Managing Disagreement in Intellectual Conversations: Coordinating Interpersonal and Conceptual Concerns in the Collaborative Construction of Mathematical Explanations

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Abstract

This paper reports research into how mathematical explanations are constructed during conversation based on videotapes of pairs of student math teachers collaboratively writing explanations in geometry. In particular, we analyzed how disagreements about parts of their explanations were managed in these conversations. In contrast to research on disagreement in everyday conversation, explanation disagreements were more likely to overlap with preceding turns and to be stated baldly without prefaces, token agreements or qualifications. However, the observed frequencies of different kinds of disagreements were not consistent with a model favoring explicit substantive disgreement either. Instead, it is proposed that both the interpersonal concerns that would motivate a preference for agreement *and* the conceptual concerns for a quality explanation that would motivate a preference for substantive disagreement are being managed by participants. Disagreements are co-constructed, and conversants are seen to jointly employ complex devices for introducing and managing disagreement across turns that can satisfy both kinds of concerns with much less conflict between them than might have been expected.

Introduction

The research reported here is part of an ongoing project to understand the processes through which conceptual change occurs during conversation (Greeno, in press; Greeno, et al., 1993). Our work is in the spirit of recent microgenetic studies that document the moment-by-moment processes through which conversation-based learning occurs (Fox, 1993; Roschelle, 1992; Schoenfeld, Smith & Arcavi, 1993). In particular, we are analyzing how conceptual explanations are revised in conversation. Since the explanations people give for phenomena are a key source of evidence for their understanding of a domain, it is reasonable to assume that explanation revision will be a key process in conceptual change (Brown, et al., 1993; Schoenfeld et al., 1993). To study how explanations are revised in conversation, we have collected a corpus of conversations in which pairs of student math teachers collaboratively constructed explanations for two related construction problems in geometry. This paper will focus on how participants dealt with disagreements about the substance of their explanations. Disagreeing was chosen partly because it can lead to explanation revision and partly because it is the kind of cognitive conflict often hypothesized to be responsible for conceptual change in peer interaction (Tudge & Rogoff, 1989).

Theoretical Framework

Our assumption, along with Clark and colleagues (Clark & Brennan, 1991; Clark & Schaefer, 1989), is that conversation is organized around a collaborative process of grounding. Through it, speaker and addressees work together to make sure each contribution to common ground has been understood well enough *given current purposes*. An important implication of this last proviso for understanding agreement and disagreement about mathematical explanations is that the exact form grounding will take is significantly dependent on what goals, purposes, concerns, tasks, etc. that participants are trying to fulfill in their conversation (Clark & Brennan, 1991).

In the case of co-constructing written explanations in conversation, at least two kinds of purposes are likely to be important—interpersonal concerns regarding the maintenance of a good relationship with one's partner and conceptual concerns gravitating around the desire (in this case partially induced by experimenter demand) to produce a high quality explanation that both participants agree to. The first array of concerns have been considered universal to all conversation, viewed almost as a precondition for interaction to take place at all (Goffman, 1967). As disagreeing with someone can be thought of as a particularly strong threat to their face, conversants generally display a preference for agreement over disagreement (Brown & Levinson, 1987; Pomerantz, 1984). Empirical studies of everyday conversation (i.e. conversation for conversation's sake) indicate that agreement is generally preferred over disagreement in that disagreements, if expressed at all, are often expressed weakly as qualifications of agreements while being frequently delayed by pauses, repair initiators or prefaces (Davidson, 1984; Pomerantz, 1984). Fox (1993) also found a strong preference for agreement in tutorial dialogues.

For purposes of developing high quality collaborative explanations, however, this preference for agreement in conversation conflicts with another functional constraint. If part of what is powerful about effective collaboration is mutual criticism to identify difficulties and root out mistakes, it would seem helpful for collaborators to be explicit about their disagreements so they could be resolved

openly and carefully. Also, withholding disagreement is not consistent with creating explanations that both participants are willing to agree to as was shown in research by Burnett (1991), who found a strong correlation between the quality of co-written argumentative essays and the percentage of time co-authors spent engaged in substantive conflict involving explicit disagreements and extended discussion of alternatives. The goal of producing high quality explanations, then, would favor participants' adopting a preference for airing disagreements about the substantive aspects of their explanations.

