sure that everyone understands the problem, gets the same answer, or agrees to take the same action. It includes seeking consensus on both ideas and actions. For example, a boy who asked, *“22.5, right? Did you guys also get 22.5?”* was trying to make sure that everyone agreed before they wrote the answer on the Q&A sheet and moved to the next question. A simple way of seeking consensus was stating an opinion and then asking, “Right?” This leadership move helped the group to achieve common ground.

Leadership moves are not necessarily effective and may or may not help a group achieve its goals. Therefore, once a speaking turn was identified as satisfying the criteria for one of the leadership categories, its effectiveness was evaluated by examining group members’ reactions in the following speaking turns. There were four major reactions to an attempted leadership: accepted, challenged with further discussion, rejected without further discussion,

and ignored. The leadership move was coded as *effective* if group members accepted it or challenged it through further discussion; for example, if the proposed idea was discussed and agreed upon, or the proposed action was carried out. If a proposed idea was confronted with a challenge, it was still coded as effective as it stimulated further discussion and consequently could help move the collaboration forward. Otherwise if the attempted leadership move was rejected without further discussion or ignored, it was coded as *ineffective*; for instance, when a child proposed an idea, but the other group members did not consider it either because they rejected it without further discussions, did not hear it, or heard the idea but ignored it. In summary, the main criteria for judging the effectiveness of an attempted leadership move is whether the move was given serious consideration by other group members. Coding for effectiveness using similar criteria has proved to be of value in previous studies of children's emergent leadership (Li et al., 2007; Mercier et al., 2014).

The effectiveness coding was based primarily on the students' verbal utterances; however, non-verbal actions that substitute for verbal expressions were also considered. For example, behavior that followed the leadership move, such as writing when writing had been proposed, or head nodding to indicate agreement, could show that the move was effective. If a child used the same move twice during a single turn, only one was counted. Also if a certain leadership move by one child was followed immediately by the same or a similar move by other children, the first child would be given credit for the move, while the second child would not. However, when students repeated themselves, whether they were credited or not depended on whether the previous move was successful. If a student tried to present an idea but with a soft voice or at an inappropriate time, there was a high chance that the idea would be ignored

and therefore the move was ineffective. If this student persisted until the idea was picked up by others, the later move was credited as effective. A second rater independently coded the leadership moves in a random 20% of the transcripts, and achieved 90% agreement (Cohen's Kappa = .88).

Results

The results are organized into five sections: (a) Number of problems groups were able to solve during Cooperative Problem Solving (CPS) and the quality of their solutions; (b) Analysis of leadership moves during CPS; (c) Role of effective leadership moves in mediating solutions to CPS problems; (d) Self-reported attitudes toward the CPS activity; and (e) Qualitative analysis of effective and ineffective leadership moves during CPS.

Number of Problems Solved and Quality of Solutions

To evaluate whether groups that experienced Collaborative Reasoning discussions performed differently from control groups in the CPS activity, separate analyses were conducted to look at the number of problems that groups finished and at the quality of their solutions.

All groups were given three problems to solve, and two of the problems included sub-questions, for a total of six sub-questions. The number of sub-questions finished by each group ranged from two to six, due to the efficiency with which groups worked and variation in the amount of time available. No significant difference was found between the CR and control conditions in number of sub-questions answered (β_{CR} = .02, *SE* = .45, *p* = .96). Time was a marginally significant predictor (β = .29, *SE* = .14, *p* = .05), with longer time associated with more questions answered. Neither the group's average mathematics score nor the top

mathematics score of a student in the group was a significant predictor of number of problems solved by the group ($\beta_{average\_math}$ = .06, *SE* = .05, *p* = .25; β_{top_math}= .05, *SE* = .11, *p* = .63).

The analysis of quality of problem solutions was conducted with only the first problem, because this was the only one finished by all groups. Students were given a picture of the number 2809 composed of 24 matchsticks (see Appendix) and were asked to move *only two* matchsticks to form (a) the maximum number and (b) the minimum number. The 33 groups' solutions were ranked according to their value for the maximum number and the minimum number. For the maximum number, the solutions ranged from 8,309 to 290,311, with 9,009 (four groups) and 9,909 (12 groups) the two most frequent solutions. For the minimum number, the groups' solutions ranged from 0009 to 2,288, with 2,008 (11 groups) and 0009 (12 groups) the two most frequent solutions. To place solutions on a psychologically meaningful scale, the absolute numerical values of answers were converted to percentile ranks using the formula, $\frac{C+0.5f}{N} \times 100\%$, where c is the count of all solutions smaller than the current answer, and f is the frequency of the current answer, and N is the total number of solutions (33 in this sample). The percentile ranks were then transformed to z scores. The z score distributions were normal with a steep bell curve.

The z scores representing quality of solutions to the matchstick problem were evaluated in regression analyses, which showed that, after controlling for available time and the groups' top and average math scores, CR groups produced significantly larger maximum numbers (β_{CR} = 1.18, *SE* = .46, *p* = .02). CR groups produced slightly smaller but not statistically different minimum numbers (β_{CR} = -.23, *SE* = .47, *p* = .63). The minimum number problem was much easier; because of the restricted distribution of scores it may not have discriminated well.

Available time and groups' top and average math scores did not significantly predict solutions to the maximum number matchstick problem (β_{time} = .24, *SE* = .15, *p* = .12; $\beta_{average\_math}$ = .02, *SE* = .05, *p* = .71; (β_{top_math} = .12, *SE* = .11, *p* = .29).

Leadership Moves during Cooperative Problem Solving

There were 693 attempted leadership moves identified from the 1,964 speaking turns distinguished in the 16 cooperative problem solving transcripts. Among the leadership moves, 509 were judged to be *effective* in the sense of getting the expected immediate result (e.g., a suggestion was followed) while the remaining 184 moves were classified as *ineffective*. Descriptive statistics of leadership moves broken down by category and comparing CR and control students are shown in Table 3.

