Is the Sum Greater than Its Parts? Reflections on the Agenda of Integrating Analyses of Cognition and Learning

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Abstract: This symposium springs from an ongoing effort to bring together contrasting methodological perspectives for the study of human knowing and learning. Specifically, we build bridges between two significant process-oriented approaches: Interaction Analysis (IA) and Knowledge Analysis (KA), to study how individual cognitive dynamics interacts with complex social dynamics. We demonstrate the kind of insights and outcomes of such integration, by zooming in, and explore two specific efforts to bridge KA and IA. Both focal pairs of analyses in this symposium make central use of the theoretical construct of coordination class, a theory is associated with KA usually used for analyzing the structure and dynamics of an individual conceptual system. Coordination class theory is used to extend an IA analysis in the first pair of analyses, and is elaborated on using IA methodology in the second pair. The presentations aim to stimulate discussions about the merits and constraints of such integrations.

Symposium Overview

An increasing body of evidence in the cognitive and learning sciences has led the field to recognition that human knowing and learning is incredibly multi-faceted in nature. Over the past decades, the field has come to understand more deeply how cognition and learning are embedded in social context, structured by both cultural forms and assumptions and by interaction with physical artifacts. Given this diversity in forms of complexity, it is not surprising that historically different intellectual lines have pursued diverse directions, drawing upon characteristically different methodological and theoretical assumptions. While multiple perspectives can offer depth and richness to our understanding of learning processes, there is a need for an increased focus on purposeful synthetic work in the learning sciences that can enable us to develop theoretical or empirical bridges across perspectives. The current lack of articulation across perspectives is both scientifically unsatisfactory and also has important consequences with respect to educational design, one of the central enterprises of the learning sciences.

The current symposium is part of a larger, ongoing effort to bring together contrasting theoretical and methodological perspectives on learning (Brown et al., 2012; diSessa et al., 2010; diSessa, Levin, & Brown, under review). In particular, we are currently focused on building bridges between two significant process-oriented approaches to studying knowing and learning: Interaction Analysis (IA) and Knowledge Analysis (KA). This work is centered on the innovative and challenging agenda of studying how the dynamics of individual cognition interacts with complex social dynamics. The aim is in this work is to be mutually accountable to issues of both knowledge and interaction in analyses of cognition and learning. Some of the central prospective outcomes of the agenda to articulate and integrate perspectives include:

- Extension and refinement of lines of research that were originally developed from one (KA or IA, in this case) perspective.
- Re-situating central constructs, with respect to new a contrasting perspective in a way that can result in expanded meaning for theoretical terms or extending the range of previous empirical results.

The current symposium gives examples of both of the above kinds of outcomes of integrative work. We examine in detail two cases of bridging KA and IA in an attempt to better understand processes of learning in interaction. We now give brief descriptions of the two methodological perspectives that are the focus of this symposium: IA and KA.

Interaction Analysis, **IA** (Jordan & Henderson, 1995) provides methods that have been used to study conceptual learning and teaching as mutually-accountable, purposeful activity (e.g., Hall & Greeno, 2008;

Stevens, 2010; Stevens & Hall, 1998) that is accomplished through the sequencing of conversational turns, the monitoring and repair of understanding, and how talk is designed with a recipient in mind. IA methods draw upon foundational work in linguistic anthropology, ethnomethodology, and Conversation Analysis (e.g., Garfinkel, 1967; Goffman, 1967; Goodwin, 1994; Goodwin & Heritage, 1990; Sacks, Schegloff & Jefferson, 1974). Knowledge Analysis, **KA** (diSessa, 1993; 2004; Parnafes & diSessa, 2013, and Sherin, 2001), focuses on the nature and form of individual knowledge systems: what they are comprised of, how they are organized, and how this organization changes over time in interactions with the physical, social, and material world. KA has intellectual roots in developmental psychology (Piaget, 1930) and computational modeling (Newell, 1980) and is primarily concerned with elucidating the form, content, and dynamics of knowledge through the study of episodes of moment-to-moment processes of thinking and learning. Both perspectives rely upon video records of actual learning interactions, pay attention to what happens on a moment-by-moment basis, look for contextuality, and try to account for shifts in contextuality.

