

## Perspectival Understanding of Conceptions and Conceptual Growth in Interaction

James G. Greeno & Carla van de Sande

To cite this article: James G. Greeno & Carla van de Sande (2007) Perspectival Understanding of Conceptions and Conceptual Growth in Interaction, *Educational Psychologist*, 42:1, 9-23, DOI: [10.1080/00461520709336915](https://doi.org/10.1080/00461520709336915)

To link to this article: <https://doi.org/10.1080/00461520709336915>



Published online: 05 Dec 2007.



Submit your article to this journal [↗](#)



Article views: 1502



View related articles [↗](#)



Citing articles: 8 View citing articles [↗](#)

# Perspectival Understanding of Conceptions and Conceptual Growth in Interaction

James G. Greeno and Carla van de Sande

*Department of Instruction and Learning  
University of Pittsburgh*

We propose a bridge between cognitive and sociocultural approaches that is anchored on the sociocultural side by distributed cognition and participation, and on the cognitive side by information structures. We interpret information structures as the contents of distributed knowing and interaction in activity systems. Conceptual understanding is considered as achievement of discourse in activity systems, and conceptual growth is change in discourse practice that supports more effective conceptual understanding. We also introduce a concept of perspectival understanding, in which accounts of cognition, including conceptual understanding, include points of view. This concept generalizes the concept of schema by hypothesizing that a perspectival understanding can be constructed by constraint satisfaction when a sufficient schema is not known or recognized. We provide an example in which perspectival understanding was jointly constructed, illustrating an interactional process we call “constructive listening.”

The metaphor of bridging in the title of this special issue and the symposium in which it originated is apt, and we are pleased to have this opportunity to discuss the kind of bridge we are working on. A bridge between two banks of a river can be built mainly from either side, or it can be built simultaneously from both sides, to meet in the middle. Some of the efforts to construct bridges between the cognitive and sociocultural approaches start from the cognitive side and build spans in the direction of the sociocultural. This scheme considers knowing, understanding, and learning concepts and conceptions<sup>1</sup> as processes that occur in individual minds, and studies and hypothesizes ways in which those individual mental processes are supported, facilitated, or impeded by conditions of social interaction. In this view, social interac-

tion—for example, in classrooms—is considered as part of the context of conceptual growth, which occurs at the level of individuals (e.g., Sinatra & Pintrich, 2003).

## INTRODUCTION: A SITUATIVE PROPOSAL FOR BRIDGING

We believe that our strategy is more symmetrical, although not entirely; its firmer bridgehead is on the sociocultural side. We adopt a version of the sociocultural approach that we call “situative,” which focuses its primary level of analysis on activity systems and communities of practice, with individuals considered as participating components of those systems. In this view, cognition and learning, including conceptual understanding and conceptual growth, are considered as functions that are accomplished by activity systems and communities of practice. Knowledge and cognition are considered as distributed between the individuals who interact within a system and the material and informational systems that they use as resources. A canonical example of this approach was provided by Hutchins (1995), who analyzed the pilots and instruments of an airplane cockpit as a system that succeeded in remembering to adjust the plane’s flaps and slats at the appropriate times during descents to landing. Rather than treating memory as simply an individual mental process, Hutchins’s analysis showed how remembering was achieved

---

Correspondence should be addressed to James G. Greeno, Department of Instruction and Learning, University of Pittsburgh, 230 South Bouquet Street, Pittsburgh, PA 15260. E-mail: jimgrno@pitt.edu

<sup>1</sup>This distinction between concepts and conceptions is from Strike and Posner (1982). In contrast to concepts, conceptions have “plurality and internal complexity” and “are in some way central and organizing in thought and learning,” for example, “A learner who is able to replace a Newtonian or Aristotelian view of motion with Einstein’s has undergone the kind of conceptual change with which we were concerned” (p. 148). In Giyoo Hatano’s presentation in Montreal (Hatano, 2005), he illustrated the distinction aptly, contrasting a concept of beef, which supports classifying a kind of meat, and a conception of beef, which we would expect of an expert chef whose knowledge includes a rich collection of ways of preparing beef, including ways in which beef can be combined with various seasonings and sauces.

through coordinated contributions of instruments and individuals' use of symbols. In this approach, individuals' knowing and cognitive functioning are considered as their capabilities for participating in activity systems. Their learning is considered as change in their participation, with positive learning being change in directions of more effective, fuller participation (Lave & Wenger, 1991).