[Insert Table 3 about here]

Analyses of students' total effective and total ineffective leadership moves were completed to achieve a general understanding of emergent leadership in the Cooperative Problem Solving activity. A preliminary 2 (CR vs. Control) * 2 (Transcribed vs. NonTranscribed) ANOVA with repeated measures on all factors and Bonferroni correction for multiple tests showed no significant difference between the CR and Control groups on the pretest measures. Thus, the two groups can be regarded as comparable in pre-intervention characteristics. The analysis further showed that the transcribed 119 children were representative of the entire sample of 252 children, except that the children in groups that were transcribed had significantly higher Chinese scores ($F(1, 250) = 6.03$, $p = .02$). However, among the transcribed children, there was no significant difference between the two conditions.

Leadership moves are count data that had a Poisson distribution with slight over-

dispersion. The data have a hierarchical structure with students nested within problem solving groups. Therefore, a generalized two-level linear mixed model assuming a Poisson distribution was employed. The GLIMMIX procedure was applied to account for between-group variance. The predictor variables were entered into the model in the following order: available time; individual math score; peer-perceived characteristics of talkativeness, having good ideas, and leadership ability; measures of status in the classroom social network; and condition, CR versus control. Model fit statistics are shown in Table 4.

[Insert Table 4 about here]

The final model for predicting effective leadership moves showed that, after controlling for available time, math score, children's talkativeness, and social status (information centrality), condition had a significant effect on children's total effective leadership moves (β_{CR} = .31, *SE* = .12, $p < .01$). Children who experienced CR discussions generated 1.36 times more effective leadership moves than their control counterparts.

Among the characteristics assessed through peer nomination, only talkativeness was a significant predictor of total number of effective leadership moves ($\beta_{Talkative}$ = 4.72, *SE* = 1.15, $p < .01$). After children's talkativeness was added to the model, the time available to groups for the CPS activity was no longer significant. Children's math competence remained a robust predictor of effective leadership (β_{Math} = .02, *SE* = .01, $p < .01$).

Among the three social status measures, information centrality had the strongest influence ($\beta_{information}$ = 45.65, *SE* = 15.87, $p < .01$); once information centrality was in the model, betweenness centrality and indegree centrality were not significant. The higher a student's information centrality within the class, the more effective leadership moves he or she

generated. If information centrality was replaced with betweenness centrality, results were similar ($\beta_{betweenness}$ = 6.05, *SE* = 1.76, *p* < .01; β_{CR} = .31, *SE* = .10, *p* < .01). When indegree centrality was substituted, condition was still significant (β_{CR} = .28, *SE* = .09, *p* < .01), whereas indegree centrality was not ($\beta_{indegree}$ = 1.23, *SE* = .96, *p* = .20).

Similar steps were taken in building up an explanatory model for understanding the relationship between children's generation of ineffective leadership moves and social characteristics and whether or not the children experienced CR (Table 5). Among the three social status measures, betweenness centrality had the strongest influence; once betweenness centrality was in the model, information centrality and indegree centrality were no longer significant. After controlling for children's talkativeness and social status (betweenness centrality), condition had a significant negative association with ineffective leadership moves (β_{CR} = -.49, *SE* = .14, *p* < .001). Compared with control students, children who had CR discussions generated .59 times as many ineffective leadership moves. Children's talkativeness (β = .67, *SE* = .29, *p* < .05) and social status (betweenness centrality; β = 2.84, *SE* = 1.11, *p* < .05) were both positively associated with ineffective leadership moves.

[Insert Table 5 about here]

Generalized regression models, with the log link function to accommodate the Poisson distribution, examined the factors contributing to generation of subcategories of leadership moves: Allocating Tasks, Proposing and Justifying Solutions, Planning and Organizing, and Seeking Consensus.

Talkativeness was the only significant predictor of effective *allocating task* moves (β = 8.57, *SE* = 2.12, *p* < .01). For ineffective allocating task moves, condition (β_{CR} = -1.53, *SE* = .43, *p*

< .01), talkativeness (β = 9.63, *SE* = 3.63, *p* < .01) and available time (β = .35, *SE* = .15, *p* < .05) were the three predictors in the best-fitting model. Children from groups that had more time and children who were more talkative produced more ineffective allocating task moves. After controlling for talkativeness and available time, ineffective leadership moves initiated by CR students were 0.22 times less frequent than those of control students.

Math score (β = .04, *SE* = .01, *p* < .01) and social status as represented by information centrality (β = 44.84, *SE* = 16.90, *p* < .01) significantly predicted effective *proposing and justifying solutions moves*, while condition fell short of being significant (β_{CR} = .26, *SE* = .15, *p* = .07). In contrast, condition predicted fewer ineffective proposing and justifying solutions moves (β_{CR} = -.74, *SE* = .22, *p* < .01); compared with CR students, control students were more likely to propose new ideas or reminders about problem constraints that went unheeded or were rejected by the other children in a group. CR children were 1.30 times more likely to successfully make proposing and justifying solution moves, and .48 times less likely to encounter failure when attempting this type of leadership move. Interestingly, good idea nomination was also associated with ineffective proposing and justifying solution moves (β = 14.76, *SE* = 3.25, *p* < .01). It seems that a reputation among peers for having good ideas does not guarantee that ideas will be persuasively presented or that others will accept them.

Effective *planning and organizing moves* were predicted by social status (betweenness centrality; β = 9.83, *SE* = 3.03, *p* = .01) and condition (β_{CR} = .54, *SE* = .17, *p* = .01). Students from CR classes generated 1.72 times more effective leadership moves in this category. Social status had a similar positive effect on the generation of *ineffective* planning and organizing moves (betweenness centrality; β = 14.64, *SE* = 5.90, *p* < .05) whereas condition had a negative effect

(β_{CR} = -.81, *SE* = .40, $p < .05$); compared with control students, CR students were 0.44 times less likely to generate ineffective planning and organizing moves.

In predicting effective *consensus seeking moves*, available time (β = .28, *SE* = .10, $p < .01$), math scores (β = .04, *SE* = .02, $p < .05$), and talkativeness (β = 8.63, *SE* = 2.73, $p < .01$) were the three significant predictors. Social status (betweenness centrality) was the only significant predictor of ineffective consensus seeking moves (β = 15.02, *SE* = 6.46, $p < .05$); students with high social status were more likely to seek consensus unsuccessfully.