The Structure of the Symposium

In this symposium, we zoom in and explore two pairs of analyses in detail. A point of synergy between these two pairs of analyses is the way that they, in very different ways, draw upon and extend the theoretical construct of a *coordination class* (diSessa & Sherin, 1998). A coordination class is a particular model of a concept, the function of which is to read out a concept-characteristic class of information across the many situations in which one encounters the class of information in the world. Coordination class theory is associated with KA and is usually used for analyzing the structure and dynamics of an individual conceptual system. Coordination class theory is used to extend an IA analysis in the first pair of analyses, and is elaborated on using IA methodology in the second pair.

The first pair of analyses originated from a study drawing on IA methods by Stevens & Hall, exploring the notion of disciplined perception documented in Stevens & Hall (1998). Drawing on this data set, Levin & diSessa add a KA layer, to explore disciplined perception and the interactional practices underlying its development through a coordination class theory lens. Following Levin & diSessa's analysis, Stevens & Hall will respond, providing both context for the original analysis and a current view from their perspective. In providing context, they will also elevate features of their methodological approach in the original analysis.

The other pair of analyses originated from a KA study by Parnafes using coordination class theory, documented in Parnafes (2007). Parnafes will highlight the principles behind the KA work she did in analyzing the development of conceptual understanding through the interaction of a pair of students with a computer simulation. Following this, Danish, Enyedy, and Parnafes focus on a small episode of student interaction from the same data-set Parnafes studied in order to use IA tools to explore the interactional patterns between the students as they constructed new understandings.

In closing, our discussant, Timothy Koschmann, will reflect upon the integrative agenda as it is exemplified in the four presentations.

Disciplined Perception Through the Lens of Coordination Class Theory

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Introduction

We explore the agenda of integrating accounts of learning developed via contrasting analytic and theoretical lenses. In this paper, we use coordination class theory (diSessa & Sherin, 1998) to reconsider an analysis of learning processes originally conducted by Stevens and Hall (Stevens & Hall, 1998). We start from the same episodes they identify as instances of "disciplined perception" and processes of "disciplining perception." Our analysis resulted in building an individual level analysis into the existing interactional account. In this paper, we reflect on the affordances of building integrative accounts through such layering of analyses.

Background and General Results of the Original Analysis

Stevens and Hall introduced the term "disciplined perception" to capture the ability of experts to "quickly register features that are relevant to their particular practice, features that are invisible at a glance to non-experts" (Stevens & Hall, p. 108). Beyond this, disciplined perception encompasses "active and embodied practices" typically extending over time and across people and things by which individuals bring heterogeneous elements (e.g., various representational media) into coordination. To study processes by which perception is disciplined, Stevens and Hall document "naturally occurring sequences in which people assemble and coordinate aspects of visual displays to make practically relevant objects of conditions visible to themselves or co-participants" (p. 108). One of the outputs of the analysis in Stevens & Hall, 1998 is a first-order model based of how learning through interaction or "disciplining perception" occurs: Joint activity progresses until a breakdown of communication is noticed (usually by the more experienced participant). This breakdown in communication then leads to intervention and attempts at repair by the more experienced participant. In this interactive process of repairing breakdowns in intersubjectivity, the perception of the less experienced participant is shaped and becomes more disciplined.

Integrative Potential and Foundations

Despite historically different theoretical and methodological lineages, in a fundamental way, Stevens and Hall's disciplined perception and diSessa's coordination class theory share important features that make them amenable to a "dialectical" or "integrative" analysis. Firstly, the social practice level description of competence given in Stevens and Hall, 1998 is not incompatible with the informational processing description given in diSessa & Sherin, 1998. Both perspectives on expertise and its development focus on the role of perception. Both perspectives develop their theoretical accounts through the analysis of data of real-time processes of reasoning. For both, what individuals are attending to and noticing in real-time is of critical importance. The original analysis of disciplined perception, done by Stevens and Hall, gave primacy to the way perception is shaped through social and material means. In reformulating disciplined perception from a coordination class theory perspective, our approach is to build from their analysis, examining in more detail what, exactly, individual participants need to see, and how they do so, in particular learning interactions.

