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Towards Productive Multivocality in the Analysis of Collaborative Learning

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Abstract: Research in Computer Supported Collaborative Learning (CSCL) is diverse and multi-vocal, in that multiple theoretical and methodological traditions speak to questions concerning how learning takes place in social settings. Whether this multivocality leads to balkanization or is a source of strength may require deliberate efforts at identifying strategies and finding boundary objects for productive discourse across this diversity. This paper and associated symposium reports on the results of such an effort—a three-year series of five workshops exploring the basis for productive dialogue between multiple analytic traditions in CSCL. After a brief introduction to our objectives and the series of workshops, we illustrate lessons learned with three examples in which a group of analysts deliberately chosen for their diversity analyzed three small corpora with respect to identifying "pivotal moments" in collaborative learning and compared their results. The project also illustrates more generally the potential value of collaborative learning among researchers.

Introduction

Researchers in Computer Supported Collaborative Learning (CSCL), and more generally in the Learning Sciences, take multiple approaches to the study of how interaction leads to learning with the support of designed artifacts. The CSCL community is an international community (Kienle & Wessner, 2006) comprised of researchers, designers and practitioners from diverse fields, drawing largely on computer science, education, educational psychology, human-computer interaction, and psychology, as well as linguistics and other educational, information, learning, and social sciences (Wessner & Kienle, 2007). Hence numerous theoretical frameworks and methodological traditions drive work in the field. This multivocality is a strength only to the extent that there is sufficient commonality to support dialogue between the "voices" and reach some degree of coherence in the discourse of CSCL (Suthers, 2006). The Learning Sciences are too diverse (theoretically and methodologically) for unification to be possible or desirable, but learning scientists would benefit from "boundary objects" (Star & Griesemer, 1989) that form the basis for dialogue between theoretical and methodological traditions applied to the analysis of learning in and through interaction. The question at hand is what constitutes effective boundary objects and how they may be leveraged.

Over the past three years, the authors and other colleagues have collaborated through a series of workshops to address this question, seeking appropriate boundary objects and strategies for supporting productive multi-vocality between multiple analytic traditions in CSCL. This paper provides an initial report of our activities and lessons learned. We start with a brief history of the project. Then we use three case examples to illustrate the value of multivocal analyses and lessons learned concerning strategies and barriers to overcome. The purpose is not to report on specific analyses, nor to claim that these analyses are complete and offer significant results. Rather, the purpose is to offer to the CSCL community what we as a collective have learned, from comparing our analyses, about how to collaborate as analysts and take advantage of theoretical and methodological diversity. An activity of this scope cannot be described adequately in a conference paper. More detailed accounts will be provided in a symposium at the CSCL 2011 conference, and in journal articles and a book that are being planned at this writing.

History

Our collaborations developed through a series of workshops at the International Conference on the Learning Sciences (ICLS) 2008, Computer Supported Collaborative Learning (CSCL) 2009, the STELLAR Alpine Rendez-Vous (ARV) 2009, and ICLS 2010. Below we describe the motivations for each workshop and how major lessons learned led to changes in our strategy in each subsequent workshop.

A Common Framework for CSCL Interaction Analysis (ICLS 2008)

A premise of our first workshop was that common conceptions, representations, and tools are needed to support and bridge between multiple theoretical perspectives as well as facilitate the application of different analytical methodologies and tools to complex data sets. Progress in any scientific discipline requires that practitioners share common objects such as instrumentation, data sources, analytic methods, etc. that enable researchers to replicate or challenge results in a manner that drives scientific progress. Shared instruments and representations mediate the daily work of scientific discourse (e.g., Latour, 1990; Roth, 2003), and advances in other scientific disciplines have been accompanied with representational advances. Similarly, we reasoned, researchers studying learning in distributed and networked environments need shared ways of conceptualizing and representing what takes place in these environments to serve as the common foundation for our scientific and design discourse.