How can these seemingly conflicting preferences with respect to disagreement be resolved? The mathematical explanation corpus was collected partly to begin answering this question.

Method

Subjects

Six Stanford Teacher Education Program (STEP) mathematics teachers volunteered in pairs to participate in the study. Participants were asked to only sign up with fellow students with whom they felt comfortable doing math. (Group exercises are common in this teacher preparation program.) All were friends, some since college. There was one female-female pair "Janet and Patricia", one male-female pair "Woody and Alison" and one male-male pair "Patrick and Jerome", all white and middle-class. Participants were paid a nominal fee ($20 each) for their two hours of participation in the study.

Materials and Procedure

Each pair was given two related construction problems in geometry that they needed to solve and write an explanation for. This paper reports results from the first problem:

> "Which measurements (lengths of sides, measures of angles) must be fixed to recreate a triangle of a particular shape and area? Why? Create a sound mathematical explanation to justify your answer. Make the written explanation you and your partner create one which other student math teachers like yourself could understand."

This problem was purposely created to raise conceptual issues both by the instruction to write a "sound mathematical explanation" and by phrasing the question as a construction problem using the terms "shape" and "area" whose relationship to related terms like "congruence" and "similarity" would need to be somehow specified to use the geometrical knowledge based on them. Participants were also told to develop the highest quality explanation they could in the time they would have available for each problem (35-40 minutes) and that as teachers who explain mathematics to students they would be particularly well-suited to do a good job. Participants were videotaped as they worked on their explanations, with one camera focused on the pair from across the table and another focused from above on what they were writing.

After finishing the triangle-construction problem, subjects wrote explanations for a generalization problem that extended the results to polygons of arbitrary size. Each subject then filled out a math and teaching background questionnaire, and participated individually in an interview about their perceptions of the goals and quality of both their explanations and their interaction with their partner. When asked, all participants reported that neither they nor their partners had any difficulty getting their ideas heard in the conversation.

Transcription Conventions

Videotapes were transcribed in accord with standard conventions in conversation analysis (e.g. Fox, 1993; chapter 2). In addition to talk, transcriptions included everything participants wrote or drew as well as all identifiable gestures towards their text or diagrams. Overlapping speech was carefully noted. Pauses of three seconds or greater were measured to the nearest tenth of a second with shorter pauses represented by a comma. Facial expressions, laughter and other kinds of gestures were also included.

Results

High Quality of Explanations

In all three cases, the quality of the resulting explanations was high given time constraints. Through discussion, all three pairs correctly determined that recreating a triangle of the same shape and area is equivalent to constructing congruent—rather than similar—triangles. They all listed several correct sets of measurements for doing this.[1] Perhaps most importantly, the explanations that pairs proferred for both their general conclusions and specific answers were characterized by sound mathematical practices including systematic consideration and treatment of alternatives, use of counter-examples, and proof by contradiction and deductive logic.

Analysis of the Frequency of Different Kinds of Disagreement Utterances

Each transcript was coded for every instance of a potential disagreement about the substance of the explanation. Disagreements about procedural matters, like who should write or on which paper, were not considered but disagreements about how to interpret the question, which measurement sets are sufficient, what evidence should be cited in their explanation, how rigorous a proof would be necessary, and similar matters were included in the analysis. Excerpts of the transcript surrounding these disagreements were then used for more detailed analyses.

Onsets of disagreement presentations. One prediction of the preference for agreement is that disagreements are delayed compared to agreements. Agreements often begin during the end of or immediately after the previous turn while disagreements hardly ever overlap, instead being delayed by pauses, prefaces and other devices (Pomerantz,

[1] Some lists were more complete than others depending on how pairs chose to spend their time.

Table 1: Percentage of Potential Disagreements Expressed Using Each Disagreement Strategy

PAIRS	Long Pauses (≥ 3 sec)	Repair Initiators	Prefaced Disagree-ments	Agree then Disagree Structures	Bald Disagree-ments	Total Disagree-ments
Patricia & Janet	0.0%	6.7%	13.3%	20.0%	60.0%	30
Woody & Alison	3.8%	11.5%	42.4%	11.5%	30.1%	26
Jerome & Patrick	0.0%	7.1%	17.9%	25.0%	50.0%	28
MEAN	1.3%	8.4%	24.5%	18.8%	46.9%	28

1984). In our data, however, an average of 25.8% of explanation disagreements overlapped the previous turn with one pair, Janet and Patricia, overlapping 40.0% of their disagreements. The least amount of overlap occurred with Patrick and Jerome who did so 14.3% of the time. Though the results are preliminary[2], they do suggest that the preference for agreement is not so strong that conversants avoid interrupting with their disagreements when other concerns are important also.