Stevens and Hall use two contrasting focal case studies to illustrate the nature of disciplined perception and how it develops: the case of Adam and Bluma, involving a young algebra student learning about linear functions via interactions with a computer program and a tutor and the case of Jake and Evan, concerning two professional, yet differentially experienced, roadway engineers working together on producing a justification for a design of an overly steep roadway. Though we have analyzed both cases through the lens of coordination class theory, for reasons of space, we focus only on the case of Adam and Bluma in this paper.

Sample Analysis: The Case of Adam and Bluma

Stevens & Hall (1998) analyze segments of an extended tutorial interchange between an experienced algebra teacher/tutor, Bluma, and a young algebra student, Adam. Adam has been working with some graphing software to explore the connections between equations, the lines they correspond to, and various points and intervals on the graphing plane. Adam comes to rely upon a particular representational form in order to solve the problems posed to him such as those that involve determining the relative locations of points and lines (e.g., whether a given point is on a line or not). The representational form in question is "grid view" a conventional pair of crossed axes, but with dots added to mark grid points, mainly at integer x, y locations. Adam uses this framework exclusively, and when Bluma tries to provoke him to use alternative strategies, he persistently does not know how, and he also makes clear that he does not see the point of alternative strategies.

A focal case is the task of deciding whether a point is on a given line. To solve this problem, Adam draws a line by marking a few "representative" points on it, for example, x = 1, 2, 3, computing the corresponding y values from the equation (of the form $y=mx+b$). Then he sketches the implied line, and merely observes whether the point in question (also plotted on the graph) is on the line or not. Although Adam clearly knows how to identify points by their coordinates, and he can also determine coordinates, given a plotted point, he systematically does not, and claims he cannot, use the equation directly to determine whether a point is on the line corresponding to a given equation. To Bluma, as a mathematically more experienced participant, physical graphs are ancillary, and one can easily "see" whether a point is on a line by evaluating the y corresponding to the relevant x using the equation, verifying that the computed y matches the y from the point in question. Finally, Adam realizes how he can use the equation of a line ($y=2x+5$) directly to check whether a given point (3, 8) is on it. This occurs after several attempts by Bluma to keep the grid view out of consideration, hoping Adam will then turn to the simpler and more epistemologically fundamental equation strategy by himself. She never suggests any details of how one does this; she only says that there is another way to determine whether a point is on a line that does not use drawing lines and plotting points.

In viewing the above events through a coordination class lens, we first identify the relevant coordination class: the determination of object location. Here, we intend both "object" and "location" in an extended sense, including things like points and lines in Cartesian space with respect to one another. Stated another way, the competence at stake involves the kinds of strategies by which people "see" where things lie with respect to one another. In this case, Adam merely "observes" the spatial relationship of a given point and a line. First, he must instantiate the relevant point and line, as opposed to simply determining their relative location where they happen to lie. This is easy for Adam—and he knows it; he knows how to plot (position) points and lines, given coordinates of a point and the equation of a line. Determining (observing) a spatial relationship, the critical coordination class operation here is easier than in many cases of determining relative position, since the only relevant determination is "point on line" or "not." Assimilating the work Adam does in response to point-on-line questions to the "relative spatial location" coordination class does two pieces of work for us. First, it explains why the method he uses is so simple and obvious to him. (First, you put things where they belong, and then you observe their relationship.) Second, it helps explain how natural Adam found this method and why he found the possibility of other strategies so foreign. How else can you determine spatial relationships without observing? Why would you want to?

