The Impact of CSCL Beyond the Online Environment

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Abstract: Accountable Talk is a form of classroom interaction that positions students as thinkers in interaction and encourages students to make their thinking visible for collaborative reasoning. This paper reports on a two-year teacher professional development program in which teachers were coached to use Accountable Talk practices in their classrooms. Online collaborative learning activities were used to prepare students for these whole-class, teacher lead discussions using the same paradigm. Findings from a series of studies embedded within the two year professional development program provides evidence that novel conversational agent designs, based on the Accountable Talk approach to discussion facilitation, improve learning during the online exercises and better prepare students to benefit from whole class discussions. In this paper we evaluate the effect on teacher uptake of Accountable Talk practices when their students have participated in these online small group activities.

Introduction

The history of CSCL has seen major advances in the theory of what makes collaborative learning beneficial, and the positive impact of technology for producing participation in those environments. New technologies enable monitoring of collaborative processes in real time and adapting support to the changing needs of groups of learners. With this emerging technology, CSCL technology now has the potential, as never before, to effect positive impact beyond the online context, and beyond the lessons in which it is used. In this paper we take one step in that direction by evaluating the use of CSCL as embedded within the context of an intervention targeted towards supporting teachers' development of what we refer to as Accountable Talk. We explore how using CSCL activities with students may facilitate the teacher's ability to take up productive discussion facilitation practices in whole group, face to face, teacher led discussions that follow the online experiences.

In this paper we first review the evidence on the use of Accountable Talk as an instructional tool to support student learning. Second, we illustrate the use of intelligent conversational agents designed based on this concept as dynamic support for collaborative learning in a CSCL environment. We review results from studies that demonstrate positive impact on student learning from participation in collaborative activities facilitated by intelligent conversational agents. Next, we introduce a two-year teacher professional development design study in an urban school district, in which CSCL activities supported by these Accountable Talk agents were integrated into the program. Finally, we evaluate the effect of inclusion of these CSCL activities on teacher uptake of the target discourse practices. We conclude with discussion and continued work.

Accountable Talk in the Classroom

Consistent with the literature on facilitation of collaborative learning groups (e.g., Hmelo-Silver & Barrows, 2006), a large body of work has shown that certain forms of classroom interaction, what we refer to here as Accountable Talk, are beneficial for student learning (Resnick, Asterhan & Clarke, in press). This literature shows that Accountable Talk is characterized by high demand tasks in which teachers help to scaffold student thinking and reasoning about subject-matter through talk. Well-structured teacher-lead discussions elicit student ideas through discourse moves that help to make student thinking visible and an object for whole class thinking and reasoning (e.g. Table 2). These discourse practices have been shown to increase student learning and reasoning, long-term retention and transfer across subject matter (Adey & Shayer, 1993; Bill, Leer, Reams & Resnick, 1992; Chapin & O'Connor, 2004, Resnick, Salmon, Zeitz, Wathen & Holowchak, 1993; Topping & Trickey, 2007a, 2007b; Wegerif, Mercer & Dawes, 1999).

Greeno argues that discourse structure positions individuals intellectually within the dialogue (Greeno, in press). Thus we make a distinction between structures where teacher questioning positions individuals as passive versus cognitively engaged with the subject matter, e.g. Table 1. One limitation of prior work has been that while there is strong evidence for the benefits of discursive teaching practices, the research has primarily been limited to special populations, including expert teachers. Other forms of dialogue have tended to dominate mainstream schooling, especially urban schools, which are the concern of this paper. In particular, discursive styles often position students to passively engage with the subject matter. For example, Table 1 helps to make the distinction between teacher moves and the intellectual work these moves elicit. The style of teaching in those contexts is mainly monologic Initiation-Response-Evaluation (IRE).