Conversational devices for expressing disagreements. The second analysis concerned how each disagreement was expressed. In the conversation analysis literature, it has been observed that in addition to pauses, disagreements are often prefaced by the following devices (Pomerantz, 1984):

- *Agreement-plus-disagreement constructions.* Conversants first agree at least in a token way with the previous utterance but then link it with a disagreement phrased as an addition, exception, or qualification of the stated agreement. A prototypical example from our data is:

  Patrick: two congruent triangles will have the same area

  D Jerome: yeah, but, shape also doesn't determine the size, you can have a little one with that shape [*draws small triangle on scrap paper*] and a big one, with that shape [*draws larger triangle with the same shape*] and they're not the same area

- *Disagreement prefaces.* These are expressions like "well", "oh" and "uh" that often precede disagreements, delaying them and perhaps also signaling an impending disagreement:

  Alison: ...so have we convinced everyone that the area will be the same for all of them [*looks at Woody, smiling*]

  D Woody: well, not really, we haven't really proven this [*points to the list of congruent segments*] have we? I mean

  Alison: no

- *Repair initiators.* Rather than explicitly disagreeing, the addressee initiates a repair in hopes of prompting a solution of the difficulty:

  Patricia: we don't have ok, these don't, SS, yeah, these 2 are counted the same

  D Janet: SSA?

  Patricia: yeah, SSA ASS they're the same thing because

  Janet: [oh yeah right right right, right right right

These three devices have been observed to accompany disagreements frequently. In contrast, the occurrence of bald disagreements without any prefaces or pauses is rare in ordinary conversation (Pomerantz, 1984). Once again, our data are inconsistent with the preference for agreement pattern. As can be seen in Table 1 above, a large proportion of explanation disagreements were stated baldly by all pairs.

An important thing to notice about this frequency pattern is that it is just as inconsistent with a preference for substantive disagreement as it is with a preference for agreement. All of the disagreements examined were about substantive explanation-related issues; yet, over half of the disagreements were delayed or made less explicit via various prefatory devices. This looks like the worst kind of compromise, one in which on each occasion of individual disagreement conversants are forced to choose to satisfy either their interactional concerns (by abstaining from or muting disagreement) or their conceptual ones (by making disagreements explicit but risking offending their partner). With this interpretation, however, we would expect both poorer and less consistent explanations and participants leaving sessions annoyed with their partner's excessively forceful expression of disagreement on a few key issues. This is inconsistent with our findings. Thus, there needs to be a way to explain this pattern of data in which participants coordinate all their concerns without assuming such an unlikely compromise between them.

[2] Besides the need for further replication, a more sensitive analysis would compare the mean gap for disagreements with that found for agreements.

Re-examining the Process of Disagreeing Over Multiple Turns

How, then, can this data pattern be explained? A key to explaining it is recognizing that the unit of analysis for disagreement is much larger than the single utterance in which a particular disagreement is most clearly expressed[3]. Like contributions to common ground, disagreements are achieved collaboratively through a process combining the dual resources of emerging expectations and opportunities for revision. The way a disagreement is expressed can be best understood given the conditional expectations for agreeing and disagreeing that have developed over the turns preceding it as well as the opportunities available in later turns for refining the specific content of the disagreement as well as what effect it may have on the relationship of the participants.