Discussion

While Stevens and Hall emphasized Bluma's role in Adam's learning, the coordination class analysis encourages us to reflect on the fact that Adam noticed something. Bluma did not draw his attention to it, except in the general sense of putting him "in the vicinity" of the thing to notice. At that moment, it was his choice to select x=3 to enact the procedure to sketch the line, unintentionally matching the x coordinate of the point under consideration, allowed him to notice that this would give a general method to solve such point and line problems. We conclude that we can only partially credit Bluma with "disciplining." The rest of the credit goes both to chance, and to Adam's ability to notice this particular thing and see its generalization. Not every student will be able to do this, so we *must* have a way to talk about individual differences between the organization of Adam's knowledge system and others' if we are to be able to predict insight and, hence, development. Our analysis points to the need to complexify the determinism implied by the first order interactional model of disciplining perception through negotiating breakdowns in intersubjectivity given in the original paper.

Our analysis is not merely a complementary analysis to Stevens and Hall's. We considered the same data and the same phenomenology within the data: the nature of technical competence and how it develops in interactions between people. The implications for the integrative agenda seem to be that two-phase analyses (in this case, first an IA account of knowing and learning, followed by a KA analysis) can lead to an enriched account that draws upon both phases of the analysis. The second phase of analysis, illustrated here, seeks to extend a previously identified theoretical idea, disciplined perception, by providing a glimpse of what is going on beneath the surface of observable actions. Our general approach has been to explicitly build on and locate within an analysis done from an IA perspective, issues that can be illuminated by a KA perspective. Thus, though the second phase of analysis we produced is not itself an integrated analysis, we see this process of layering and elaboration of analyses as serving an instrumental role with respect to the larger integrative agenda.

Yipee KAIA and other Cowboy Expressions of Joy

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Appreciations

We start by appreciating the spirit of exchange evident in Levin and diSessa's effort to re-analyze a fragment of interaction from our earlier chapter on "disciplined perception" (DP), using a theory of coordination classes consistent with their approach to *knowledge analysis (KA)*. We have left Adam, Bluma, Jake, and Evan behind us, but they are still richly present in our analytic imaginations—this is the sort of durability of memory you get by engaging with *interaction analysis (IA)* of learning.

Some History

Disciplined perception is a concept built out of close analyses of video recorded cases of people in interaction, engaged in complex sociotechnical practices. Our interest in putting this concept into circulation was, in part, corrective, as theoretical work often is. At the time the paper was written and revised (between 1992 and 1998), the field we now call the learning sciences mostly cared about learning and knowing in disciplines, particularly in math and science. In the work we were doing, prominent accounts of cognition and learning left out too much that mattered to how people learned and used knowledge together. These accounts were richly furnished with actants of the mind—schemas, concepts, sub-goals, productions, p-prims—but were anemic when it came to actants of the observable world—voices in conversation, computer screens, drawings, pointing fingers, moving hands, and noticing eyes. We wanted to correct this, to provide a theoretical alternative.

Our Alternative (Then) and Agreement (Now)

Borrowing techniques and principles from conversation analysis and ethnomethodology we attended to observable actions and interactions, and moreover to what participants in interaction were noticing, seeing, using, and making matter to themselves and to each other. What we were studying after all were *their* interactions. That we refrained (for the most part) from looking past the observable actants (turns at talk, hands in motions, computer screens, drawings, gestures, pointing, etc.) into the world of mental actants that are so readily visible to many cognitive scientists was indeed part of the corrective. That being said, we held no epistemological or ontological stance (nor do we now) that rules out a parallel and integrated account, one that seeks to argue for durable interior resources we 'acquire' and carry around with us that give shape to our actions. We remain skeptical about how observable actants and actions can be *seen through* to provide a confident account of interior actants and processes. But Levin & diSessa make a creative attempt to take our account of the observable actants in interaction more or less as we provide it and then speculate on mental actants that they would argue are present and at work, operating "beneath the surface of observable actions." The devil is in the details, but in principle we share with our colleagues here the goals of an "integrative account."

Some Details

We have chosen to focus on two points where the details Levin and diSessa's analysis depart from ours in ways that matter theoretically. These are treating Adam's grid calculus as a pre-classified way of thinking and arguing that our DP concept is simple and deterministic as an account of learning and teaching.