Table 1. Comparison of discourse structure and intellectual positioning

Inititation-Response-Evaluation (Mehan, 1979)	**Accountable Talk**
Jonathan, what is the answer to number 7… Correct	*Jonathan, how might we arrive at an answer to number 7… so you mean… Elizabeth do you agree with Jonathan's reasoning?*

With rising student-to-teacher ratios in urban classrooms, the classroom discourse community has begun to question how discussions in classrooms can be academically productive, particularly if we wish to use such situations to develop reasoning skills. Efforts to support uptake of productive discussion facilitation practices in these environments has become a growing concern. The challenge for our research has been: *how do we make Accountable Talk* a widespread instructional practice across populations and contexts, in particular, non-expert teachers in urban schools.

We have been conducting a longitudinal design study of Accountable Talk, which we report on here, in an urban school district that has failed to meet national standards for achievement on standardized tests for 5+ years, and whose students were 63% below proficient in Reading and 56% below proficient in Math, a large percentage of which are African American students. The intervention has been targeted towards developing teachers' use of Accountable Talk discourse moves (Table 2) in the context of high school biology lessons to support student reasoning about biology. Table 2 illustrates the set of discussion facilitation moves that are the target of the professional development training, which are based on prior research (Resnick, Michaels & O'Connor, 2010). This same list of facilitation moves is used in the transcript analysis discussed later.

Table 2. Target Accountable Talk Teacher Moves

Speaker	**Utterance**	**Accountable Talk Moves**
TEACHER	Explain your thinking**.**	SAY MORE
TEACHER	They were all adopted?	REVOICE
TEACHER	What do you think Desmond? Can you repeat what she said?	RESTATE
TEACHER	What's it prove? Put it into words.	PRESS FOR REASONING
TEACHER	If capital 'G''s dominant, wouldn't all babies be orange?	CHALLENGE
TEACHER	Kelly, are they right?	AGREE/DISAGREE
TEACHER	Help him out Stephen.	ADD MORE
TEACHER	So then put it in your own words. Explain why she's right or wrong.	EXPLAIN OTHER

Intelligent Agent Support for Accountable Talk

A key contribution of this paper is a demonstration of the impact of CSCL activities on teacher uptake of Accountable Talk practices. The CSCL activities used in this study included dynamic support provided by intelligent conversational agent computer programs. Conversational agents have a long history of successful support for individual learning with technology (Rosé et al., 2001). A series of results offer hope that they can be used productively to offer support for collaborative learning, especially in chat environments (Kumar & Rosé, 2011). The agents used in this prior work interacted with students through multi-step directed lines of reasoning focused on specific conceptual content rather than focusing on the style of interaction between the students. In our work, we have been developing conversational agents with a different style. In particular, our goal has been to pattern the behavior of the agents after Accountable Talk facilitation moves. In our work to date we have focused on two Accountable Talk facilitation moves in particular, namely Revoicing and Agree-Disagree. These moves in particular have two important functions. First, they mark a students' contribution, a social move that suggests that their contribution matters. Second, they prompt the contributor and other students to operate on the idea, an intellectual positioning move. These kinds of agent discourse moves might be followed by a series of student moves and reasoning behaviors such as reflecting on the idea, modifying, elaborating, or retracting it.

For both types of facilitation moves, the agent behavior in the discussions in the CSCL environment was implemented by programming the agent to compare student input against a list of correct statements drawn from the data collected during pilot runs of the system. If an entry in this list could be interpreted as a paraphrase of the student's input based on analysis of word overlap, it was offered by the agent as a "revoice" to the students, or alternatively, a prompt was offered for the other group members to discuss whether they agree or disagree with the statement. Some examples are given in Table 3. The same statement was never offered more than once in the same session as a revoicing. When student statements were not close enough to match the revoicing list but contained the first mention of important lesson concepts (like "indicator" or "molecule size"), the agent would nudge the student or a peer to expand or restate their contribution.

Table 3: Examples of Revoicing Agent Behavior

Student Contribution	Revoicing Agent Response
basically the glucose will get inside	Maybe you could state that as "the cell membrane is permeable to glucose."
it changed because the tube absorbed the iodine,	So are you saying "the molecules diffused through the membrane?"
I predict that if the holes in the plastic are large enough, the glucose will go into the water solution..	Maybe you could state that as "both water and glucose molecules are able to move between the two environments."