To summarize, compared with control children who did not experience CR, those who participated in CR discussions generated more *effective* proposing and justifying solutions and planning and organizing moves. CR children generated fewer *ineffective* allocating task moves, proposing and justifying solution moves, as well as planning and organizing moves. Talkativeness and social status were positively associated with both effective and ineffective leadership moves.

Was quality of solutions to problems mediated by effective leadership?

We hypothesized that it was through more effective leadership during CPS that CR groups were able to produce significantly larger maximum numbers compared to their control counterparts. To test the hypothesis, we carried out a mediation analysis at the group level. The analysis drew upon data from the 16 groups in which both leadership moves and problem solutions were examined. The outcome variable was quality of solutions to the *Maximum Number* matchstick problem and the independent variable was *Condition* (CR = 1, Control = 0). *Effective Leadership*, the aggregate of effective leadership moves by each group, was the hypothesized mediator. Because groups did not have the same amount of time for the CPS

activity, available *Time* was entered as a covariate. Because groups may have allocated time differently, either to maximize quality of solutions or to maximize number of problems completed, *Number of Completed Problems* was entered as a second covariate.

We constructed three models to examine [1] the effect of Condition on Maximum Number after controlling for the two covariates of Time and Number of Completed Problems (see Figure 1A), [2] the effect of Condition on Effective Leadership (see Figure 1B), and [3] the effect of Condition on Maximum Number after entering the mediator Effective Leadership and the two covariates (see Figure 1B).

Model 1 confirms that Condition significantly predicted Maximum Number (β_{CR} = 1.67, *SE* = .64, *p* = .02). Neither Time nor Number of Completed Problems was significant in Model 1 or Model 3; nevertheless, the two covariates were retained because retaining them improved model fit. Model 2 confirms that Effective Leadership significantly differed between conditions, with CR groups employing more effective leadership moves than control groups (β_{CR} = 10.5, *SE* = 2.95, *p* < .01). In Model 3, the effect of condition on Maximum Number dropped to non-significant, (β_{CR} = .64, *SE* = .85, *p* = .47); while the impact of Effective Leadership on Maximum Number was significant (β = .13, *SE* = .04, *p* < .01). Based on Iacobucci's (2012) method, which takes into consideration the binary nature of the independent variable (CR vs. Control), Effective Leadership mediated the effect of Condition on solutions to the Maximum Number problem ($Z_{mediation}$ = 2.35, *p* < .01). Because the coefficient for Condition in Model 3 is greater than zero (β = .64), the mediation was partial.

To summarize, the mediation analysis supports the hypothesis that participating in Collaborative Reasoning discussions increased effective leadership during the Cooperative

Problem Solving activity, which in turn led to improved quality of solutions to the maximum number matchstick problem.

[Insert Figure 1 here]

School Engagement and Attitudes toward Cooperative Problem Solving

To determine whether experience with Collaborative Reasoning facilitated Cooperative Problem Solving from the perspective of the student, an analysis of students' engagement and attitudes was carried out based on the surveys children completed at the beginning of the study and after the CPS activity. For the sake of parsimony, the first principal component was extracted from answers to the 9 Likert-scale attitude questions in the pre-survey and named *prior engagement in school*. Likewise, the first component was extracted from answers to the 8 questions in the post-survey that asked about attitudes toward the cooperative problem solving activity and named *positive feelings towards CPS*.

The component scores calculated from the post-surveys were the dependent variable in multiple regression analyses. Students' gender, Chinese and math test scores, and prior engagement in school were entered as first-level predictors, condition as the second-level predictor, and the interaction between condition and the other variables as the third-level predictors.

Controlling for the other factors, students who experienced CR had significantly more positive feelings towards the CPS activity than control students ($\beta_{CR} = .72$, $SE = .11$, $p < .001$). Students' prior engagement in school was a significant predictor ($\beta = .45$, $SE = .08$, $p < .001$), while students' Chinese test scores had a marginal effect ($\beta = .017$, $SE = .009$, $p = .07$). Gender and math scores did not affect self-reported feelings towards CPS. There was an interesting

interaction between condition and students' prior school engagement ($\beta_{CR*Engagement}$ = -.28, *SE* = .11, *p* = .011); CR discussions led to larger boost in positive feelings towards CPS among students whose prior school engagement was low.

Qualitative Analysis of Effective and Ineffective Leadership Moves

To provide insight into why some leadership moves were effective while other moves were not, we completed a qualitative analysis of attempts to lead. We will introduce the qualitative analysis by presenting excerpts, representative of the corpus as a whole, from transcripts of the cooperative problem solving activity for each subcategory of leadership. These excerpts illustrate the themes that emerged in our analysis of the attributes of effective leadership, which is presented later in this section. Leadership moves are highlighted in bold. Words between square brackets [ ] are notes made by the transcriber.

Allocating tasks. To successfully finish the problem solving activity, children had to brainstorm with each other, discuss alternative solutions, decide on the best answers, and write the answers down, all in a short amount of time. Clear task division and a good coordination among group members thus became essential. The first example from the transcript of a control group shows a problematic attempt to allocate a task.

Liu Qi	***[Speaks to Mei Yu] Okay, write!***
Mei Yu	*Why me?!*
Liu Qi	*Stop arguing for no reason. Write! Quickly!!*
Li Yun	*[Nudging Mei Yu impatiently] Hurry up and write.*
Mei Yu	*Why should I write? [She picks up the Q&A sheet while complaining]*
Jun Ye	*[Looks at his watch, speaks impatiently] Hurry up!*
Mei Yu	*What shall I write?*
Liu Qi	*98-*

Jun Ye	*[Turns around to look at Mei Yu] 9889! The biggest number is 9889.*
Mei Yu	*The biggest number is 9889. [Saying the number while writing; Liu Qi and Li Yun watch her writing]*

In the first example, Liu Qi asked Mei Yu to write down the answer for a problem in a demanding manner without a clear indication of what to write. Mei Yu was reluctant to follow and questioned why she needed to be the one who writes. Two other children impatiently repeated Liu Qi's request. Although Mei Yu finally picked up the Q&A sheet and started to write, she seemed unhappy and did not know what she should write. A boy, Jun Ye, told her the number to write down. No one in the group explained to Mei Yu how they came up with the answer. They simply watched her write it.

