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Perspectives on Learning:

Methodologies for Exploring Learning Processes and Outcomes

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Abstract

The papers in this Special Issue were initially prepared for an EARLI 2013 Symposium that was designed to examine methodologies in use by researchers from two sister communities, Learning and Instruction and Learning Sciences. The four papers reflect a common ground in advances in conceptions of learning since the early days of the "cognitive revolution" in the 1960s. This commentary shows the interdependence between advances in theory and advances in methodologies. Four shifts in conceptions of learning are described. That these shifts are evident in the work of both communities suggests a blurring of the boundaries between the two.

Keywords: Learning, collaboration, mixed methods

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The papers in this Special Issue were initially prepared for an EARLI 2013 Symposium that was designed to examine methodologies in use by researchers from two sister communities, Learning and Instruction and Learning Sciences. A main goal was to explore what these methodologies might reveal about underlying conceptions of learning and potential common ground across the two communities. Indeed, the four papers, taken together, reflect a common ground in advances in conceptions of learning since the early days of the "cognitive revolution" in the 1960s. The papers depict highly systematic, thoughtful, and rigorous approaches to studying learning as it is happening whether individually, in small groups or large; in classrooms, in workplaces, or in labs; face - to - face or virtually; in one moment in time or over extended periods. They also illustrate the interdependence between advances in theory and advances in methodologies.

During the 30 year period from 1960 – 1990, the majority of studies of learning took place in one location: the laboratory; looked at individual cognition as a function of an operationally defined and restricted set of variables, in one time frame with occasional return visits. Although some researchers were examining learning in the context of tasks students might be asked to do in school, many of the "learning" situations were set up as experiments that were highly constrained to maintain experimental control over "extraneous" variables; as well the tasks were frequently "toy" problems that had little relevance to classrooms or other contexts outside of cognitive theory and the academic settings in which the research was being conducted. Consequently, it was difficult to see how findings from the lab could possibly have relevance to everyday learning. Emphases were on manipulating characteristics of the materials, the task, or both and observing how people "solved" the tasks and their success at doing so with some emphasis on understanding how they had completed the tasks. Some of the findings emerging from that research shaped instructional studies in which people were instructed to summarize sections of text, underline main ideas, break down tasks into subtasks before solving them, group words based on taxonomic categories to improve memory, and similar heuristics. Published studies of this sort attest to the success of these approaches in building a cognitive theory of learning and problem solving that superceded extant behaviourist/empiricist views (cf. Greeno, Collins, & Resnick, 1996). There was, however, little uptake of these theories by educational practitioners.

In addition to changes in the conceptualization of learning and the kinds of questions being asked about learning, data analytic methodologies have come a long way since the 1960s. Some of the (older) readers of this article will remember the days of doing ANOVAs by hand, with "advances" marked by programmable Wang calculators, and main frame programs that automated the process. Of course, you had to batch process jobs, submitting stacks of punch cards containing the data (all the time living in fear that you would drop the deck and have to start again making sure they were in the right order) and then wait for the print out. Turnaround varied from 10 minutes to 24 hours. Over the past 30 years there have been huge advances in the technologies and data analytic applications available on devices that are small enough to carry around the way we once carried pads of paper and notebooks (not electronic ones). These technologies have expanded the ways we dare to think about analyzing our data, enabled us to collect and make sense of new forms of data, and automated or semi-automated analysis methods that we used to do solely by hand.

Currently, the Learning Sciences and Learning and Instruction communities operate with theoretical frameworks on learning that reflect more complex views of learning in four major ways. We now understand and attempt to study learning

1. in multiple and iteratively designed environments
2. over multiple time scales
3. occurring in social groups of multiple and collaborating individuals

4. with effects evident at multiple levels ranging from behavioural to neural.

As a set, the papers in this Special Issue reflect these shifts in conceptions of learning and its investigation and provide us with methodological tools that enable us to rigorously investigate learning processes and outcomes despite the greater complexity of doing so. There is evidence of one or more of these shifts in conceptions of learning among researchers who identify with Learning Sciences, as well as among those who identify with Learning and Instruction, suggesting something of a convergence, or at least a blurring of the boundaries of the two communities.