It's a "grid calculus" not a "particular representational form." What we called Adam's "grid calculus" provided him with a way of dealing with problems posed by Bluma, the software in the tutorial interaction, and their tutoring conversation over time. At least for a while. It was not a "particular representational form" in our thinking and analysis. That was a substantive theoretical point. By calling it a "calculus" we deliberately wanted to draw attention to its history and powers, a discovery or invention that was *his*. The coordination class analysis developed in the paper by Levin and diSessa pre-assigns the meaning and value of Adam's activity to a "particular representational form" and pre-assigns a "simpler and more epistemologically fundamental equation strategy" to Bluma. This assignment of relative value of the two different practices for graphing functions *in these tasks as they unfold in time in these interactions*, though we do agree are different and said so, is not demonstrated or directly analyzed in the coordination class approach. It instead seems given before their analysis starts—not something for discovery in interaction *by* Adam and Bluma. This runs off the rails of our understanding of interaction analysis (with its CA and EM roots). So this is not a productive integration strategy, from our perspective.

DP is an interactive achievement, not a way of shuffling individual mental contents. One of Levin and diSessa's central challenges to our interpretation, consistent with their view that our DP concept is simple and deterministic, is their claim that the tutor's actions of 'disciplining' are only "partially" responsible for an observable change in Adam, implying that we were arguing they were entirely responsible, or otherwise "determined". We did not argue that disciplining perception determines anything here or that Adam was particular determinable. And we find this interpretation of our view extremely hard to hold if we restore the storyline we painstakingly built up over an analysis of the previous seven episodes. Across those episodes we depict an Adam who is everything but malleable. We depict a young person who has found, uses, and tenaciously holds on a cognitive practice, which while idiosyncratic from a normative perspective, is his and moreover works in the practical context of the work that he is asked to do with the math problems. Our goal was to describe the actual observable practices of disciplining in whatever forms they took, which turned out to be diverse. (For an outright programmatic defense of a research program founded on documenting and studying this diversity, see Stevens, 2010). The strongest move the tutor Bluma makes in all the episodes is not deterministic at all; it seeks to block Adam's use of the grid, a move oriented to having him try to 'figure it out" in a different way, presumably the conventional way. This happens only when she finally notices that he is using the grid calculus to "figure out" the problems, a practice that was until then seemingly all but invisible *to her* because of *her* disciplined perception that privileges the equations as a means for figuring it out. Our account is not simple, though we were refreshed by this suggestion since both of us generally face down the opposite accusation of rendering things too complex, even when we regularly find and show them to be so in the unfolding interactions of the people we study. Our account *does* include material and social actants that are explanatory, actants and observable phenomena that are (thus far) entirely missing from the explanatory vocabulary of coordination class theory or the use of KA brought to the re-analysis of the conversations and activities we analyzed.

Levin & diSessa's reinterpretation focuses on turns at talk from a final episode when there is an articulated turning point in Adam's practice, when he *finally* recognizes the possibility of using an equation. As we note, this is *Adam's realization* and it should seem clear that we in no way suggest that Bluma *determines* this realization. However, we do make a point of highlighting that there is *interactional evidence* that she *influences* it. In the episode, the math problem involves how a hypothetical student Sue would determine if a point is on a line only expressed as an equation. In turn 4 of the episode, there is strong evidence that Adam thinks the route to answering involves deploying some version of the grid calculus. As in the previous episode, even though the grid is gone, he starts to actually restore it by drawing it, such is its robustness in this sociotechnical system for him. But then Bluma makes a hard insertion into his conversational turn that—while determining nothing—certainly conveys to him a sense that he should be doing something different. His answer is responsive to this move both in the way it starts with "oh well" and how it moves on to his own articulation of what "I *should* be doing". So while we are fully in agreement with Levin & diSessa that Bluma does not determine the disciplining here, the question is whether such a hard pivot in his actions doesn't provide good evidence of *influence*.