The next excerpt contains effective leadership moves from students in a CR group that succeeded in getting group members to do what was suggested:

Hui Mi	***[Speaks to Chang Hong and others in his subgroup] Hey guys, we are working on the biggest number now. Could you please figure out what the smallest number should be? Our answer for the biggest number is 9909.***
Xue Ran	*Please show me how you got 9909.*
Hui Mi	*You see … [All the children turn their heads towards Hui Mi, and sit closer to her] Moving these two matchsticks will be enough. [begins to show on her scratch paper]*
Chang Hong	*Ok, I know. I think the smallest number should have the smallest value on the last position.*

In this example, Hui Mi was trying to increase the group's productivity by asking a subgroup of students to find the smallest number, while she and two other students were working on the biggest number. She was very clear in her suggestion, and expressed it in a polite way. The other students were curious about how she got the biggest number, and they

were very attentive as she explained. Then, as Hui Mi had suggested, Chang Hong initiated a discussion of how to find the minimum number. The example shows that children sometimes strategically split into subgroups. Most CR subgroups checked with each other and achieved consensus before moving on to the next problem, but control subgroups sometimes did not do this.

Proposing and justifying solutions. This category of leadership moves included children's attempts to bring up new ideas and remind others of the problem constraints. When effectively done, proposing solutions would help the group explore possible answers and keep the discussion on track. The following example revealed how Jing Yi, a relatively quiet girl who was perceived to be highly competent in math by members of her group, successfully proposed an innovative idea to solve the most difficult problem. // indicates interruption of a turn.

Jing Yi	***Ah, I have an idea now! [Pauses for 3 seconds] That is, that is, so there are nineteen steamed buns here, we can add one and get 20 steamed buns now. Then the buns can be divided exactly, emm, they can be exactly divided by 2, 4, 5, and then //***
Guo Hua	*// But the key point is that we cannot add one!*
Jing Yi	*We cannot add one?*
Guo Hua	*No we can't.*
Jing Yi	***It's not said in the problem that we cannot.***
Wang Duo	*What about removing one?*
Jing Yi	*Nineteen steamed buns, adding one, and we have 20 steamed buns now, and then //*
Qi Min	*// But we cannot add one!*
Jing Yi	***No, we can. [Pauses to look around everyone, then continues speaking] Listen, so one half, one quarter, and one fifth of 20 steamed buns will be added up to 19. So we can then get rid of the extra steamed bread, and perfectly solve the problem!***
Wang Chen	*What?*

Qi Min	*Remove the steamed bun that was added later?*
Jing Yi	***Yes. Adding one steamed bun first, then divide the 20 buns, and then remove the added steam bread. [Pauses 3 seconds and looks around the group] We need to add one steamed bun at the very beginning.***
Chong Xiao	*Ah, that's smart! Ok, write it down, quickly!*

Jing Yi's initial proposal was challenged by Guo Hua, who maintained that adding a steamed bun broke the constraints of the problem, to which Jing Yi responded, "It is not said in the problem that we cannot." She re-phrased her explanation several times, until her group mates understood and agreed. She held everyone's attention by saying "Listen," and twice looked around the group to ensure that her ideas were heard. When facing the doubts of her group mates, she listened to what they had to say but she did not withdraw or change her mind. Her openness and her persistence helped the group eventually reach a consensus about her proposed solution, ratified in the words of Chong Xiao, "Ah, that's smart! Ok, write it down quickly!"

In the following example, Mao Mao tried several times to propose solutions for the maximum and minimum number matchstick problems. Despite the fact that the numbers he came up with were close to the best among all the possible solutions, he had trouble getting the group's attention and acknowledgement.

Yu Qing	*Let's put the Q&A sheet here to make it easier for us to read. [Everybody starts reading the question.]*
Mao Mao	***9009!! [The group remains silent for 10 seconds and nobody seems to pay attention to Mao Mao's answer] 9009!!***
Yu Qing	*[Turns her head, and speaks to Mao Mao impatiently] Don't tell me your answer!!!*
	[Ten-second silence]
Qiu Yu	***Oh, I know how to solve the problem! [Puts her finger on the***

	graph of 2809] Move the match here, so we get 9. [Yin Run also points her finger at the number.]
Guan Chen	*Move to the front?*
Mao Mao	*Yes*
Yu Ting	*[speaks to Yu Qing] Don't write on the Q&A paper! You alone used a whole piece of paper!*
Yu Qing	*I used this piece of paper first. [She is writing on one of the scratch papers.]*
Mao Mao	*We can only move two match sticks.*
Yu Qing	*The smallest number... What's the largest number?*
Qiu Yu	***9009 is the largest number, and the smallest number is 0009.***
Yu Qing	*But you can only move 2 sticks!*
Qiu Yu	*Move this stick there, and move that stick here.*
Mao Mao	***9009 is the biggest number! [raises his voice] The biggest number really is 9009!***
Yu Qing	*How did you get 9009? Okay, never mind, just write 9009.*
Guan Chen	*The biggest number is 9009, 9009.*
Yuting, Yinrun, Yuqing	*All right, let's write 9009.*
Mao Mao	***The smallest number is 0009!***
Yu Qing	*Don't say aloud your answer! You can write it down yourself!*
Mao Mao	***The smallest number really is 0009! Look, [demos on the Q&A sheet where Guan Chen is writing] move this match stick here, and move that match stick there.***
Yu Qing	*Stop talking, let him finish writing first.*

Mao Mao's initial proposal of the maximum number 9009 was made at the beginning of the CPS activity, when most of his group members were still trying to figure out possible answers. His quick announcement of an answer irritated Yu Qing, who was impatient with Mao Mao for interrupting her before she could think through the problem. After a moment of silence, Qiu Yu came up with the same answer that Mao Mao had proposed. However, instead of simply telling the answer, she demonstrated with her fingers how she figured out the

solution. Qiu Yu's demonstration was effective, as she caught Guan Chen's attention. Later when Mao Mao tried to propose the smallest number, he got cut off twice again. Both times, he was talking and trying to grab the Q&A sheet for a demonstration, while another group member was writing down the answers to a different problem. Apparently Mao Mao did not pay attention to the group dynamic and failed to realize that the group was not ready to move on.