Method

The primary goal of the study reported in this paper was to facilitate discursive change in the classroom in order to support student learning. This longitudinal study was conducted as a two year design study in 9th grade biology classrooms in an urban school district. The objectives of the study were to (a) develop teachers' capacity to facilitate Accountable Talk discussions in biology; (b) increase the amount of Accountable Talk in whole class discussions over time; and (c) increase student learning through participation in the Accountable Talk discussions.

Sample

As previously mentioned, much of the existing literature on discursive instruction has been limited to special populations, including expert teachers. Our intention was to make Accountable Talk widespread instructional practice. In particular, we sought to target populations of teachers that were not yet experts in Accountable Talk, and likewise, student populations that have not otherwise experienced rich discursive instruction. An urban school district in Pennsylvania agreed to participate in the study with a focus on high school biology. In Year 1 we trained 17 district biology teachers, from 8 high schools. The teachers had varying levels of experience, ranging from 1-15+ years experience. Of the 17 teachers, 7 consented to participate in the study, which reduced to 4 teachers in 2 schools after attrition. 108 9th grade biology students, from 12 classes (5 remedial) consented to participate in this first year of the study. In Year 2, we worked intensively with 3 consenting teachers (2 after attrition), in the same school, with 113 consenting 9th grade biology students from 12 classes (8 of which were remedial level), which represented 63% of 9th grade biology students. In this paper we report on analyses of one teacher's classes over the two-year period, who participated in the intervention both years, which enabled us to examine his growth in Accountable Talk facilitation across his classes over the 2-year period. 59 class sessions altogether were recorded and transcribed from this teacher.

Classes were audio recorded and live transcribed, focusing on recording utterances and attributing them to individual speakers. Audio recordings were used to fill in transcripts from live transcription. In the second year of the study, we developed software that enabled us to live transcribe and attribute turns with a timestamp, which helped to greatly reduce the transcription time of dynamic multiparty classroom talk.

Teacher-Level Intervention

The teacher-level intervention focused on developing teachers' use of Accountable Talk in whole class discussions. There were 3 core strands to the professional development intervention: (1) identifying leverage points in curriculum; (2) planning discussion lessons; (3) Accountable Talk simulations. In Year 1, the professional development was conducted in 6 half-day pull out sessions over the course of the academic year. Each session consisted of a series of tasks engaging these core strands. With respect to Strand 1, the coach worked with teachers to identify leverage points for Accountable Talk within the district-mandated curriculum. For Strand 2, the coach lead teachers in collaborative planning of discussions lessons, focusing on identifying overarching questions that could open up space for deep reasoning about the subject-matter. For Strand 3, the coach led Accountable Talk discussions, in which the teachers took on the role of students in the discussion. In the first iteration of the intervention, teachers voiced difficulties in translating their experience in simulated discussions with their teacher peers, to discussions that would be appropriate for their learners and their conceptual level. For example, Excerpt 1 includes comments from teachers during these post simulation reflective discussions: "…but my kids can't do this!", "…I won't be able to do this in my school!", "…We [teachers] know more, that's why WE can do AT [Accountable Talk]".

What we saw in the dialogue, as we tracked participating teachers' Accountable Talk discussions after the intervention, was a slow change in their discursive style (see Table 4).

Table 4: Excerpt of Year 1 discussion for the target teacher

Turn	Speaker	Utterance
1	Teacher	so if you had to make a prediction how would you-- what would you predict would happen in this situation just looking at it now?
2	Student 1	that uh--
3	Teacher	I'm asking Student 4
4	Student 4	um the sugar is going to get in the water
5	Teacher	ok so Student 4 thinks that some of the sugar is going to come out to the water. Ok. Alright what about the water? Is the water going to stay there?
6	Student 3	no it's going to go inside
7	Teacher	so we think the water is going to move inside ok. Alright. Why?
8	Student 1	Uh
9	Student 5	Because
10	Student 4	high concentration
11	Teacher	Right
12	Student 2	Permeability
13	Teacher	ok both, there's a concentration gradient that's what we call that right. So if you have a high concentration on this side and a low one on this side in between this is called a gradient. So things always move from high to low right.