Looking Back and Forward

We end with a question that has lingered in the ongoing conversations between our group and theirs and a wider set of colleagues represented in this symposium, all of whom are exploring the possibility of integrating perspectives. As is well known, most of the interior actants that populate 'knowledge analysis' accounts have been generated in clinical interview contexts. Those are contexts that rely on the view that a subject's knowledge is probed and elicited by a skillful interviewer and rely as well on the idea that the knowledge that is displayed by subjects is not shaped in decisive ways by any particular thing an interviewer says or with what timing or prosody he says it. But this influence as an empirical possibility is the very premise of interaction analysis, to be shown, or not shown, in actual analyses of recorded interactions. So the idea that a non-explicit, non-deterministic conversational turn like Bluma's could truly influence a shift in knowledge, as interactional evidence suggests it did here, might be perceived as a significant threat to a much larger enterprise.

A Coordination Class Analysis of Individuals in Interaction

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In this presentation I will revisit the KA I completed a few years ago (Parnafes, 2007) with new attention to how knowledge analysis was employed to analyze the individual students' understanding. I intend to abstract the principles of analysis and comment on the assets and limitations of that analysis. I will also examine the way that interaction and social context was taken into account in the specific KA.

The prior research investigated how computer-based representations facilitate the development of conceptual understanding in the domain of harmonic oscillation using coordination class (CC) theory (Parnafes, 2007; 2010). CC theory was used for the analysis of student understanding in this context because it enabled me to look at the process of conceptual change at a fine-grained level, with the aim of describing the mechanisms of developing understanding. In addition to the conceptual processes, CC theory refers to perceptual processes, and thus was particularly suitable for analyzing processes of learning in a learning environment rich in external representations. This also provided an opportunity to examine possible relations between representations and conceptual change.

The research included case studies, in which dyads engaged in learning activities to explore the phenomenon of natural harmonic oscillation through the interaction with physical oscillators and with a computer-based simulation. The choice to work with dyads rather than to use clinical interviews, which are typical in KA methods, was due to several reasons. First, it was important to establish a relaxed atmosphere in order to promote meaningful, productive discussions. Second, students who worked together expressed their thoughts verbally with no need for prompting. Third, interaction in dyads advanced the development of explanations since, in some cases at least, students challenged each other and asked questions about their partner's explanation. The choice of looking at the interaction of dyads through learning activities, thus, created good opportunities for rich and high-quality data production.

The other side of that richness is that the analysis of conceptual understanding of two students interacting and affecting each other's understanding, posed some critical methodological challenges. Coordination class theory accounts for describing the fine details of the architecture of an individual conceptual system and its development. But in the case of the interaction of two students, the evolution of each individual's coordination class was a function of the interactional activity between the students, resulted in a complex system of collaboration. In such a setting, the researcher has to deal with the complexity introduced by having two conceptual systems interacting with each other, and with a material environment.

As an example for this complexity, and the way I handled it using CC theory in the KA tradition, I use one episode of a case study from this research. In this case study, two 10th graders explore a simulation that has multiple representations of natural harmonic oscillation. They work with the simulation to explore how to make the oscillator go fast. Throughout the episode, the two students seem to act as if they share the same understanding, and they collaborate on this task almost with no disagreements or breakdowns.

The focus of a knowledge analysis would be primarily conceptual, analyzing the structure of the students' knowledge and how this structure develops as the activity unfolds. In the case of the interaction between students, I considered two choices for analyzing the two students' conceptual systems. One option was to treat each student's conceptual system separately (considering and treating as relevant the input from the interacting person). The other choice was to treat both students together as one system, assuming both students are on the same page. In the analysis I did, when it was apparent that the two students were thinking and reasoning differently, one student's conceptual system was analyzed separately, with the other student taken into consideration as providing inputs for the conceptual processes of the analyzed student. When the students were in sync, the analysis focused on both of them together, as if they formed a "shared" conceptual system.