The goal of our first workshop (organized authors Suthers, Law, and Rosé, and Nathan Dwyer) was to establish requirements for a common conceptual and representational framework to support collaborative learning process analysis, by (a) demonstrating our analytic tools to one another in the context of analyses we have conducted, (b) identifying commonalities among these tools and analyses along four dimensions, and (c) generating requirements for a common conceptual model and abstract transcript that might also form the bases for shared analytic software. The dimensions were (1) purpose of analysis, (2) the units of interaction that are taken as basic in the analysis, (3) representations of data and analytic interpretations, and (4) analytic manipulations taken on those representations. We found that the dimensions were helpful for characterizing diversity, but we realized that our multivocality presented challenges in identifying a single common conceptual and representational framework for analysis. Yet, we felt we were gaining some understanding from looking at each other's analyses. A "tool fair" also generated considerable interest, and we noted the need to make our theoretical assumptions explicit.

Common Objects for Productive Multivocality in Analysis (CSCL 2009)

In our second workshop (organized by authors Suthers, Law, Lund, Rosé, and Teplovs), we decided to tackle multivocality head-on by having analysts from different traditions assigned to analyze the same data set. Two corpora were used, from the Virtual Math Teams and Knowledge Forum. We continued to use the four dimensions to characterize different analyses, and added the dimension of (5) theoretical assumptions underlying the analysis (which permeate the other dimensions, e.g. Ochs, 1979). We examined our analytic processes to discover commonalities along the five dimensions that can support productive multivocality. We also sought to determine whether analytic differences are complementary (potential sources of richer understanding) or incompatible (potential barriers to a common discipline). We found that our commonalities did not fall along the dimensions, but rather were that we shared (a) learning through collaborative interaction as our topic of study, and (b) the desire and willingness to engage in this activity together. Also, we found that multiple analyses of shared data corpora provided a promising basis for dialogue, but noted that there were disconnects between the analyses presented because the analysts were approaching these corpora with entirely different questions. This observation led to the objective of identifying "pivotal moments" in the next workshop.

Pinpointing Pivotal Moments in Collaboration (ARV 2009)

Our third workshop (organized by Lund, Law, Rosé, Suthers and Teplovs) continued the prior strategy of having researchers from different theoretical and methodological traditions analyze shared data corpora. We used a different Knowledge Forum corpus, and a Japanese primary school mathematics class exemplified later in this paper. As before, we assigned analysts to data, deliberately pairing up analysts from different methodological traditions, and assigning some analysts to data from settings they did not normally study. We addressed the mismatch in analytic objectives that was problematic at CSCL 2009 by asking analysts to identify "pivotal moments" in collaborative learning. The definition of pivotal moments was purposefully left unspecified, providing a projective stimulus that drew out different researchers' assumptions and insights and leading to exciting comparative and integrative discussion. As expected, analysts differed in their conception and identification of pivotal moments, but these differences (as well as some congruencies) generated productive discussion of how learning arises from interaction. In this workshop we first articulated our current strategy for multivocality: assigning diverse analysts to shared corpora with analytic objectives that are deliberately open to interpretation (i.e., "pivotal moments"). During this and the prior workshop, our own objectives shifted: we talked less about sharing the *same* concepts or representations; and more about *boundary objects* (such as the corpora and "pivotal moments") supporting dialogue between different traditions. Boundary

objects "have different meanings in different worlds but their structure is common enough to more than one world to make them recognizable, a means of translation" (Star & Griesemer, 1989, p. 393). Yet we wanted to explore further how shared frameworks (e.g., Suthers, Dwyer, Medina, & Vatrapu, 2010) and shared analytic software tools (e.g., Tatiana; Dyke, Lund, & Girardot, 2009) could serve as or produce appropriate boundary objects.