1. Learning in Multiple and Iteratively Designed Environments

Design-based research marked a pivotal shift in perspectives on learning and its study in classrooms. Svihla (this issue) provided an excellent description of the goals of this research approach. Up until the time that this approach to research on learning was introduced in the early 90s by Ann Brown (1992) and Allan Collins (1992), educational research in schools typically took the form of relatively short-term experiments that involved comparisons of the effects of different methods or materials on various cognitive skills. The studies were usually conducted by the researchers. Teachers "cooperated" with the researchers in terms of providing access to their students for the duration of the study but were otherwise minimally involved in contributing to the instructional design or the materials. A major goal of this research was ascertaining which instructional methods were better than others for achieving largely cognitive objectives such as more accurate mathematics performance, better memory for new vocabulary, and better comprehension of text. Accordingly, assessments were designed to measure changes in students' performance as a function of having participated in the study either in the "experimental treatment" or the "control" group. Along with these types of cognitive studies there were similarly designed studies that examined the impact on individuals of having worked in cooperative groups (e.g., Johnson & Johnson, 1999; see for review Webb & Palincsar, 1996).

As Svihla described, the goals of DBR reflected a fundamental shift to an emphasis on studying learning processes in situ as both social and interactional (Collins, 1992). Learning processes were studied in the context of designed learning environments developed through collaborations of researchers and practitioners and based on principles that constituted a learning theory. Enactments of designs were objects of study for purposes of understanding how, with the understandings that emerged from close study of, and reflection on, the interactions and student work informing iterative refinement of the learning theory principles, and designs. Svihla does an excellent job of depicting the ways in which DBR has developed since its initial introduction. Suffice to say it made apparent the need for methodologies to capture processes occurring over multiple time scales and among individuals in social configurations.

2. Learning processes over multiple time scales

Complex views of learning make it clear that processes occur over time, with different learning processes occurring at different time scales. Molenaar (this issue) provided an excellent rationale for the need for temporal analysis methods. She described a variety of the issues involved in shifting from a focus on whether a particular construct has been learned or not to a focus on how that construct is learned, what that learning looks like at different time scales, and indeed what constructs are conceptualized as emerging over longer versus shorter time frames (cf. Lemke, 2000). She referenced a variety of constructs that we now

think of as emerging over events and across time but that used to be thought of as personality traits (e.g., motivation, persistence). She discussed various computational tools that can aid in segmenting, coding, and relating different time scales. These methodologies are critical to doing the analyses needed to understand learning over different time scales.

A variety of issues face us as individual researchers and as a community as we apply methodologies for temporal analysis: What units of time are appropriate for particular constructs of interest, especially when multiple time scales operate in parallel? How do we determine the time scale most appropriate for tracing the emergence of a construct over time? Or alternatively, how do we capture the interrelationships between events occurring over time but at different time scales? Of potentially many patterns of events that might be extracted by pattern detection software, how do we determine which are psychologically meaningful and at what scale of time they are meaningful?

Equally necessary are new forms of representation that can assist us in conveying our findings to the broader community. Molenaar (this issue) presented one form of representation. Figure 1 illustrates a different form of representation in which we plotted the discourse moves of three students comprising a small group engaged in a science investigation (Radinsky, Goldman, Doherty, & Ping, 2010). This particular figure shows the moves for the first day of the investigation. We plotted similar representations for each day and then used the graphs to identify regions where there were clusters of moves across the three students that suggested there were interesting dialogic discourses occurring. We then "dove" into these segments of the discourse to determine the character of the "argumentation" in which the students were engaged and whether the claims and evidence being offered were similar or different later in the investigation versus earlier. As well, we considered how participation and roles in the discourse revealed dimensions of identity and positioning with respect to disciplinary competence. This form of representation was a useful analytic tool and with some refinement might be a useful way to represent the time course of argument development (Radinsky, et al., 2010).

Molenaar highlighted the need to conceptualize different dimensions of time in order to define important temporal characteristics. She cited papers by Bloome, et al. (2009) and Lemke (2000) as informing this discussion. In addition, Bahktin's (1981) framings of time in relation to discourse, meaning, and learning will be a useful resource. We also need to (re)connect learning and development. Indeed, the move from the more traditional educational research paradigms to DBR and related learning sciences methodologies creates a convergence between research on development and research on learning. That is, one distinction between development and learning had traditionally been the time frame over which phenomena of interest emerged. Those that occurred over multiple years were called developmental, e.g., oral language; those over minutes or hours, learning, e.g., declarative knowledge such as "c – a – t" spells cat; or propositions such as EARLI is a professional research organization. Arguably, a second distinction was whether the phenomenon emerged with or without formal instruction, the latter being deemed developmental phenomena and the former learning. For example, children develop oral language but learn to read with explicit instruction. Because developmental psychologists have long been concerned with the study of change over time, they have developed techniques that examine change over relatively longer periods of times such as growth analysis (Willett, 1989), as well as techniques that look at moment - to - moment change, such as sequential analysis (Bakeman & Quera, 1995) and microgenetic analysis (e.g., Kuhn, 1995; Siegler & Stern, 1998). These methods are rich resources for examining learning over multiple time scales.