Looking just one or two turns before the explanation disagreements begins to shed light on why the disagreements may have been expressed in such a variety of ways and with overlap as well as delay. There is an interesting pattern in the strength of proposals before strong and weak disagreements. Bald and/or overlapping disagreements often occur after weakened proposals (61%) while agreement plus disagreement structures, repair initiators and prefaced disagreements do so less often (27%, 43% and 50% respectively). Proposals before such strong disagreements are weakened by devices like:

- *Including Qualifiers Like "I think" or "maybe",*

  Alison: but, well, I think though that t- the side between the two angles would be fixed then also, like couldn't you do [*moves pen towards top of pink paper*]

  D Woody: [if I fix two angles that's fixing the third angle because it's got to be 180 minus the two angles [*chuckles lightly*] that I give you

- *Phrasing Proposals as Questions (inviting disagreement more than an assertion would), or*

  Jerome: then what about the area? [*looks at Patrick, 7.8 sec pause*], how would that?

  D Patrick: [it's assumed, isn't it?

- *Making a Repair or Indicating Possible Doubt During a Subsequent Version of a Proposal Made Before the Disagreement is Uttered (i.e. a subsequent utterance that rephrases or comments on the original proposal).*

  Alison: Right, so why doesn't that prove congruence? Oh because,
  ok ok,

  D Woody: [it doesn't prove congruence]

  Alison: because the sides could be different lengths

  D Woody: [it might prove similarity] is there angle angle similarity for triangles? there should be

  [*Alison's "oh because" expresses potential doubt*]

[3] However, as in this work, focusing on 1-turn disagreements is a useful analytic tool for the first-cut of an analysis.

These examples begin to suggest that participants can jointly construct their interaction so that explicit disagreements can be expressed without serious threat to face. By phrasing proposals explicitly but weakly, proposers simultaneously make clear what their specific preferences are while signaling that they are open to revisions by their collaborator. This is good both for producing quality explanations and for maintaining positive working relationships.

A related phenomenon is seen by examining turns following strong disagreements that were not invited by the form of the previous proposal. In them, speakers produced subsequent utterances that were expressed much more weakly. For example, the subsequent version of Woody's disagreement ("if you had any of these three right?") employed both a try-marker and a conditional:

Alison: and area by itself wouldn't be enough

D Woody: but area would also be unnecessary, if you had any of these three right?

Alison: right [*6.0 sec pause*] so you don't need to know the the height?

Woody: nope

Although some weak followup utterances undoubtedly have to do with the absence of the addressee's agreement with the original counter-proposal (Davidson, 1984), expressing uncertainty afterwards could also serve to reduce the potential negative interpersonal impact of the first, baldly-stated, disagreement. This is an effective means for disagreeing when disagreements need to be explicit. A first version can make the substance of the disagreement explicit while the second version can express openness to the addressee's view of the matter. This is better than the agreement-plus-disagreement constructions where interpersonal concerns are addressed, but disagreements may be too muted for getting the intellectual work done.

Though our results are preliminary, the existence of these devices for preempting the social threat of a bald disagreement before it has been uttered and reducing its impact afterwards suggests that it should not be assumed that disagreements expressed baldly will necessarily threaten face. An analysis across several turns shows that more complex interactive devices can be used to maintain face while communicating the substance of disagreements.

Creating More Effective Agreements and Disagreements Through Challenges and Noticings

In examining the transcripts further two other devices were discovered which help in the effective management of agreement and disagreement that takes into account both interpersonal and conceptual concerns. The devices, which we call "challenges" and "noticings", are effective because rather than expressing either agreement or disagreement they leave the issue either ambiguous or open.

Challenges can be interpreted as showing the specific nature of a potential disagreement that could occur while, in doing so, showing the addressee a way to avoid the disagreement by meeting the challenge. An example of a challenge occurs in the following episode:

Alison: and these 2 [*points to two sets of proportionality relationships*] don't [*draws double arrow between the two proportionality relationships*] work (3.0) so in other words this [*starts to laugh*]

C Woody: [[*smiling*] so what have you shown?

Alison: this, well that [*points to formulas more generally*] shows that the h- area has to be the same

[*10.0 sec pause while Woody looks at what Alison has written*]

[*after 10 seconds with no agreement offered, Alison begins re-explaining her proof*]

Woody's challenge pinpointed his possible difficulty with Alison's proposed proof (which started many turns earlier), which is that he is not sure what she has proved. Alison meets the challenge insofar that she proposes a summary statement. However it does not satisfy Woody enough to agree with her so she goes back to the beginning, re-explaining her proof.