What we can see in Table 4 is that the teacher is trying to elicit student reasoning in turn 1 by asking students to make a prediction, and in turn 7 which elicits justification for prediction, however in turn 13 he seems to be lecturing and returning to a focus on getting the answer right.

In the second iteration in Year 2, we focused on translation of professional learning to instructional practice. We refined the intervention so as to better support teachers in translating instructional learning into instructional practice. We adopted a coaching model (West & Staub, 2003), which included a tripartite pre-, during- and post-phase of professional development.

Table 5: Excerpt of Year 2 discussion for Teacher Nelson

Turn	Speaker	Utterance
1	Student 1	The strip will turn green and the pouch will weigh more because the glucose will enter the pouch
2	Teacher	Ok. You know what is important about what he said? He added "because" and then he put some reasoning there. That's what we want everybody to do. Ok, would you read that once more, louder, so everybody can hear it?
3	Student 1	The strip will turn green and the pouch will weigh more because the glucose will enter the pouch
4	Teacher	Ok. So he predicted that the glucose is going to enter the pouch and the strip will turn green, so he had a because. He told why. That's good. Student 2. Thanks.
5	Student 2	I said it continued at a steady rate in the glucose and the prediction is the glucose will always increase. And at the bottom, I said, "We think it will-" wait- "We think there will be glucose in the inside of the membrane eventually."
6	Teacher	We think that there will be glucose inside the membrane eventually.
7	Student 2	Yeah. The think on the scale

In the pre-instruction conference, coaches worked individually with teachers in their classrooms to plan lessons, again focusing on identifying leverage points for Accountable Talk within the curriculum and eliciting teachers to predict *their students'* ideas. In the midst of the during-instruction phase, the professional development coach observed lessons in person or via skype, attending to how teachers were using Accountable Talk to draw out student ideas and support reasoning. The post-instruction conferences elicited teachers' reflections on the observed lesson, again focusing on their facilitation of discussions using Accountable Talk to promote student reasoning. The teachers went through 7 iterations of the pre-, during- and post-conferences over the course of the academic year. The refinement of the intervention aimed to develop teachers' capacity to lead Accountable Talk discussions, in their classes, with their students. Teacher facilitation in Year 2 discussions (Table 5) can be characterized by greater attention to reasoning through dialogue, drawing out student ideas for joint reasoning, rather than searching for correct answers, characteristic of I-R-E.

Student-Level Interventions

In addition to the teacher-level intervention, we developed a series of student-level interventions designed to prepare students to engage better in the whole group teacher led discussions. Some of these activities were online CSCL activities focused on collaborative inquiry, while others were face-to-face activities focused on developing reading comprehension skills. We expected these activities to increase student responsiveness to attempts by the teacher to engage them in active discussion and therefore serve a reinforcing effect of the teacher-level intervention. Each of the CSCL interventions were themselves experimental studies in which students were randomly assigned to groups within their classes, and groups were randomly assigned to conditions. Results of these experimental studies are published elsewhere. In this paper, because we are evaluating the effect on teacher behavior, and because students within classes were assigned to different conditions within these studies, we are not evaluating the effect of those experimental manipulations, rather we are evaluating the gestalt effect of the class having participated in the study on the teacher's behavior. Regardless of condition, all students benefitted from the carefully designed enhancement activities. What varied was only the amount and style of support offered during the activities.