3. Learning in social groups of multiple and collaborating individuals

A core assumption of the Learning Sciences is that learning is social and interactional and takes place through situated activity (Brown, Collins, & Duguid, 1989). Collins, Brown, and Newman (1989) labeled the approach cognitive apprenticeship, reflecting the importance of observing the habits of mind as well as the actions of the more knowledgeable others in the community (cf. Vygotsky, 1978). Hence, discourse about activity and interaction with others engaged in the activity became a central focus for understanding learning. Researchers with intellectual roots in a variety of disciplines have long relied on discourse among participants in a joint activity as a window into knowledge building processes of groups as well as individuals, and, along with gestures, into processes of learning through joint activity (Gee, 1992; Goodwin, 1994; Hutchins, 1995; Lave & Wenger, 1991; Sawyer, 2006; Scardamalia & Bereiter, 1991; Schegloff, 1991, 2007). Video and audio recordings have typically provided the raw data and various types of very time-consuming and intensive qualitative analyses have been used by researchers to provide evidence for claims about learning outcomes and processes. Frequently and understandably given the labor-intensive nature of these analyses, the evidence provided in any one empirical report has tended to be based on relatively small data sets or corpora.

Many computer-supported collaborative learning (CSCL) environments make available written traces of learning interactions that can also be mined to understand learning processes and outcomes for individuals and for groups. Although initially these were also analyzed by humans using processes similar to those used for coding discourse that was transcribed from video and audio recordings, a number of computer-assisted methods have been developed that make the work of coding less time-consuming. Stegmann (this issue) argued that to understand the mechanisms that produced enhanced learning outcomes in CSCL, three hypotheses needed to be tested. These have been conceptualized as a "triangle of hypotheses:" "(a) instructional/technological support facilitates learning activities; (b) facilitated learning activities have positive effects on learning outcomes; and (c) mediated by learning activities, instructional/technological support has a positive effect on learning outcomes." (Stegmann, this issue, p. #, citing Wecker, Stegmann & Fischer, 2013; Fig. 1). It could be argued that these three hypotheses can be thought of as constituting an activity system (Engeström, 1987, 2001) in which tools (technology support), activities, and performances of individuals and groups exist in interaction with one another and over time. Stegman and colleagues argue that conceptualizations other than experimental designs are needed to establish relationships between learning tools, activities, and outcomes. They propose the use of nomological nets to ensure that direct and mediating relationships between the tools and outcomes can be tested. Nomological nets specify what constructs are indexed to which observables over what time frames. As well interrelationships among constructs are specified. Empirical evidence derived from collaborative activities constitute input to revisions and refinements of theoretically grounded nomological nets. These revisions may reflect mediational variables that become evident through indepth analyses of the discourse, of changes in the interactions and discourse over time, and at different "units" of analysis (e.g., individual, dyad, small groups, entire activity system).

Stegmann (this issue) argued that the indepth analyses required to "test" initially specified nomological nets should take advantage of statistical techniques designed to detect patterns of interactions as they occur over time. These techniques require some form of quantified information; therefore, qualitative analyses need to be quantified. Fortunately, there are a number of computational algorithms that can assist researchers in doing so. Importantly, these systems assist researchers in parsing the input as well as counting instances of particular codes and discovering repeating sequences of codes. The construct specification required by nomological nets is one way of ensuring that codes, sequences of codes, and

recurring patterns relate to theoretically meaningful constructs. Thus nomological nets can assist researchers in determining whether "discovered" patterns have psychological validity and practical utility.

Construct specification in nets can also assist with an additional "sticky wicket" in efficient yet automated detection of meaningful patterns of interactions. Essentially, over what time frame are patterns of interaction to be detected and at what levels? That is, if a pattern is detected in a series of successive turns does that pattern then become a "unit" that can act as input to a subsequent pattern analysis effort? How are such patterns related to constructs in the net? One might envision a series of intermediate level patterns being inferred from turn by turn coding. These intermediate levels (essentially patterned sequences of turns) are the units upon which further pattern detection analyses are conducted. Determining and optimizing appropriate time scales over which patterns of code sequences are constituted depends on understanding the intentions and assumptions of specific designed learning environments, particularly what and when specific processes are expected; why, and how they support expected outcomes. Although patterns and sequences can be detected automatically it will take human interpretive lenses and socio-cognitive theories to specify the constructs these index and their meaningfulness in the context of learning. The issue of levels is relevant not only to pattern detection but to learning in general, as reflected in the fourth aspect of a more complex view of learning.