Planning and organizing. Many steps were involved in successfully completing the cooperative problem solving task, including appropriate time allocation for each problem, carrying out the procedures, and behavior regulation. This category of leadership moves mainly managing the topic. Below is an excerpt that contains successful leadership moves in this category.

Tang Wei	*Wait, wait, move this match here and another match, we get 0009! That's the smallest number.*
Ya Qian	*0-0-0-9?*
Tang Wei	*Teacher, is 0009 a valid number?*
RA	*You should decide it yourselves.*
Tang Wei	*See, let's move the horizontal match from 8 to 9's left lower part //*
Lei Hu	*// These are two match sticks!*
Tang Wei	*No, one!*
Lei Hu	*Oh, yes, one!*
Tang Wei	*So then we move the middle horizontal match from 9 to its right lower part, and now we get 0009! [Speaks to someone not in view] The biggest number is 9909!*
Ya Qian	***[Pats Leihu to get his attention back from speaking to someone not in view] Look,*** *[points to the number] Move this stick here, and move that one there, it's 0009. [confirms her understanding of Tangwei's answer, and Tangwei agrees that she is right]*

Tang Wei	*9909, the biggest number is 9909. The smallest is 0009.*
Ya Qian	*Remove the wrong answer.*
Tang Wei	***Let's write down the answer later.***
Ya Qian	***We needed to review it later, so let's keep the answer on our scratch paper first; instead of writing it down on the Q&A sheet right now.***

In the above example, Ya Qian asked Leihu to pay attention by patting his back and saying "look." When Tang Wei suggested writing down the answer later, Ya Qian supported his suggestion, and also further justified it by explaining that the group needed to review the answers before they wrote them down on the Q&A sheet.

Zi Han	*9809. Oh, it should be 9909.*
Guan	***That's the biggest number, what is the smallest number?***
Liu Heng	*[Speaks to Guang, who is about to write down the answer on the sheet] Don't write it down at this moment, if you want to write, you should write on your scratch paper.*
Zi Han	*The answer, no, we should write the answer down on the Q&A sheet. What is the answer? [starts to write down on the sheet]*
Jin Meng	*[Checks on her subgroup] 9909?*
Zi Han	***Now let's think about the smallest number.*** *[speaks to Ji Long] It would be great if the first number is 1.*
Guan	***Wait, wait, you guys work on the first question, and we start on the second question, then we won't do the same work****.*
Liu Heng	*I kept saying about it several times, you just don't listen.*
Zi Han	***Ok, you guys think about what the smallest number is, and you three stop just fooling around!***
Jie, Wei Wei	*[a bit annoyed] When did we fool around?!*
Guan	*We will work on the second problem.*

In this excerpt, four and a half minutes have passed and Zi Han, a girl who was searching for the biggest number, realized that the group might not be able to finish all the problems. She asked some of the group to find the smallest number, and asked three students whom she

must have thought were wasting time to stop fooling around. Zi Han did not seem to intend to be rude, but actually the three students—Jie, Guan and Wei Wei—had been working on the problem. These three children were annoyed by the unfair judgment, and one of them, Guan, responded that they would move to the second problem instead of searching for the smallest number.

Seeking consensus. Achieving consensus enables the group to move forward. Here is another example of effective leadership from a CR group illustrating coordination to achieve consensus:

Tang Shi	*You can only move two matchsticks?*
Qian Qian	*Yes, so move this matchstick here! And then move the other stick there, see, 2086.*
Tang Shi	*Ok, emm, all right, it is 2086 [starts to write on the Q&A sheet].*
Lei Feng	***Wait, please don't rush to write it on our Q&A sheet, we need to review the answers first.***
Qi Qi	***Let's write it on our scratch paper first.***
Tang Shi	*Ok, write 2086 first on the scratch paper.*

In this example, when Lei Feng asked the group to slow down and make sure the answer was correct. He was polite and provided a rationale. His proposal was supported by Qi Qi, who further suggested that they should first write the answer on the scratch paper. Both of the leadership moves had an inclusive tone using "we" and "let's." In contrast, the two examples of ineffective leadership from two control groups highlight a common problem in social relationships. Control group students trying to lead often seemed insensitive and demanding. Control group students who were expected to follow were often resistant, and appeared to be

easily offended even when it seemed no offense was intended.

Our analysis of why some leadership moves were more effective than others consisted of four steps. First, we read through all the instances of effective and ineffective leadership, searching for any distinguishing linguistic features. For example, we noted the frequency of first-person plural nouns (i.e., we, us, our) and second-person nouns (i.e., you, your). We kept running notes about the tone of voice of instances of attempted leadership, if this was apparent from the transcript; for example, “Stop fooling around!” is expressed in a demanding tone. We looked for the presence of politeness markers, or their absence, as in the indirect request, “Shall we move on to the next problem?” or the use of “please.” In step two, we evaluated leadership moves in context and examined in which situations leading moves were proposed. For example, were the leading moves appropriate at the moment? How were the leading moves proposed? Did the child who attempted a leading move continue to follow up if the move was not initially successful? In step three, we summarized the themes discovered in steps one and two for each of the subcategories of leadership, and compared them across the four categories to make a comprehensive list. In step four, we explored the connection between successful leadership in the CPS activity and children’s reflections in the whole class debriefing after each CR discussion.

Upon close examinations of the leadership moves, we identified four common attributes that differentiate between effective and ineffective leadership moves, which are *appropriate timing, inclusive tone, respectful attitude,* and *open-mindedness*.

Appropriate timing. Most of the effective leadership moves were proposed at a time when it was needed and others were ready to hear it. As we saw from the example of Mao

Mao, a solution proposed when the group is not ready is unlikely to be accepted. Children who had CR discussions seemed to have a better sense of when to make leadership moves. Although children might perceive a story discussion differently from the problem solving activity, both activities required the ability to hold on to one's thoughts, listen to others, and take the floor at the right time without interrupting others. Children's comments during CR debriefing sessions suggested progress in following the no interruption norm, which possibly supported the effectiveness of their leading attempts.