Besides occurring as responses by themselves, such challenges also occurred after agreements in an agreement-plus-challenge structure. For example:

Patrick: Well I take, I take the language particular shape to mean congruence like as it's given to us, in other words-

Jerome: hmm

Patrick: and therefore area follows, I take that from the wording of the problem, you don't?

C Jerome: y:::y:eah, but would that explanation work on someone who doesn't know what congruent means?

[*6.0 sec pause*]

Patrick: it would serve as a definition for the term if they didn't know it yet. [*laughs*]

Jerome: yeah [smiles] if you know what congruence is, then, that's obvious, hm

In this case, Patrick successfully met the challenge. Each pair used challenges on several occasions.

The other technique, noticings, was used primarily by one pair, Patrick and Jerome. This pair organized themselves into a participation structure in which Jerome was more responsible for the moment-by-moment management of task demands while Patrick would focus on more global concerns, interjecting comments that would sometimes result in dramatic changes in the direction of the interaction. Some of these comments are what we call "noticings". They express global observations about the way the explanation is being carried out and result in further elaboration and justification from the addressee. For example:

Jerome: ok, what'er the really basic theorems you've got? the unproven parallel one, Euclid's fourth [*writes 'Euclid' followed by a list from 1 to 4, w/ 4 being followed by a pair of horizontal parallel lines*]

N Patrick: trying to go from basic principles, huh?

Jerome: umhm, cause I don't remember that many theorems, don't remember that many basic principles either

Our hypothesis is that noticings promote discussion of reasons for choosing one explanation over another while posing only a minimal face threat.

Discussion

As a whole, these analyses of disagreement in mathematical discourse suggest that there are important differences between conceptually focused conversations (that is, conversations focused on constructing conceptually coherent understandings and explanations) and the "everyday" conversations that have been the focus of conversation analysis. The pattern of disagreement found in this corpus of conceptually focused conversations was at odds with the standard empirical evidence for a preference for agreement in everyday conversation. Our conversants were much more likely to express their disagreements baldly and with little delay.

Our hypothesis is that this is explained by the fact that participants in conceptually focused conversations need to simultaneously coordinate their conceptual goals with the interpersonal goals important for almost all social interactions. In particular, for these kinds of conceptually focused conversations to be successful, participants must find ways to make their disagreements explicit while avoiding having this threaten the face of their partner. Devices for satisfying both goals included allowing for bald and explicit disagreements by phrasing proposals weakly, quickly following a bald disagreement with a weaker subsequent version, asking specific challenge questions in lieu of explicitly disagreeing or agreeing, and using noticings to prompt further elaboration. Conversations can become very complex, especially when people are trying to satisfy multiple interpersonal and conceptual goals at once!

Viewed more generally, this line of research advances the recent effort in cognitive science to understand the mutual interactions of social and individual cognitive processes (Hatano, 1994; Hutchins, 1991). We integrate as much as we can of the social and the individual levels in our analyses of cognition in hopes that eventually it will be possible to do analyses of such processes at a single level of analysis. However, there are important limitations to what has been achieved so far that makes this still out of reach. Not enough of the specific, conceptual content has been included in the analysis. Though individual cognitive concerns are included from the start, they are only the most general of conceptual concerns: norms for productive intellectual argument that could conceivably apply over a wide range of content areas. There is not much in our analysis that turns on the fact that these conversations are about mathematics rather than, say, geology.

What would such a theory need to include and how could it include it? In the case of the analysis of disagreements we offer here, several things about mathematics could have important influence over the conversations. First, what counts as a potential disagreement at all given a particular proposal is crucially dependent on discipline-specific practices that influence what kinds of factors it is possible to

have disagreements about and how such disagreements are expected to be phrased. In addition, participants' personal epistemologies about what kind of knowledge mathematics is may strongly influence the degree to which mathematical statements can be uttered as matters of fact, as matters to be decided by authorities (like textbooks and mathematicians) or as matters to be proven using already agreed on or still-developing systems of inference. Finally, it will be crucial to include specific conceptual content into such analyses. In this case, the connections the participants made between such concepts as *congruence*, *similarity*, *shape*, and *area* would be crucial for understanding the mathematics in their conversation. Our hunch is that overall disciplinary factors like argument patterns and epistemologies can be tractably included into the analysis. However we expect that integrating analyses of conceptual content with conversational structure will provide the greatest challenge.

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