4. The effects of learning are evident at multiple levels ranging from behavioural to neural.

Learning is "visible" at different levels. De Smedt (this issue) is to be applauded for emphasizing the need for alignment between the level and topical focus of research questions and the methods selected to investigate the questions. He pointed out that if the research question is targeted at the macrolevel, behavioral methods would be most appropriate. Cognitive neuroscience methods become appropriate for research questions focused on microlevel processes. The two most common cognitive neuroscience methods are electroencephalography (EEG) and functional Magnetic Resonance Imaging (fMRI). EEG methods provide temporal information about when particular processes are taking place and fMRI methods provide spatial information about where in the brain processes are taking place. Cognitive theories provide needed links between behavioral and neural levels.

Furthermore, echoing the point made above – that socio - cognitive theory needs to guide the interpretation of patterns in interactions, De Smedt (this issue) called for detailed cognitive theory of learning phenomena to provide needed links between behavioral and neural levels. He cited the cognitive theories and the behavioral data on which they are based as critical for interpretations of the information that results from the application of cognitive neuroscience methods. To demonstrate his claims, De Smedt (this issue) illustrated three ways in which cognitive neuroscience methods elucidate mathematical instruction. These are convincing demonstrations of the value added of obtaining data on the same phenomenon at multiple levels and coordinating findings across levels. Predictions can be pursued across levels by postulating what should be the case at one level based on manifestations at another level.

The value added of using multiple methods to examine learning at multiple levels is not restricted to mathematics. For example, in the area of language acquisition, researchers have used EEG methods to establish predictive relationships between phonemic and word-level development. Specifically, infants below six months of age are sensitive to phonetic contrasts in all languages; between six and 10 months, a perceptual narrowing process occurs that results in sensitivity to only those phonetic contrasts that matter in their native language. EEG methods have established that better neural discrimination of native language phonetic contrasts is associated with faster vocabulary development (Kuhl & Rivera-Gaxiola, 2008). Kuhl

and colleagues have also used neural activation patterns to determine that the perceptual narrowing process occurs several months later for infants reared in two-language homes compared to those reared in monolingual homes. Finally, neural indicators of phoneme learning demonstrate that social interaction plays a critical role in language acquisition (Kuhl, 2007). In each of these cases, evidence from the neural level provides measures of far greater precision than could be obtained behaviorally.

5. Summary and Challenges

More complex views of learning require more complex methodologies for addressing key questions about learning and the conditions that support it, including explicit instruction. The four papers in this special issue illustrate methodologies that assist with capturing the iterative design-based research process, learning processes and outcomes that occur at different time scales and levels, and make possible the formulation and testing of hypotheses that relate different levels to one another. The papers present examples of ways in which these methodologies are augmenting the knowledge base for understanding learning as it occurs across individuals as well as within individuals. As such they make valuable contributions to the field.Moving forward, there are a number of areas that need attention in terms of further theoretical and methodological development. Briefly, more emphasis needs to be devoted to formative assessment that provides opportunities to better facilitate instructional processes and outcomes. This includes the design and testing of tools for capturing learning interactions that are classroom, teacher, and student friendly. Such tools would enable students and teachers to reflect on their learning processes as well as outcomes at much finer levels of detail than is currently feasible. Ideally, researchers would develop and test various technology-based tools for accomplishing these goals and would then engage in “user testing” of tools that travel outside research labs and into the hands of teachers and learners. A type of tool that would be helpful in this process is one that enables visualizations of the ebb and flow of learning processes across people and across time.

Finally, the Learning Sciences community has tended to design within specific disciplines and fields; the Learning and Instruction community has tended to test principles and variables thought of as general across all learning situations. Neither perspective has as yet come to grips with the tension between generalist and discipline-specific views of learning nor the limitations of each view. What is needed are studies that 1) embrace a disciplinary perspective but that also situate that discipline in the context of epistemological orientations and inquiry methods that have been adopted and developed within other disciplinary communities; and 2) examine the “fit” of principles, constructs, and explanatory mechanisms suggested by cognitive, developmental, and social psychological research to learning phenomena observed in designed learning environments. Studies of the first type will advance our understanding of the general and idiosyncratic aspects of learning in different disciplines. Studies of the second type will advance our understanding of explanatory mechanisms that have traction across a wide versus narrow band of learners and situations of learning. There are also aspects of learning processes and outcomes that need far more systematic and sustained research over shorter and longer time scales. Specifically, we need to conduct systematic research on relationships among persistence, engagement, identity, learning processes and outcomes, within and across formal and informal contexts of learning. Some of this research is currently being conducted; more of it needs to be conducted. The methodologies discussed in these papers can be synergistic with respect to tackling these challenges.