Inclusive tone. It was observed that when children used plural forms, particularly "we" instead of "you," when asking others to take action, the attempted leadership moves were more likely to be accepted. This characteristic of effective leadership is illustrated in both examples of allocation of tasks shown above. CR children frequently used forms such as "we should." This emphasis may arise because of Collaborative Reasoning norm that everyone shall be included in the discussion. In the debriefing sessions after CR discussions, children several times mentioned that they had invited everyone to share opinions and participate in the discussions, and happily described this as progress. The perception that successful collaboration involves participation from everyone was likely to be a byproduct of experience with CR discussions.

Respectful attitude. The qualitative analysis suggested that when children were trying to lead in a bossy manner, they often offended other group members and were unlikely to achieve the intended result. In many groups composed of children who had not experienced Collaborative Reasoning, children trying to lead seemed demanding and impolite. When this happened, children asked to follow frequently got upset and sometimes refused to follow.

Children who experienced CR discussions were less often bossy and impolite. One of the CR norms is to respect everyone. The discussions provided opportunities to see peers' reactions when someone behaved without respect. In the early debriefing sessions, some children expressed frustration at being ignored or teased during the discussion, and the researcher reminded the class to treat others as they would prefer to be treated.

Open-mindedness. Being open to challenges and calm in the face of disagreement seemed to be a key factor that determined whether an attempted leadership move would be successful. In one of the examples described previously, Jing Yi was very calm when faced repeated doubts from her group members about her proposed solution to the steamed bun problem. She was not offended by the challenges; instead, she was persistent and continued to explain her idea, stating the idea in slightly different ways. Her ease in dealing with disagreement echoed what we observed from the debriefing sessions. Students complained in early sessions about how readily some group members got frustrated when others disagreed with them. By discussing stories about controversial issues with no agreed-upon right or wrong answer, children had the opportunity to learn to appreciate contrasting opinions, and to understand that disagreement shall be focused on opinions instead of people. In later debriefing sessions, children started to express how proud they felt about being able to allow different perspectives into the discussion.

The four characteristics of effective leadership moves described above not coincidentally share the norms that Collaborative Reasoning discussions are supposed to honor: free talking without hand raising, no overlapping speech, respectful listening, encouraging participation from everyone, considering different perspectives, and being critical but open

minded toward differing opinions. Children who had the opportunity to participate in five CR discussions became more familiar with the expectations and procedures for open format collaboration, which also held true for the CPS activity, despite the differences in content and form. Though children from Control classes were able to initiate effective leadership moves, they did so significantly less often compared to children from CR classes, which we attribute to the fact that opportunities for children to learn how to collaborate are limited in the typical Chinese classroom.

General Discussion

The major findings of this study are that students who participated in Collaborative Reasoning (CR) discussions generated significantly better problem solutions during the subsequent Cooperative Problem Solving (CPS) activity than groups of control students. CR students initiated significantly more effective leadership moves during CPS, and significantly fewer ineffective leadership moves, than control students. A mediation analysis suggested that the increase in effective leadership moves during the CPS activity explains the improved quality of problem solutions by students who experienced Collaborative Reasoning. Findings from the attitude survey indicated that, as compared to control students, CR students had more positive feelings towards the cooperative problem solving experience, especially CR students who previously were less engaged in school.

To our knowledge, this is one of the first studies showing generalization of social skills across different task domains. The task of constructing the largest possible number from an assembly of matchsticks is quite different from a discussion of, for instance, whether zoos are good places for wild animals. Matchstick problems and story discussions have different goal

structures, entail different participant roles, and presumably draw on somewhat different skills, abilities, and interests. That results were positive despite these differences implicates generalization of social skills across domains as the explanation for the findings.

The children were shuffled into new groups before the problem solving activity, so becoming comfortable during discussions in working with particular classmates can be ruled out as the source of positive findings during the problem solving activity. Problem solving groups composed of students who had participated in Collaborative Reasoning and groups composed of control students completed a similar number of problems in a similar amount of time, so the explanation that CR group focused more time and attention on the matchstick problems can be ruled out. The one viable explanation seems to be that social skills involved in leading and following acquired during collaborative discussions were employed in cooperative problem solving. That is to say, children acquired generalized skills in leading and following during collaborative discussions, and therefore were be able to successfully use them in the cooperative problem solving activity.

The finding that children used social skills involved in leadership across task domains can be interpreted in terms of leadership schema theory. According to Li et al. (2007) and Miller et al. (2013), a leadership schema is knowledge about the overall structure of group processes, the range of leadership functions, the reciprocal relationship between leading and following, and an understanding of cues for when and how to lead and follow. The essential idea is that free-form dialogic discussions such as Collaborative Reasoning usually contain recurrent patterns of successful communication that promote harmonious social relationships and help the group reach its substantive goals. Students abstract the common elements in these recurrent patterns

and which thereby alters subsequent thought and action (Sun, Anderson, Lin, & Morris, 2015).

Given the fact that there was no overall difference between CR and control children in attempted leadership moves, but a significant difference in leadership effectiveness, we can argue that children's experience with social dynamics during CR discussions allowed them to observe, learn, and practice leading and following in ways that were both productive and acceptable to other children. This interpretation is supported by the qualitative analysis of the videos and transcripts of problem solving activities. The themes that arose from the qualitative analysis were that effective leadership moves typically shared the characteristics of appropriate timing, inclusive tone, respectful attitude, and open-mindedness, which correspond to the norms participants are supposed to honor during Collaborative Reasoning discussions.

In groups composed of children who had experienced Collaborative Reasoning, emergent leaders usually tried to include others, typically spoke to others in a polite way, and generally seemed to adapt to the changing needs of their groups in response to the demands of problems. In comparison, in groups that had not experienced Collaborative Reasoning, children trying to lead often seemed bossy and impolite, and sometimes seemed inflexible. Children asked to follow in groups that had not experienced Collaborative Reasoning sometimes seemed resistant and occasionally displayed irritation or hurt feelings.

These findings fit well with previous research on why cooperative groups may succeed or fail (Barron, 2003; Chiu & Khoo, 2003). Nonetheless, because we focused on leading, we would not care to claim that we captured the complete picture of how children developed their understanding of both leading and following. What seems like more effective leadership may have been due to more receptive followership. Children who experienced CR may have had

greater responsiveness to the suggestions of others.