These ideas—that knowledge and cognition are distributed and that an individual's learning is change in her or his participation—are our bridgehead on the sociocultural side. Our bridgehead on the cognitive side is the theory of information structures and processes, including concepts of schemata, propositional networks, and goals that organize activity. In this chapter, we add to the usual set of hypothetical information structures by including a concept of perspectival understanding. While we use these formalisms to characterize information contents of activity, we reinterpret them. The structures and processes of information-processing theory are usually interpreted as properties of individual cognitive systems. We interpret them as characterizing informational contents of interaction and processes of constructing common ground in activity systems. We construct and evaluate hypotheses about these informational contents using transcriptions of discourse, in much the same way that thinking-aloud protocols are used in studies of individual problem solving and comprehension.

The bridge that we hope can connect theoretical concepts of distributed cognition and participation with theoretical concepts of information structures and processes is not a simple combination of concepts from the two approaches. The bridge has additional structure. The goal of the bridge is to connect sociocultural concepts and methods that explain dynamic aspects of interaction with cognitive concepts such as propositional networks, schemata, strategies, and (additionally) perspectival understandings that explain informational aspects of what people say and do in their activity. The structure of this bridge involves concepts and hypotheses about generating structures of information in interaction.

Our main goal in this article is to present a framework in which issues of conceptual understanding and conceptual growth can be considered in the situative perspective. The general idea is to consider understanding a concept as an achievement of an activity system, analogous to Hutchins's (1995) considering remembering as an achievement of the activity system of an airplane cockpit. In our analyses of episodes of interactive activity in which conceptual understanding was achieved, we are developing a concept of perspectival understanding that we introduce in this article. We then offer a few conjectures about potential implications of considering conceptual understanding and conceptual growth as achievements of interactive activity, rather than (only) as cognitive achievements of individuals, and propose that constructing perspectival understandings is an important process in conceptual understanding and conceptual growth.

## Conceptualizing Conceptions in Interaction

In this general situative framework for analyzing cognition, how do conceptions and conceptual learning fit in? Greeno (1995) began to develop a conceptualization that we use and extend in this article.

In our situative perspective, conceptual understanding and conceptual growth are considered as achievements of interaction. Concepts and conceptions function in the practices of a community, especially in discourse. They are important resources in activities of planning, coordinating, and evaluating what they do, and in explaining to newcomers how the community's systems function. In an intellectual community, such as an academic discipline or a school classroom, concepts and conceptions are a major product of the group's activities, and the community's practices include explicit methods of presenting, discussing, and using concepts and conceptions, evaluating alternative conceptual understandings, and fostering and evaluating members' progress in their knowing and understanding concepts and conceptions in the community's domain.

*Some aspects of discourse practice.* Key concepts in this situative model are aspects of discourse practices. They include: (a) informational constraints and affordances, including schemata, some of which are in the group's common ground, (b) discourse considered as joint action, and (c) positioning of individuals in participation structures of discourse activity.

We understand constraints in the sense of situation theory (Barwise & Perry, 1983; Devlin, 1991). Constraints are conditional relations between situation types, which are defined by properties and relations of objects and events in situations. Discourse constraints include simple conventions of reference. For example, in conversations in mathematics classes and many other settings, if a situation includes the statement: "the length of this rectangle," and there is a rectangle that has been designated, perhaps by pointing to it in a diagram, then the term "length" refers to the quantitative distance between ends of one of the sides of that rectangle, probably one of the longer sides if the rectangle is not a square. We understand affordances in the sense of Gibson's (1986) ecological psychology. An affordance is a relation between properties of a situation and properties of an action in which someone can interact with other people and some material or informational system in the situation. For example, if there is a diagram that includes a rectangle and the discourse practice of participants in the situation includes an appropriate constraint on the meanings of "length" and "rectangle," these provide an affordance for referring to the quantitative distance along the rectangle's longer side by saying, "the length of this rectangle."

Many constraints and affordances of discourse involve structures and processes more complex than lexical reference. These include patterns of turn taking (when is it

appropriate for someone to begin talking), constraints and affordances of relevance (what are appropriate things to say next), and schemata in the subject-matter domain (what inferences are acceptable, given what has been said and understood and the properties and relations of objects and events in the situation).

By considering discourse as joint action, we follow Clark's (1996; especially Clark & Schaefer, 1989) theory of conversation, where information is entered in common ground by contributions in which participants collaborate. A minimal unit of conversation, in this view, includes a presentation by one of the participants and acceptance of that by (an)other participant(s), with acceptance taken as evidence by the participants that they have achieved mutual understanding sufficient for their communicative purposes. Evidence of acceptance varies in strength. The lowest level of evidence is remaining silent, thereby refraining from asking a question or presenting a challenge to what the initiating presented said. Stronger evidence is often expected and given, such as nodding, saying "mmhmm" or "I see" or "okay," or restating the presented information. Contributions often are more complicated than simple presentation-acceptance pairs. Instead of accepting the presented information directly, someone may express uncertainty, ask a question, present a reservation or challenge to what was said, or propose an alternative. Then there is a process of negotiation, and the outcome may be acceptance of the initially presented information, acceptance of some modified version of it, acceptance of some alternative information, or acceptance of the negation of what was presented. The participants need not reach agreement for there to be a contribution; what is accepted can be that there are different opinions held by different participants in the conversation. Discourse practices include constraints and affordances that involve levels of evidence that are expected or required for mutual understanding, for the kinds of questions or challenges that are appropriate, and for considerations that are relevant in negotiating the contents of contributions.