Productive Multivocality in the Analysis of Collaborative Learning (ICLS 2010)

In our fourth workshop (organized by Lund, Suthers, Law, Rosé and Teplovs), we sought to build on the success of the third workshop; replicating the strategy of having deliberately diverse analysts identify pivotal moments in shared corpora. There were two novelties. First, we brought in new data corpora and new analysts. Corpora included a Group Scribbles mathematics classroom in Singapore and university level chemistry study groups in the U.S (both are exemplified later in this paper). Second, we wanted to revisit the possibility that a shared software tool and its data and analytic representations would help support more detailed comparisons between analyses, by providing all the data and analyses within the common tool. This latter effort enabled analyses to be shared ahead of the workshop and is reported in Dyke, et al. (submitted for this volume). The primary strategy again proved to be productive, surfacing issues and insights exemplified by the case studies below. In the remainder of the paper, we briefly summarize the lessons learned from comparing the analyses of the three data corpora identified in the above historical account.

A Multi-vocal Analysis of Pivotal Moments for Learning Fractions

Summarized by Kris Lund. Data and analysis provided by Hajime Shirouzu. Additional analyses by Ming Chiu and Stefan Trausan Matu.

The data concerns six students studying the multiplication of fractions in a 6th grade classroom in Japan. Their task was to cut out 3/4 of 2/3 of a piece of origami paper and then to discuss whether or not their solutions were the same. A teacher led and monitored activity and work was carried out both on the blackboard and by folding pieces of the paper. Video data was supplied and the Japanese was transcribed, translated into English and synchronized with the video as subtitles. Drawings of each student's folded origami solution were also provided. Three analysts were asked to detect the pivotal moments occurring in the interaction and were given the latitude to define this as they wished.

The first analyst and data provider, Hajime Shirouzu, defined pivotal moments as occurring when a learner reflects on his or her own externalized results of problem solving or that of others with the result that either individuals or the collective achieve conceptual change: pivotal moments can be either individual or collective. Shirouzu found three collaborative pivotal moments. First, the class as a unit reached a new level of understanding when the dialogue illustrated a collective display of abstract dimension (e.g. the areas could be equal for two different paper foldings, but the shapes and ways of folding could differ). A second pivotal moment was when a learner withdrew his diagrammatic explanation in spite of another learner's strong support (e.g. "is this wrong?" "that's ok!"). Finally, a third pivotal moment occurred when an algorithmic explanation was collectively approved (e.g. "when 2/3 is multiplied by 3/4, the product is 6/12 and it is equal to 1/2 after being reduced, all (answers) are 1/2 of the whole"). Shirouzu took the individual as his unit of analysis and, based on convergence/divergence theory, tracked both intra and inter-mental activities as displayed by or inferred from the interaction (Shirouzu & Miyake, 2002).

The second analyst, Ming Chiu, defined time periods that were divided by five pivotal moments, also described as *breakpoints* (Chiu, 2008), where one description of activity changes to another (e.g. from teacher instructions to student folding to looking at one another's solutions). He observed that pivotal moments could differ across cognitive problem spaces vs. social relational spaces and across separate high vs. low micro-creativity time periods. Whereas Shirouzu qualitatively noted three pivotal moments of high-level thinking, Chiu identified six time periods of distinctly different frequencies of new ideas. Each conversation turn was coded across five variables (evaluation of the previous action, knowledge content regarding problem, validity, justification, invitation to participate). On top of this first coding scheme, *micro-creativity* was defined as occurring when a new idea was mentioned that was also correct and a correct evaluation was either agreeing with a previous speaker's correct idea or disagreeing with a previous speaker's wrong idea. Breakpoints were defined statistically wherein the fewest breakpoints described the most variance in quantity of new ideas. Chiu had to adapt his technique for use on a small dataset. In such a case, although statistical results may not be significant, they still suggest specific relationships to explore qualitatively.