CSCL Activities

At one time point in Year 1 and at two time points in Year 2, the students participated in online small group activities facilitated by intelligent conversational agents, immediately prior to a teacher-led whole class discussion on the same topic. The Year 1 study and the first Year 2 study were both run during a unit on Diffusion. The second Year 2 study was run during a unit on Punnett Squares. A conversational agent-as-facilitator must be able to manage several differently-scoped supports and behaviors concurrently. Recent work has produced software architectures for conversational agents (Kumar et al., 2011) that can implement such orchestration within CSCL environments. In our implementation, the conversational agent acts as an instructor and facilitator, and presents a series of group exercises in a chat room with a shared whiteboard (Mühlpfordt & Wessner, 2005). In all three studies, students worked in groups of three to make predictions, discuss observations, and generate interpretations of their observations. In all cases, student groups were supported by intelligent facilitator agents that provided a macrolevel structuring of the task and some level of micro-level support such as encouragement to participate and positive reinforcement for contributions to the discussion as has been demonstrated to have a positive effect on group processes and learning in earlier studies with intelligent conversational agents as group discussion facilitators (Kumar et al., 2010). In all cases, students were instructed about Accountable Talk and were encouraged to use these practices in their discussions. What differed by condition was the nature of support targeting these behaviors specifically that were offered to students. The two target facilitation behaviors we have experimented with separately and in combination in our studies have been the Agree-Disagree move and the Revoicing move. In the first study, groups either received no additional support, support of an agent that directed them to provide facilitation behaviors to each other, or support of an agent that engaged directly in the facilitation behaviors. In the final two studies, we dropped the agent that directed the students to engage in the facilitation behaviors. Across the three studies, we found positive effects of the agent that engaged in Accountable Talk facilitation behaviors.

Support for Reading Comprehension

The second student-level intervention focused on developing students' readiness for a teacher-lead whole class Accountable Talk discussion through face to face collaborative learning. We conducted a collaborative reading experiment designed to scaffold students' reading and understanding of biology texts (O'Donnell & Dansereau, 1992) prior to an Accountable Talk discussion of the same topic. In Year 1 students in 5 classes were randomly assigned to either a collaborative learning condition or individual learning condition. Students in the collaborative learning condition were randomly assigned to groups to read the same text using a scripted collaboration protocol designed to structure peer learning and metacognitive learning strategies. Students in the individual learning conditions using the same scripted protocol for the text, but worked individually. In Year 2, 7 classes were randomly assigned to either the collaborative learning condition or the individual learning condition. Three classes were assigned to the collaborative learning condition and four classes were assigned to the individual learning condition. We revised the collaborative learning protocol so as to create authentic knowledge gaps in which collaboration was necessary to complete the task. In the collaborative learning condition, students were randomly assigned into groups of three for jigsaw reading of 1 of 3 texts (Aronson, 1978). The jigsaw activity included four phases, (1) reading and synthesizing text individually; (2) discussing and refining syntheses in same-text groups; (3) disseminating syntheses in groups with students that have read other texts; (4) discussing substantive themes across readings. The individual learning condition followed the same procedure for reading the three texts, thus received the same reading support, but did so individually in writing, allowing for a comparison between individual learning and collaborative learning to support readiness for Accountable Talk discussion participation.

Coding

Years 1 and 2 generated a corpus of 168 transcripts of Accountable Talk discussions, 59 of which we analyze in this paper as discussed above. Two raters hand-coded two full transcripts with the codes from Table 2, with an agreement of .8 Kappa. This amounted to approximately 500 teacher turns. In order to analyze change over time in teacher behavior, we needed the full set of transcripts used in our analysis to be coded. Thus, we made use of a machine learning tool called LightSIDE (Mayfield & Rosé, in press). Using LightSIDE, we first ran experiments over the two hand coded transcripts to verify that reliability of coding with automatically trained models would be at an acceptable level. We evaluated a model in LightSIDE utilizing the SMO classifier and a 10-fold cross validation evaluation methodology. Using this methodology, we divide the coded data into 10 equal segments, and on each of 10 iterations, we train a model on 9 of those segments and test on the tenth. We then average performance values across the 10 segments. We did this separately for each type of Accountable Talk move as a separate binary classification tasks as well as for the whole set taken together as a multi-way classification task. For the multi-way classification, performance was low, i.e., only .52 Kappa (Human agreement just on Agree-Disagree was kappa of .86). Performance also varied across the individual binary classification experiments. The performance for the Agree-Disagree move was the highest, with a kappa value of .56. Using a classifier trained over all of the hand coded data, we then automatically coded all of the other sessions on the Agree-Disagree dimension since it had the highest kappa. Then, we reassigned the codes over the whole corpus using cross-validation so that the codes on all segments would be automatically assigned, and therefore more consistent, so that we could avoid seeing a big difference in performance on the two sessions that were picked to hand code just because they were coded by hand rather than by computer. This is a standard practice in machine learning. Ideally, we would prefer to measure growth in uptake of all Accountable Talk moves over time. However, to the extent that teachers appropriate the facilitation moves as a set, as they are coached on all of them, we expect a high correlation between acquisition patterns. In this paper, we treat number of Agree-Disagree moves as a probe that is indicative of the teacher's uptake of Accountable Talk practices. And we leave for future work a more exhaustive analysis across the different facilitation moves, looking for different appropriation patterns over time.