Here is an example from the analysis, taken from Parnafes (2007). The students try to figure out what "fast" mean in oscillatory motion using a computer-based simulation. They are now working with the simulation and experimenting with different parameters of the simulation. On the computer screen there is a velocity versus time graph, as well as other representations. One of the students, Robin, points with the mouse to areas on the graph and says:

"These are the same skinniness level but they are not as high." She compares the graph appearing on the screen to a graph appeared previously with a different parameter value. Following this utterance, there was a short interaction between the two students that led them to re-check the previous representation, and verify and consult with each other. However, the inferences made after this exchange was similar to the first inference made by Robin.

The KA analysis of this segment in Parnafes (2007) focused on what Robin had said and her reference to the areas on the graph, and since both students were involved in this activity and seemed to be in agreement the analysis referred to both, even though Robin was the one who made the inferences: "Sue and Robin compared inferences from two settings: before, with smaller displacement, and now, with larger displacement. The distance between the "hills of the graph" was the same, but the peaks of the graph were higher in the current case" (p. 436). The information read from the graph and the inferences made were all considered to be shared by the students: "The students now had clear and stable perceptual foci that allowed them to detect the patterns in the simulation: the "skinniness" of the graph and its height" (p. 436). Furthermore, the short exchange between the students and the verification wasn't at all considered in this analysis. This interaction wasn't considered as consequential for the conceptual processes that were happening during this activity and was thus ignored.

What the analysis didn't do was to handle two active conceptual systems at the same time, with lived interaction between them. Many interactional moves were not analyzed and were considered transparent to the conceptual process of either the "system" or the two individuals. The interaction was "flattened", and what was brought into focus was one conceptual system (either of one actor, or a shared), and the processes that occurred within it. What happens outside that system was only considered as an input for the system.

Despite the limitations of these choices, the KA using CC theory produced some insightful and significant results about students' processes of developing understanding. The analysis offered a detailed description of students' critical steps in the development of conceptual understanding. The use of CC theory enabled me to track the development process of students' understanding with the simulations' representation. The detailed analysis resulted in a model describing four mechanisms that drive the development of understanding through the mediation of computer-based representations.

The results came out of the KA using CC theory could have been very difficult to produce, in the first place, with an integrative approach of paying equal attention to both knowledge and interaction. There are tradeoffs that we should be willing to consider in order to focus deeply on a particular aspect of interest. If we are aiming to produce a new theory on conceptual understanding, we may want to simplify the complexity introduced by interrelations to other aspects. Thus, "flattening" interaction enabled focusing deeply on individual conceptual understanding while compromising the depth of interaction and social context. However, integrative analysis may be conceived as being done in stages, where a later stage of analysis allows a richer analysis to eventually emerge that serves new purposes than the original analysis.

A Coordination Class in Interaction

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Our work is grounded in the assumption that knowledge and interaction are fundamentally inseparable. This suggests that there is value in considering how interactional context influences the analysis of knowledge, and how an understanding of knowledge might in turn advance our considerations of interaction. Traditional approaches to knowledge analysis typically focus on social context and aspects of interaction to the extent that these aspects appear to be directly consequential for the analysis of conceptual structure and processes. In line with Parnafes' reflection on KA (this symposium), efforts are often made to account for the influence of an interlocutor on one individual's knowledge rather than treating a dyad as a combined unit that is co-constructing knowledge in interaction as many interaction analysts would assume. Interaction is not analyzed systematically and in any case doesn't play a central role in the attempt of understanding the learning situation. Therefore, in this paper our goal is to explore the implications for explicitly and intentionally combining knowledge analysis with interaction analysis in order to describe the process through which multiple participants may co-construct knowledge.

In direct contrast with the KA focus on knowledge over interaction, IA is designed to understand how people make sense of the social context that they are concurrently co-constructing with others. Knowledge is typically only viewed in terms of how it sheds light on the interaction. Thus, individual students' understanding is rarely explored in depth beyond its role in promoting interaction. Further, because IA takes a strong line towards avoiding analysis of anything beyond what is present in the current interaction (e.g., a focus on talk and gesture), this kind of knowledge is rarely explored in the way that KA does.