The third analyst, Stefan Trausan-Matu, defined pivotal moments in collaboration by detecting changes in the degree of inter-animation of voices as illustrated by collaborative and differential utterances. *Collaborative* utterances illustrate a convergence pattern and correspond for example to the collective display of

understanding already mentioned (Shirouzu's first pivotal moment and Chiu's fifth breaking point). An example of a *differential* utterance is when an explanation given by one learner is perceived as incomplete, thus inciting a second learner to add to it. In the polyphonic view, this exemplifies a type of "dissonance" between the two learners that is remedied by the second learner's addition. Trausan-Matu used a polyphonic model of group interaction where a conversation contains different longitudinal threads (or "voices") composed of utterances, each of them having independence, but achieving a joint discourse (Trausan-Matu & Rebedea, 2009). He found four groups of collaborative pivotal moments or sequences, and differential pivotal moments within these collaborative sequence. These collaborative sequences overlapped in every case with the three pivotal moments defined by Shirouzu and in one case with Chiu. In other words, each of the three analysts identified one pivotal moment in common: the display of new collective understanding referred to earlier. Discussions of differences between these analyses led to several conclusions concerning productive multivocality, discussed below.

Each researcher focused on a different unit of analysis (pivotal moments of either reflection on externalized results of problem solving or regarding changes in the degree of inter-animation of voices vs. time periods of different frequencies of new ideas punctuated by breaking points). Shirouzu and Trausan-Matru described sequences of turns as pivotal moments because they focused on moments of collaboration and dissonance/divergence, whereas Chiu restricted his breaking points to a single conversation turn, as his goal was to divide the interaction into distinct periods. These differences in focus of attention reflect both how questions spurred by underlying theoretical frameworks (intra-mental interaction, convergence, divergence, micro-creativity) guide the eye, and how criteria for applying particular analytical techniques influence choosing the unit of analysis, although such differences did not require changing Shirouzu's method for segmenting the interaction.

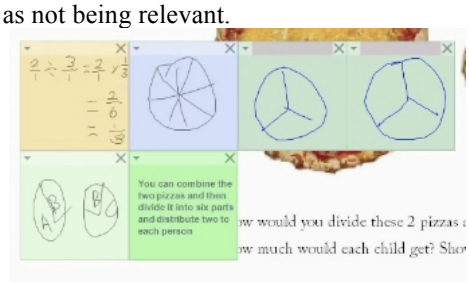
The pivotal moments and breakpoints only intersected once: Shirouzu's first pivotal moment was Trausan-Matu's second and comparable to Chiu's fifth breaking point. Shirouzu sees this moment as a collective display of new understanding and tries to explain it through individual trajectories whereas Trausun-Matu explains it as resulting from the characteristics of individuals (e.g. divergent thinker). Both analysts draw inferences on individual thought processes from the interaction, but employ different methods based on different epistemological views on how the individual relates to the collective. Chiu views this moment as indicating the end of a period of frequent ideas, occurring just after teacher acknowledgment. Indeed it is compatible that the moment when collective understanding is reached could correspond to the beginning of a drop in new ideas because learners are consolidating their knowledge in terms of concepts already expressed. Re-examining this moment in terms of Chiu's definition of ideas as "new" or "old" led Shirouzu to suggest that in his framework, new ideas could correspond to conceptual or procedural changes to how to view the solutions, progressing potentially towards a collaborative pivotal moment. A lesson for multivocality related to confronting one analysis with another is that it leads to fine-tuning of analytical concepts, explanations of why analysts did not converge and thus to a better comprehension of the phenomena studied while rendering explicit researchers' epistemological views. Also, sharing analyses can widen perspectives on how the data can be interpreted: Shirouzu studied Chiu's five breaking points and noticed that frequency of new ideas corresponded to when and how the pedagogical designer's intentions were actualized by students' behavior.

Since gestures were transcribed by Shirouzu, Chiu and Trausan-Matu took them into account, considering that some gestures exhibited new ideas or displayed collaborative or differential positions that could signal a pivotal moment. An important issue for sharing data and methods arose that involved applying the polyphonic framework to data other than chat interactions. It was shown that inter-animation and polyphony appears also in non-verbal interactions (e.g. all learners move their chairs except one); thus the analytical framework's reach was extended to new types of previously unconsidered data.