Analysis of Change Over Time

In order to measure behavior trends and differences between years or between classes within years in these trajectories, we used standard growth modeling techniques. To compute these growth models, we used the Generalized Linear Latent and Mixed Models (GLLAMM) (Rabe-Hesketh, Skrondal, & Pickels, 2004) add-on to STATA (Rabe-Hesketh & Skrondal, 2012). Our growth models were three level models where time points were level one units, classes were level two units, and years were level three units. Thus, the structure of the model was time points nested within classes, which were in turn nested within years. Time was measured as days since the beginning of the school year.

Specifically we used what is referred to as a random intercept and slope model, which allows estimating a separate latent trajectory for the teacher's behavior in each class over time, where each trajectory is characterized by a regression with latent slope and intercept, relative to a slope and intercept per year. The slope and intercept per year is fit to a distribution around a slope and intercept for the whole model. The resulting set of slopes and intercepts from the classes within a year form a pair of distributions that can then be compared with the corresponding distributions for the other years in order to determine whether the teacher's behavior trajectory differs significantly based on intercept, slope, or both between years. A comparison can also be made between classes within years. A significant difference in intercept indicates that the teacher's trajectory differs from baseline with respect to the dependent measure at the initial time point. A significant difference in slope indicates that the teacher's growth in the dependent measure over time differs from baseline. Time points that correspond to months when there were no recorded lectures from a class were dropped from the analysis. Since a separate intercept and slope is estimated for each class, these time points can be dropped without biasing the model to the extent that would be the case if a single slope and intercept were estimated directly from the full unstructured collection of data points. Additional covariates can be added to the growth model to account for other factors that may have affected the level of the dependent variable.

Results

In order to evaluate teacher behavior over time, we used as a probe the automatically tallied number of Agree/Disagree facilitation moves used by teachers per class session. Number per class was used in our growth models as the dependent variable. Time point was the independent variable in the basic three level growth model, with time point nested within class period, which was in turn nested within years. In this basic model, we found a significant effect of time point ($F(1,57) = 4.27$, $R^2 = .07$, $p < .05$), but no difference between years or class periods either in terms of intercept or slope. The basic trajectory within each year is indicated as a regression line per year in Figure 1. Each dot, circle, or x in the scatter plots per year in Figure 1 represents one class period.

In a second analysis, we divided time points into 3 types. The first notable type were class periods that immediately followed a class period where the students participated in a CSCL activity. These are marked as Collaboration in Figure 1. The second notable type were class periods that immediately followed a class period where the reading comprehension enhancement activities occurred. These are marked as Other Group Prep in Figure 1. All other class periods are marked as Baseline. This 3-way factor was added to the model as a fixed effect within level 3 units. When we evaluated this more complex model, this factor was found to be significant, and it accounted for more variance in the dependent variable ($R^2 = .36$, $p < .001$). In a posthoc analysis, we determined that only the time points in the Collaboration group were significantly higher than baseline, and the effect size was 1.7 standard deviations.