Our integrative analysis attempts to do both. We attempt to analyze the role of interaction in producing, shaping, and revealing students' knowledge, as well as how knowledge helps to structure, promote and necessitate new interactive components. Specifically, we attempt to complement Parnafes' (2007) prior KA by creating a synthesized account that we believe goes beyond what either KA or IA would accomplish individually. To support this effort we re-analyze the same episode as presented by Parnafes with the intention of explicitly introducing an IA and integrating it with the prior KA to show how the two can enhance each other. By contrasting this synthesized analysis with the prior analysis it also becomes possible to articulate how the one builds explicitly upon the other and to attend to the strengths and weaknesses of both approaches. Thus our paper also analyzes the episode of two students working together with a computer simulation to jointly develop and produce a way of reasoning and making inferences about the interrelations of speed, time and distance in the context of natural harmonic oscillation. We focus on small group work as a site for understanding the relationship between knowledge and interaction, as this kind of organization is both ubiquitous and assumed to support learning in a number of ways.

Several assumptions guide our attempts to do integrative analysis of KA and IA, and we use this specific case, already analyzed with a KA approach, to demonstrate the merits of such integration. First, we assume that individual learning is often influenced by interaction and collaboration with others. Second, we assume the shape or structure of what is learned will often reflect the nature of the interactions in which learning occurs. Third, there are potential benefits to well-organized collaborative learning that might make collaborative knowledge construction different and perhaps more flexible or robust than individual knowledge construction.

To help illustrate how the two approaches might be integrated, we conducted our analysis in three passes. First, we completed a strict KA that focused on the organization of the students' knowledge. Second, we completed a strict IA that focused on how the students were interacting and why. We refer to these analyses as "strict" because we attempted to avoid developing un-systematic and common-sense inferences about the aspect of the analysis that we were not focusing on. That is, we attempted to avoid casual analyses of interaction during our KA or knowledge in our IA pass. Finally, we attempted an integrative analysis that builds on both while aiming to explicitly identify the role of interaction in influencing students' knowledge and vice versa. To accomplish this we examine the sequential production of talk, identifying moments where the students construct intersubjectivity, or appear to lead to conclusion. As they achieve intersubjecitvity, we then highlight the interactional elements necessary to help create this moment of shared attention and understanding.

For example, our case study episode begins with Robin noticing that two graphs have the same "skinniness" but one is higher than the other (the same segment presented by Parnafes, this symposium). From a KA perspective, we note how Robin therefore is noticing a representational discrepancy, and building on her understanding of graphs and of velocity to recognize that these features are both relevant and different, though she has not yet articulated why that might be the case. From an IA standpoint, we note how crucial gesture (using the mouse) is to this exchange, allowing Robin to help direct Sue's attention to key features of the graph, and allowing them to develop a shared sense of what they are discussing (intersubjectivity). Furthermore, simple descriptive phrases such as "skinniness" which are non-technical appear to help establish intersubjectivity. We also see Sue ratifying the sense that there is in fact a shared intersubjective understanding of the setting with simple phrases such as yeah and yes. Our integrative analysis then further suggests that this simple establishment of intersubjectivity is in fact made possible by some shared knowledge structures—that Sue's ability to read the same anomaly that Robin sees allows them to be on the same page, while the fact that they are actually on the same page (indicated later in the episode) helps to strengthen our belief that their knowledge structures are similar with regard to these concepts. This work to establish a shared understanding is then crucial to how the students make sense of the notion of speed in the remaining episodes, which we will describe in greater detail in our full paper.

While this is only a very brief example from the first line of interaction, it helps to illustrate our approach. In particular, we can begin to see here how the combined approach helps us to systematically identify the relationship between the interaction and interactional processes and the knowledge that is so crucial to this exchange. In the remainder of our analysis, we further indicate how the ongoing effort to maintain intersubjectivity within the social context of doing inquiry in a classroom helps to move the students' knowledge construction forward. At the same time, it is increasingly clear that without an evaluation of the students' knowledge, we could make little sense of some of the exchanges beyond saying simply "the students appear to agree on what this means." Given our interest in analyzing and designing educational environments, this approach therefore supports our efforts in better understanding how learning and knowing are supported through rich social contexts.

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