In the present study, gender did not show any effect on attempted or successful leadership moves. This is inconsistent with the results of Li and her associates (2007), who found that during Collaborative Reasoning discussions of stories, girls made far more leadership moves than boys. Li et al. studied children in the United States, whereas the present study was conducted in China, but culture is unlikely to have made the difference, because other studies undertaken in China also suggest girls are more likely than boys to exercise leadership during story discussions (Dong et al., 2008, 2009). A possible explanation arises from the long-known fact (e.g., Maccoby & Jacklin, 1974) that girls outperform boys on verbal tasks, in this case story discussions, whereas boys outperform girls on spatial and mathematical tasks, in this case matchstick problems that involved spatial reasoning and number system concepts.

Interestingly, children's talkativeness and social status were positively associated with *both* effective and ineffective leadership moves. The talkativeness finding is not surprising, but it might have been supposed that social status would be associated with some level of effectiveness. Among the measures of social status, information centrality and betweenness centrality, which take into consideration indirect ties to others in the social network, were better predictors than indegree centrality, which counts only direct ties. One limitation of the present study is that no analysis was made of the CR discussions to verify that children were acquiring leadership skills. Some of the CR discussions were videotaped. But, analyzing these discussions would be challenging since a number of children were not fully visible and audio quality was poor. Many discussions were running concurrently, the room was noisy, and the contributions of soft-spoken children were frequently unintelligible. Although difficult to

document because of the poor audio quality, our impression is that this set of discussions is typical of the CR discussions previously observed in China (Dong et al., 2008, 2009) and elsewhere in the world (e. g. Clark et al., 2003). In typical CR discussions, children begin to lead, taking over some of the functions that would be performed by the teacher in the traditional classroom. Another limitation of the study is that, while we interviewed teachers and children completed a survey about classroom practices, and these sources revealed no differences among the classes, we did not systematically observe the four participating classes; therefore, we have limited information with which to rule out differences in teaching style, discourse patterns, or other aspects of classroom environment that could have led to differences in children's behavior during the cooperative problem solving activity.

The current study moved beyond investigating leaders to examining the process of leading. The shift from examining attributes of emerging leaders, to the nature and features of effective leadership, motivated the qualitative analysis of attempted and successful leadership moves. The shift also motivates the question of how we can help children improve their skills in leading, and maybe following as well.

Leadership by children has been given scant attention in the otherwise voluminous literature on cooperative and collaborative groups, probably because of the unquestioned assumption that teachers hold the authority and are the leaders in the class (Miller et al., 2013). But leadership is a concept that has the potential of fitting well with established lines of educational research on collaborative groups. Child leadership provides a possible solution to teachers' concerns about misbehavior and unproductive use of time in lightly supervised small groups. It is widely believed among researchers who study cooperative learning (e.g., Johnson

& Johnson, 2003) that children must be explicitly taught the interpersonal skills needed for successful cooperation, if work in small groups is to be successful, but these skills may emerge naturally during CR discussions, thereby reducing or eliminating the need for explicit instruction.

The most extensive training on social and communication skills in preparation for group work came from the SPRinG project (e.g., Blatchford, Kutnick, Baines, & Galton, 2003), where teachers sequentially taught children trust skills, communication skills and social problem solving skills over a year-long period. Eventually teachers integrated all the skill training into their daily curriculum to promote social relationships among children. Less extensive but still substantial training was provided by Webb and Farivar (1994) in prosocial behavior, communication skills, and helping skills, where not only did the teacher introduce group norms, but the class made charts of social skills and completed group process sheets to check whether they carried out the skills. Similarly, Gillies and Ashman (1996) asked teachers to provide two 45-min collaborative skills training sessions to students, where teachers first taught small-group procedures, encouraged children to identify the behavior that would facilitate participation, and asked children to actually practice what they learned and make charts of the skills that they believed had promoted group collaboration.

The social skills training provided in the present study was less extensive than that provided in most previous studies of group work. Children were introduced to the norms of Collaborative Reasoning in one 45-min session. They managed their own discussions most of the time with a whole-class debriefing at the end of each discussion. Despite limited explicit training, this study showed that children were able to improve the interpersonal and group

management skills through participation in CR discussions.

Many studies have shown positive effects from social skills training (cf. Gillies, 2003, 2007; Johnson & Johnson, 2003, 2007). The ideas of transfer and generalization are implicit in these studies; otherwise there would be no point to social skills training. The present study goes beyond most of these studies, however, in being explicit about and controlling for some of the situational and task parameters that could give rise to generalization of a less interesting kind, attributable, for instance, to getting to know a particular group of classmates well; thus, documenting an apparently robust form of generalization. Furthermore, children acquired social skills from collaborative discussions and employed the skills in a different task without extensive training or adult guidance, again suggesting robust generalization.

To recapitulate, as compared to children who continued normal classroom activities, children who experienced Collaborative Reasoning discussions produced significantly better problem solutions and had more positive feelings toward the problem solving experience. Analysis of problem solving transcripts indicated that, as compared with control students, CR discussion students initiated significantly more effective leadership moves, and significantly fewer ineffective leadership moves, including allocating tasks, proposing and justifying solutions, planning and organizing, and seeking group consensus. The qualitative analysis suggested that effective leadership involved the attributes of appropriate timing, open-mindedness, inclusive tone, and respectful attitude, which can be traced to the norms for Collaborative Reasoning discussions.

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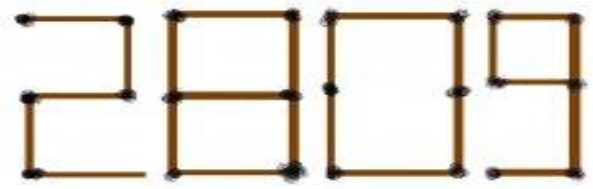
Appendix

Cooperative Problem Solving

1) Look at the number 2809 below, it is made up of 24 matches. Now given a chance to move only 2 of the matches: (a) what is the biggest number you will get? (b) What about the smallest one?