In summary, comparison of approaches and results showed that analysts realized how theoretical frameworks guided the way they looked at their data (Lund, in press), but they were still able to match new meanings to the interpretations of others (in different frameworks) that were relevant to them. Analytical concepts such as convergence, dissonance and ideas were fine-tuned as a result of comparing analyses and led to better understanding of the phenomena studied. Units of analysis were critical for orienting interpretations, but the segments chosen by Shirouzu were sufficient for the analyses carried out by Chiu and Trausan-Matu. Using individual threads to explain collaborative outcomes was a consistent approach across analysts. However, comparisons of analyses surfaced different beliefs concerning how individual participation in the collective can be measured and comparison made this explicit. Parallel qualitative and statistical analyses revealed both the same and different pivotal moments. Such mixed-method analyses of pivotal moments can mutually inform each by triangulating results and/or stimulating further qualitative or statistical analyses to shed further light on the identified pivotal moments and/or breakpoints. Finally, sharing data that had gestures transcribed incited analysts to consider gestures in their analysis, an aspect of interaction they did not usually consider and allowed one particular analytical method to be extended.

A Multi-vocal Analysis of Small Group Problem Solving Using GroupScribbles

Summarized by Gregory Dyke and Dan Suthers. Data and analysis provided by Chee-Kit Looi and Wenli Chen Additional analyses by Heisawn Jeong, Richard Medina, and Jan van Aalst. The process of analysis consists, in part, in the transition from the empirical domain of the interaction (speech utterances and events in the software environment) to the conceptual or epistemological domain of the analytic framework (e.g. ideas, representational practices, knowledge building, social cognition, etc.). This transition is effected through a representational domain (e.g. spreadsheets, transcripts, contingency graphs, etc.). In combining four analyses from the perspectives of uptake, knowledge building and group cognition, we found that agreement on how the representational domain mediates between the empirical and conceptual domains facilitates productive discussion in the conceptual domain. Our multi-vocal discussion revealed that, while all analytic frameworks gave a similar account of the interaction, thus validating this account, their interpretations with regard to learning varied, each raising questions for the other frameworks. These questions served as catalysts for the improvement of the analyses, and could also prompt extension or validation of the underlying frameworks through adoption of new constructs or the explicit rejection of others as not being relevant.



The analyses focus on a sixteen-minute excerpt from a three-year school based project. During this excerpt, four students in a Singapore primary school interact verbally and via the Group Scribbles software (Roschelle et al., 2007) to solve and contrast solutions to the problem of dividing two pizzas equally among three children. They must then examine and comment on the solutions provided by other groups. All four analyses agreed on the following account of the interaction: Helen and Victor both formulate similar graphical solutions and agree on their equivalence. Terry seems unable to come up with a graphical solution and, after having verbalized this difficulty and seen Helen and Victor's solution writes an equivalent textual solution. Quentin develops his own symbolic solution (which contains an error due to inattention) without interaction with the others. During the commenting of solutions of other groups, Helen appropriates a colored version of her representation, Terry demonstrates his understanding of the various representations, and Quentin corrects his solution. The interaction is dominated by off-topic activity by Victor, and his peers' reactions to this activity.

Richard Medina's analysis was conducted using concepts and methods from the uptake analysis framework (Suthers et al., 2010). Analysis of contingencies and interpretation of uptake across both verbal and inscriptional acts showed that Helen, Victor and Terry demonstrated a specific orientation to inscriptional activity and artifacts in their interaction. Of particular interest is Terry's comment, "You can combine the two pizzas and then divide it into six parts and distribute two to each person." provided after a brief sequence of negotiation with Helen and Victor. In terms of uptake, this is a pivotal moment not so much that it demonstrates Terry's views on the problem (and his verbalization of Helen's inscriptional proposal) but rather that it is a punctuation of a sequence of talk and inscription among Helen, Victor, and Terry. Terry's proposal stands against both Helen and Victor's proposals even though he aligns it with Helen's. In this instance we can notice that the single action is not isolated from its social and material contingencies. Identifying Terry's punctuating comment as an instance of uptake of representational practice as well as ideas requires some unpacking of the action leading up to his conclusion. Seeing this analytically requires a perspective shift from individual acts to relations between acts.