Keypoints

- Contemporary views of learning depart from solely "in the head" views of learning.
- Learning occurs in multiple and iteratively designed environments over multiple time scales.
- Learning occurs in social groups of multiple and collaborating individuals with effects evident at multiple levels ranging from behavioral to neural.
- New methodologies are needed to capture the processes and outcomes of this complex perspective on learning.

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References

Bakhtin, M. M. (1981). Forms of time and of the chronotope in the novel: Notes toward a historical poetics. In M. M. Bakhtin The dialogic imagination: Four essays, trans. by Caryl Emerson and Michael Holquist (pp. 8 – 258). Austin, TX: University of Texas Press.

Bakeman, R., & Quera, V. (1995). Analyzing interaction: Sequential Analysis with SDIS and GSEQ. NY: Cambridge University Press.

Bloome, D., Beierle, M., Grigorenko, M., & Goldman, S. R. (2009). Learning over time: uses of intercontextuality, collective memories, and classroom chronotopes in the construction of learning opportunities in a ninth-grade language arts classroom. Language and Education, 23(4), pp. 313-334.

Brown, A. L. (1992). Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings. The Journal of the Learning Sciences, 2, 141-178.

Brown, J. S., Collins, A, & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18, 32 – 42.

Collins, A. (1992). Toward a Design Science of Education. In E. Scanlon & T. O'Shea (Eds.), New directions in educational technology (pp. 15-22). Berlin: Springer-Verlag.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), Knowing, learning, and instruction: Essays in honor or Robert Glaser (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

De Smedt, B. (this issue). Advances in the use of neuroscience methods in research on learning and instruction. Frontline Learning Research.

Engeström, Y. (1987). Learning by expanding: An activity-theoretical approach to developmental research. Helsinki: Orienta-Konsultit.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. Journal of Education and Work, 14(1), 133-156.

Fischer, F., Kollar, I., Stegmann, K. & Wecker, C. (2013). Towards a script theory of guidance in computer-supported collaborative learning. Educational Psychologist, 49(1), 56-66.

Garcia-Sierra, A., Rivera-Gaxiola, M., Percaccio, C. R., Barbara T. Conboy, B. T. Romo, H., Klarman, L., Ortiz, S., Kuhl, P. K. (2011). Bilingual language learning: An ERP study relating early brain responses to speech, language input, and later word production. Journal of Phonetics, 39, 546-557.

Gee, J. P. (1992). The Social Mind: Language, Ideology, and Social Practice. NY: Bergin & Garvey.