2) (a) First solve this equation $(1-\frac{1}{5})$ x=18, then suppose you are going to explain division with fractions to your peers with this equation. You need to explain it by relating to the real world, for example, making a word problem. What would you say be a good story for the equation above? (b) Now if the equation has been changed to a mathematical expression 18 ÷ $(1-\frac{1}{5})$, will you get the same answer as for question (a)?

3) Monk Tang plans to invite his 3 disciples to have dinner at his temple. He asks the young monk to divide the 19 steamed breads into 3 different serving sizes, and each size should be 1/2, 1/4, 1/5 of the total number of the steamed breads. Besides, none of the single steamed bread should be broken into halves. The young monk is so puzzled because 19 cannot be divided exactly by 2, 4 or 5. Could you please help the young monk solve the problem?

Table 1

Means (SDs) of Age, Gender, Chinese and Mathematics Achievement, Peer Nomination Measures of Social Characteristics, and Prior School Engagement

	Entire Sample		Transcribed Sample	
	CR	Ctrl	CR	Ctrl
Number of participants	131	121	61	58
Age	11.05 (.67)	11.06 (.71)	11.06 (.65)	10.95 (.72)
Percent boys	54.2%	63.6%	56.9%	59%
Chinese	89.82 (5.23)	88.58 (6.61)	90.14 (6.34)	90.16 (4.35)
Math	86.54 (13.05)	84.96 (13.16)	87.05 (11.05)	87.78 (8.70)
Social status				
Indegree centrality	.065 (.05)	.071 (.05)	.068 (.05)	.073 (.05)
Information centrality	.015 (.006)	.017 (.006)	.015 (.006)	.017 (.006)
Betweenness centrality	.015 (.02)	.017 (.02)	.014 (.02)	.02 (.02)
Talkativeness	.024 (.19)	.027 (.16)	.039 (.23)	.048 (.20)
Good Ideas	.036 (.11)	.051 (.13)	.049 (.13)	.059 (.13)
Leadership	.034 (.13)	.041 (.13)	.040 (.15)	.050 (.14)
Prior school engagement	.15 (.96)	.17 (.98)	.15 (.77)	.17 (.87)

Table 2

Zero-order Pearson Correlations of Individual Pretest Measures (N = 252)

	1	2	3	4	5	6	7	8	9
1. Chinese	1	.54**	.22**	.21**	.12	.15*	.10	.06	.10
2. Math		1	.22**	.19**	.19**	.14*	.08	-.02	.15*
3. Good Ideas			1	.69**	.70**	.39**	.24**	.18**	.08
4. Leadership				1	.56**	.35**	.18**	.12	.09
5. Talkativeness					1	.33**	.24**	.15*	.15*
6. Indegree centrality						1	.41**	.63**	-.04
7. Betweenness centrality							1	.44**	-.07
8. Information centrality								1	-.16**
9. Prior engagement in school									1

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 3

Leadership Moves of CR Students and Control Students, Adjusted for CPS Time

	CR Students			Control Students		
	Effective	Ineffective	Total	Effective	Ineffective	Total
Allocating Task	1.11	.15	1.22	.83	.54	1.37
	(1.69)	(.42)	(1.87)	(1.13)	(.98)	(1.89)
Planning & Organizing	1.81	.16	1.96	1.08	.39	1.46
	(2.03)	(.42)	(2.18)	(1.19)	(.68)	(1.69)
Proposing Solutions	1.72	.58	2.3	1.45	1.14	2.59
	(2.14)	(1.04)	(2.63)	(1.45)	(1.27)	(2.32)
Seeking Consensus	.49	.14	.62	.56	.30	.85
	(.91)	(.42)	(.91)	(.79)	(.60)	(1.12)
Total	5.24	1.03	6.26	4.04	2.37	6.41
	(5.22)	(1.33)	(5.91)	(3.16)	(2.15)	(4.93)

Note. Leadership moves were adjusted to take account of the time differences among groups in CPS activity. Each group's CPS discussion time was scaled to 15 minutes. The number shows the mean of individual leadership moves across the 8 groups within each condition.

Table 4

*Poisson Regression Models Predicting **Effective** Leadership Moves*

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Fixed Effects						
Intercept	1.43*** (.07)	-.33 (.53)	-3.92*** (.84)	-2.62** (.82)	-1.02 (1.07)	-1.53 (.95)
Time		.13*** (.04)	.19*** (.04)	.15*** (.04)	-.01 (.07)	.02 (.06)
Math			.03*** (.01)	.02*** (.01)	.02** (.01)	.02** (.01)
Talkativeness				5.42*** (1.12)	4.56*** (1.17)	4.72*** (1.15)
Social status					54.57** (16.23)	45.65** (15.85)
Condition (CR=1)						.31** (.12)
Random Effects						
Variance of intercept	.06 (.03)	.02 (.02)	.03 (.02)	.01 (.02)	.05 (.04)	.02 (.02)
Fit Statistics						
AIC	765.37	758.96	723.82	703.84	691.50	687.93
-2Log Likelihood	761.37	752.96	715.82	693.84	679.50	673.93

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 5

*Poisson Regression Models Predicting **Ineffective** Leadership Moves*

	Null Model	*Model 2*	*Model 3*	*Model 3*	*Model 4*	*Model 5*
Fixed Effects						
Intercept	.32 (.16)	-1.58 (1.43)	-4.30* (1.72)	-2.46 (1.85)	-.86 (1.46)	-.19 (1.07)
Time		.14 (.10)	.18 (.10)	.13 (.11)	.07 (.11)	.05 (.08)
Math			.02* (.01)	.01 (.01)		
Talkativeness				8.54*** (2.10)	7.58*** (2.08)	7.38*** (2.03)
Social status					7.72* (3.39)	7.34* (3.16)
Condition (CR=1)						-.85*** (.21)
Random Effects						
Variance of intercept	.27 (.14)	.24 (.12)	.21 (.11)	.26 (.13)	.24 (.12)	.06 (.06)
Fit Statistics						
AIC	419.16	419.47	414.07	400.26	396.42	386.63
-2Log Likelihood	415.16	413.47	406.07	390.26	386.42	374.62

Note. *$p < .05$. **$p < .01$. ***$p < .001$.