Chee-Kit Looi and Wenli Chen's analysis (Looi & Chen, 2010) also utilized uptake analysis. In spite of being conducted independently from the Medina analysis, a strikingly similar uptake graph resulted. They specialized uptake categorically into agreement, disagreement and incomprehension in order to further unpack semantic relatedness. This provides a more complete account of Helen and Victor's attitudes towards their respective solutions. They also note the isolation of Quentin, wondering how his symbolic solution would have benefited from mutual understanding with the other solutions.

Jan van Aalst's analysis examined the data from a knowledge building perspective (Scardamalia, 2002) and found that, after a promising start with four different ideas being shared, there is only minimal discussion about the two graphical solutions, implicit agreement with their textual equivalent and no coordination with the (initially incorrect) symbolic solution. Because the students had not appropriated practices oriented towards idea improvement and synthesis they only did so after instruction by the teacher. This suggests that they have not taken control of the learning opportunities offered to them.

Heisawn Jeong's analysis examined the interaction from a cognitive interpretation of group cognition. She took the artifacts created by the group as a proxy for the group understanding and examined how it evolved over time. The results showed how group understanding, as reflected in the contents of the group space, evolved over time. Contributions, once made, were subject to comments and revisions, and in some cases removal. While the understanding evolved to include several correct solutions to the problem, the 'quality' of the group

understanding was not high. Solutions in the form of drawings and formulas were not integrated, and the group space remained fragmented. Her analysis also examined how each contribution emerged from artifact-mediated discourse. The majority of the contributions were collaborative in that students provided prompts, questions in the process. Unlike typical verbal discourse, however, the collaboration was mediated by both verbal and non-verbal activities in the GS workspaces as students interacted verbally as well as through comments and checkmarks on the contributions

The representational coordination of these analyses was conducted using the Tatiana conceptual framework and software (Dyke et al., 2009). Initial comparison appeared to show wide discrepancies in interpretation, but closer examination showed that these were mostly gratuitous differences resulting from conflicting choices as to the granularity of the unit of analysis and whether or not private spaces were considered. Medina's analysis tracked the uptake of both ideas and representational practices over time, interpreting spoken and inscriptional acts in relation to prior acts. Looi & Chen's analysis was concerned only with the uptake of ideas attributed to inscriptions in the public space, and differentiated uptake relationships according to agreement, disagreement and incomprehension. Van Aalst's analysis was also concerned with ideas, but analyzed ideas expressed both in private and public spaces. Jeong's analysis introduced the concept of a contribution thread, isolating interaction according to the contribution that prompted it. Although initially the analyses differed on whether they looked primarily at verbal data and whether private events were included, discussion between analysts led to agreement to examine all public events (verbal utterances and published notes). A subsequent iteration of analysis showed that none of the analyses laid claim to anything specific or differentiating with regard to their empirical foundations, enabling focus to shift onto how the different analyses complemented each other and the questions they raised.

The combination of these analyses allowed a clearer understanding to emerge. The contingency graphs unpacked the interaction, making contingencies explicit. Following each contribution as it evolved in the group space helped show that uptake (from the Medina analysis) not only happens across students, but also across contribution threads (from the Jeong analysis), highlighting the focal points for learning. The knowledge building perspective showed the missed opportunities where new ideas (in particular Quentin's solution) were not taken up by others and contributed to the fragmentation of the group space. All analyses, in spite of their very different theoretical frameworks, showed that this interaction was sub-optimal. Each, however, would perhaps suggest different methods for improvement. Further questions were raised surrounding conceptual issues such as our positions with regard to off topic and "disruptive" behavior; how to theorize concepts for which empirical grounds are implicit or missing, such as contingencies implicit in students' visual orientation, hypothesized cognitive events, and missed opportunities; and relationships between interaction, individual learning, group cognition and knowledge building.