Goodwin, C. (1994), Professional Vision. American Anthropologist, 96, 606–633.
Greeno, J. G., Collins, A. M., and Resnick, L. B. (1996). Cognition and learning. In D. C. Berliner and R. C. Calfee (Eds.), Handbook of educational psychology (pp. 15-46). New York: Macmillan.
Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. Theory into Practice 38, 67-73.
Hutchins, E. (1995). Cognition in the wild. Cambridge, MA: MIT Press.
Kuhl, P. K. (2007). Is speech learning "gated" by the social brain? Developmental Science 10, 110–120.
Kuhl, P. K. & Rivera-Gaxiola, M. (2008). Neural substrates of language acquisition. Annual Review of Neuroscience, 34, 511 – 534.
Kuhn, D. (1995). Microgenetic study of change: What has it told us? Psychological Science, 6, 133-139.
Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge, England: Cambridge University Press.
Lemke, J.L. (2000). Across the Scales of Time: Artifacts, Activities, and Meanings in Ecosocial Systems. Mind, Culture and activity, 7(4), 273–290.
Molenaar, I. (this issue). Advances in temporal analysis in learning and instruction. Frontline Learning Research.
Radinsky, J. L., Goldman, S. R. Doherty, R. & Ping, R. (2010, June). Small Group Argumentation with Visual Data: Negotiating What Is Seen and What It Means. Paper presented at the annual meeting of the American Educational Research Association, Denver, CO.
Sawyer, R. K. (2006). Analyzing collaborative discourse. In R. K. Sawyer (Ed.), Cambridge handbook of the learning sciences (pp. 187 – 204). NY: Cambridge University Press.
Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. Journal of the Learning Sciences, 1, 37 -68.
Schegloff, E. A., (1991). Conversation analysis and socially shared cognition. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), Perspectives on socially shared cognition (pp. 150 – 171). Washington, DC: American Psychological Association.
Schegloff, E. A., 2007. Sequence Organization in Interaction: A Primer in Conversation Analysis. Cambridge: Cambridge University Press.
Siegler, R. S., & Stern, E. (1998). Conscious and unconscious strategy discoveries: A microgenetic analysis. Journal of Experimental Psychology: General, 127, 377-397.
Stegmann, K. (this issue). Advances in the analysis of computer-supported collaborative learning processes. Frontline Learning Research
Svihla, V. (this issue). Advances in design-based research. Frontline Learning Research.
Vygotsky, L. S. (1978). Mind in society: the development of higher psychological processes. Cambridge: Harvard University Press.
Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D.C. Berliner & R.C. Calfee (Eds.), Handbook of educational psychology, (pp. 841-873). NY: Macmillan Library Reference.
Wecker, C., Stegmann, K., & Fischer, F. (2012). Lern- und Kooperationsprozesse: Warum sind sie interessant und wie können sie analysiert werden? [Learning and Cooperation Processes in Case-Based Learning. Interesting Issues and Analysis Approaches] REPORT: Zeitschrift für Weiterbildungsforschung, 35(3), 30-41. doi:10.3278/REP1203W
Willett, J. B. (1989). Some Results on Reliability for the Longitudinal Measurement of Change: Implications for the Design of Studies of Individual Growth. Educational and Psychological Measurement, 49, 587-602.
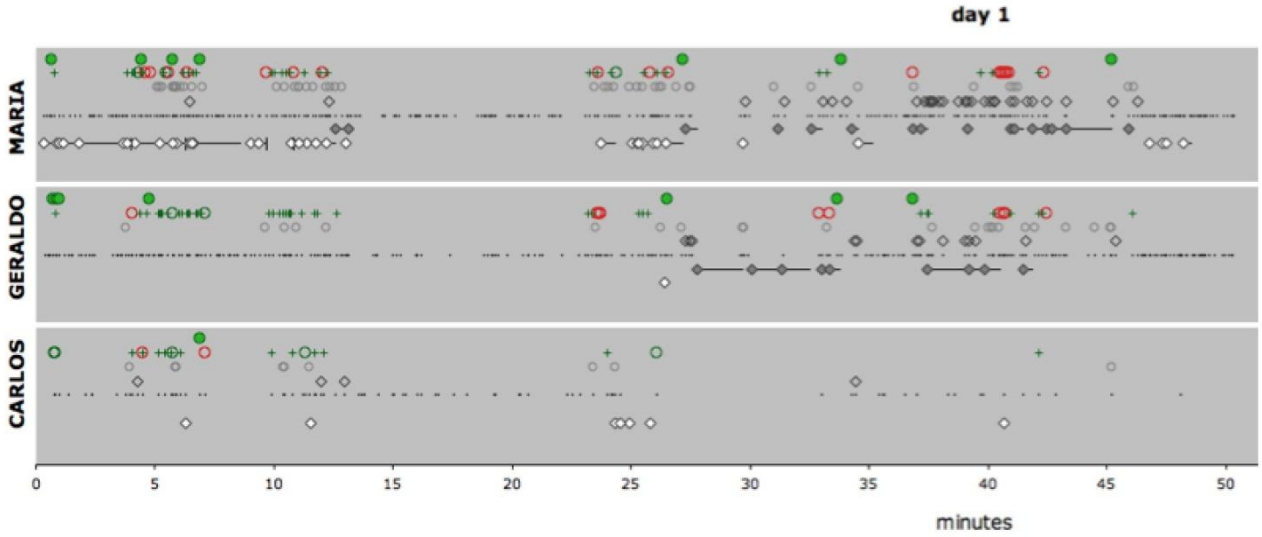
Figure 1. Representation of the discourse moves of three students engaged in a science inquiry task. (cf. Radinsky, J. L., Goldman, S. R. Doherty, R. & Ping, R. (2010, June). *Small Group Argumentation with Visual Data: Negotiating What Is Seen and What It Means.* Paper presented at the annual meeting of the American Educational Research Association, Denver, CO.)