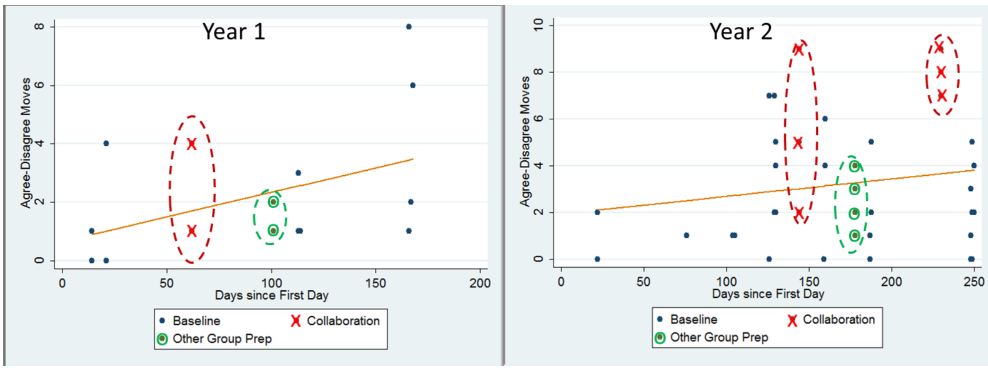

Figure 1 Results from two years of automatically coded class discussions

Thus, the finding is that having the students participate in a CSCL activity in the session immediately before a teacher-lead whole group discussion has a strong enabling effect on the instructor's facilitation behavior. We interpret the growth in the amount of teacher facilitated Agree-Disagree moves immediately following the CSCL activity that elicited these same behaviors helped to ready students for subsequent discussion We do not find the same effect of the reading support activities, which were focused mainly on comprehension and not on inquiry skills, and were also not facilitated in the style of Accountable Talk.

Discussion

The results of our analysis complement the positive results reported in other publications about CSCL activities facilitated by intelligent conversational agents. As far as the authors are aware, this is the first evaluation of the impact of CSCL activities on discussion behavior in a larger group context outside of the online environment.

As we have reported, some of the challenges of the teacher-level intervention was their belief that this kind of instruction could be used with their students in their urban school district. As we interpret the finding of the CSCL activity in relation to shifting the discursive culture of 9^{th} grade biology, one possible explanation for the results is that the teacher, knowing that the students had participated in preparatory activities, expected the students to be better prepared, and behaved differently because of that. While we cannot completely rule out that possibility, it is difficult to reconcile that interpretation with the fact that the reading enhancement activities did not lead to the same effect. In both cases the teacher knew the students were participating in enhancement activities meant to prepare them for the whole group discussion.

Conclusions and Current Directions

In this paper we have analyzed the results from a two-year teacher professional development program in an urban school district from the perspective of evaluating the impact of CSCL activities on teacher uptake of Accountable Talk facilitation moves in sessions immediately following the sessions in which the students participated in the CSCL activities. We find a strong reinforcing effect of these activities.

One limitation of the present analysis is that we do not analyze in detail the connection between student behavior within the small groups and their behavior in the large group discussions. Furthermore we do not analyze in detail the behavior of the students and how specific student behaviors that differed in the sessions immediately following the CSCL activities were responsible for the change in teacher behavior. One of the contributions of this paper is that it raises these important questions, which we leave for future work.

Another limitation of the study is that although it was conducted over 2 full school years, and although the effect size of the impact was very large, the total number of data points in the analysis is relatively small. Furthermore, the analysis only involves data from a single teacher. Thus while we have employed quantitative techniques in our analysis, we must consider the results we have obtained merely a case study. Nevertheless, the results show promise of an important role that CSCL can play in teacher professional development.

One of the big questions left for future work is why the impact on Accountable Talk uptake was local, and not sustained. One possible explanation is that what was driving the change in teacher behavior we observed was that students had thought deeply and critically about the ideas prior to that whole class discussion. If that readiness to engage at that level was not exhibited by the students at other time points because the preparation was not happening at those time points, the teachers may not have felt empowered to engage with the students at the same level. A possible solution is to make CSCL activities a more regular part of student involvement in the course.

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