We drew three important lessons from this multivocal collaboration: First, an important first step is to eliminate gratuitous differences in the scope of data to be analyzed so that essential differences can be foregrounded. Second, once this is done, comparisons can draw analysts out of their epistemological cocoons as they encounter different interpretations that challenge their own. Third, shared representations of data and analyses can serve as boundary objects in both of these processes.

A Multi-vocal Analysis of Peer Led Team Learning for Chemistry

Summarized and analyzed by Carolyn Rosé; Data provided by Keith Sawyer. Additional analyses by Jun Oshima and Jan-Willem Strijbos. One advantage as well as challenge of multi-vocal approaches to analysis of collaborative learning interactions is that it reveals the ways in which our individual operationalizations of complex constructs such as *leadership* are limited. In bringing together analyses from multiple perspectives addressing similar issues with the same dataset, our eyes opened to the richness and complexity of how these constructs are embodied in language. Here we bring together five frameworks for analysis of leadership to analyze interactions from Peer-Led Team Learning (PLTL) groups in an undergraduate chemistry class, specifically two categorical coding schemes that embody separate theoretical frameworks specifically designed to analyze collaborative learning discussions, two coding schemes drawn from the field of systemic functional linguistics designed to capture aspects of social positioning within discussions, and a social network analysis approach designed to make patterns of exchange at a coarse grained level apparent to analysts for their own interpretation.

Our analysis focuses on transcripts of two different groups working on the same presented problem. These two groups in particular were chosen from a complete set of 18 groups because they demonstrate two very different approaches to group problem solving; one group (AKA the Germino group) focused on deeper conceptual understanding while the other group (AKA the Markham group) was more narrowly focused on identifying the appropriate algorithm to determine the correct answer. In this presentation, we examine the synergy between multiple analyses through the lens of exploring relative authoritativeness and receptivity within the discussions as two separate constructs related to leadership. All three analysts agreed that the Germino group had a clear leader, whereas leadership within the Markham group was more diffuse. However,

finer grained analyses revealed important distinctions that reveal how each of these operationalizations is limited, and how we can deepen our understanding of complex constructs such as leadership through multi-vocal analysis. Broadly, we consider the idea of leadership from two directions, first in terms of how authoritative a speaker presents him or herself as being, and second, in terms of how receptive other group members are to a member's positioning of him or herself as a leader, which is based on the nature of their conversational responses.

Let us first consider the issue of authoritativeness in presentation of self. Jun Oshima's innovative word level network analysis was accomplished by quantifying and comparing "social relationships" between words within discourses. To this end, a social network analysis methodology was applied, whereby an edge represented a co-occurrence relationship between words within contributions to a discourse. Influential students identified in this analysis were those who used words that appeared in central locations within the graph. One student emerged as a central player within the Germino group, but not within the Markham group. The same student was identified as authoritative within Jan-Willem Strijbos' analysis. In this case, authoritativeness was measured by patterns of occurrence of turns labeled as Dominance+ and Dominance-, where positive dominance statements show leadership through positive polarity statements, such as declaring an idea as correct, while negative dominance statements show leadership through negative polarity statements, such as providing corrections or challenges. The Rosé analysis approached the idea of leadership through two constructs from the field of systemic functional linguistics, namely Martin and Rose's negotiation framework (Martin & Rose, 2003) and Martin and White's operationalization of heterogolossia (Martin & White, 2005). In the negotiation framework, authoritativeness is demonstrated by making a contribution to a discourse that is not offered as an invitation for validation from another group member. For example, an assertion that is made in response to a question that is framed as a hint rather than a serious question, and then followed by an evaluation, is not coded as an authoritative assertion. Based on this analysis, the Rosé framework identified the same student as authoritative that the Oshima and Strijbos analysis did. However, the heteroglossia framework painted an alternative picture. Within that framework, assertions framed in such as way as to acknowledge that others may or may not agree, are identified as heteroglossic. Such assertions can be either expanding, in other words adding to the set of items up for negotiation, or contracting, in other words eliminating items from consideration. This can be seen as similar to the notion of positive dominance and negative dominance within the Strijbos framework, and frequently there is a correlation between these two constructs. However, it is not always the case that heteroglossic assertions that are framed as negative polarity statements perform the function of contracting the set of options under negotiation. For example, if a constraint is eliminated, then more items are made negotiable since fewer constraints need to be satisfied. This subtle distinction between the Strijbos and Rosé approaches to measurement of leadership lead to differences in how students were ranked in the less clear cases. Furthermore, while the student identified as authoritative by all three analysts was identified as having more negative dominance statements in the Strijbos analysis, one might expect that student to have more contracting than expanding heteroglossic statements, it ended up being that case that student had more expanding statements.

Receptivity of leadership as evidenced by the response of other group members is another dimension along which interesting differences emerge in the investigation of leadership within the Chemistry discussions. Within the Oshima analysis, a much higher level of interconnectivity was evidenced within the Germino group. High levels of vocabulary sharing could indicate higher levels of receptivity between students. In the Strijbos analysis, receptivity was indicated though Collaborative Orientation vs. Individual Orientation codes. Similar to the Oshima analysis, Strijbos identified the Germino group as having more Collaborative than Individual utterances, whereas the Markham group was the opposite. In the Rosé analysis, however, receptivity is analyzed through identification of "transactive" contributions, which operate on reasoning displayed in a prior contribution (Berkowitz & Gibbs, 1979). If the Rosé analysis was consistent with the Oshima and Strijbos analyses, we would see more transactivity in the Germino discussion, but interestingly, the opposite turns out to be the case. This is because although the discussion was focused on moving step by step through the problem rather than discussion concepts at length, the group reasoned out the problem solving steps together, checking each other's work. This multi-vocal analysis of receptivity to leadership reveals how quantitative approaches to analysis of such constructs may inadvertently adhere to tightly to shallow features of interactions, such as the way highly transactive exchanges appear in conceptually oriented discussions, and thus miss valuable interactions occurring where the focus is more procedurally focused.

In looking at these 5 different analyses, a multi-faceted image of ideal leadership emerges that would not be visible in any single one of the frameworks investigated. For example, our multi-vocal separation between different leadership constructs allows us to view how it is possible to present ones views as standing on their own without denying others the right to have their own voice. With such a multi-vocal analysis, we can view how few leaders have mastered both aspects. Furthermore, a person who presents him or herself as authoritative might be more likely to elicit receptivity from his or her collaborators, but it may not always the

case for various reasons. Thus, this multi-vocal analysis has a greater potential as an assessment framework for identifying where strong but not stellar leaders may need improvement.

Conclusions

Sharing analyses has benefits both for the individual analysts and the community. Analysts are confronted with aspects of the data highlighted by others that they might not have themselves considered; epistemological assumptions are challenged; analytic concepts are fine tuned; and a multidimensional understanding of the phenomenon being investigated and analytic constructs used to approach it is gained. The process leads to greater dialogue and mutual understanding in our community. Productive multivocality is facilitated by eliminating gratuitous differences in the scope and representation of data considered, and by deliberately pairing diverse analysts charged with a common yet flexible analytic objective. At this writing, a fifth workshop is planned for the Alpine Rendez-Vous in March 2011, in which we will incorporate one new corpus and examine two others in more depth (with additional data), and complete our planning for a book on our project.

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