By considering positioning of individuals in discourse participation structures, we follow Philips (1972), Erickson and Mohatt (1982), Holland, Lachicotte, Skinner, and Cain (1998), and others in recognizing that constraints and affordances for agency in discourse interactions are not equally distributed among the participants. Entitlements, expectations, and obligations for initiating contributions, for expressing agreement or disagreement, for questioning or challenging others, for deciding whether an issue will be taken up and whether it has been resolved, and for setting the next topic all are vested differently in different participants, which constrain and afford their participation differentially.

*Cognition and knowing in interaction.* Research on cognition studies and develops explanations of performance in activities, focusing on processes such as thinking, reasoning, understanding, perceiving, and remembering. In our

analyses, we consider these processes as functions of interaction conducted by activity systems, for example, as Hutchins (1995) analyzed remembering by an airplane cockpit.

A standard information-processing model of problem solving (e.g., Newell & Simon, 1972) or comprehension (e.g., Kintsch, 1998) includes hypotheses about a knowledge base of concepts, assumed facts and other information, and strategies, assumed to be in the memory of an individual who works on solving the problem or understanding the text.

The hypotheses we consider about background knowing for group problem solving or understanding are analogous, except we assume that the knowing is distributed across the group and its resources, with significant aspects of knowing in the group's common ground. In our view, background knowing includes practices of communication and collaboration (Gee, 1996; Hanks, 1996), which include informational constraints and affordances such as meanings of terms, relations between concepts, factual information, and uses of representational forms that usually do not require explicit statements in discourse to support communication because they can be "taken as shared" in Cobb and his associates' (e.g., Bowers, Cobb & McClain, 1999) felicitous phrase. They include strategic patterns of working on problems, including types of goals and subgoals that are commonly used to organize activity. They also include patterns of interaction that occur commonly to repair apparent failures of efforts to communicate or discrepancies in intentions or expectations in ways to proceed on tasks that the group is working on (e.g., Levinson, 1983).

In a standard cognitive model, operations of problem solving or comprehension are performed, or not, depending only on the current state of the information in the situation (including the problem solver's goals and plans) and on levels of activation of cognitive elements. In interaction involving more than one participant, we assume that operations that contribute progress in problem solving or understanding are products of joint action that Clark and Schaefer (1989) called "contributions to discourse."

While an operation in interaction is a collaborative event with different parts performed by different participants, a model of cognition in interaction can address issues involving who does which part, as well as the content of each part and of the contribution as a whole. Each contribution is initiated by someone, and there is different agency involved in initiating a contribution than there is in accepting it or in questioning or challenging what someone else initiated. Concepts of participant structure (Erickson & Mohatt, 1982; Philips, 1972) and positioning (Holland et al., 1998) provide explanations of ways that different individuals participate in an activity. In any episode of interaction, participants are positioned in ways that combine to constitute the contribution that they jointly perform. Participants, including students in classrooms, take on participatory identities that correspond to regularities in the ways that they are expected and entitled to participate in interaction (Gresalfi, 2004; Holland et al., 1998).

## Conceptions and Conceptual Growth in Practice

The background knowing that is shared by experienced members of a community of practice includes many concepts and conceptions. We consider a concept or a conception as a family of interrelated constraints and affordances that functions in organizing some aspect of the community's activities. Concepts are relatively definite, compact sets of constraints and affordances, such as categories that are specifiable in terms of defining features. Conceptions are broader and less definite (see footnote 1).

Many concepts and conceptions are explicit in a community's practices and activities. Generally, what we call an explicit concept or conception has a label, though there are exceptions, and the community has established conventions of discourse for discussing the concept or conception's meaning and for discourse in which that concept or conception plays a role. For example, *linear function* is an explicit concept in algebra classes. It has a name, has a compact definition, representational forms, and there are definite procedures for operating on symbolic expressions that represent its examples. An algebra curriculum includes instruction in these constituents of the concept. We can also think of *linear function* as a conception, sometimes called "the concept image" (Tall & Vinner, 1981), which includes patterns of information in situations and problems that can be represented as linear functions, relations between different linear functions that are not specifically identified that can be used in making inferences, and other aspects that might be referred to as "function sense" by analogy with "number sense" (cf. Greeno, 1991).

Practices also include concepts and conceptions that are implicit, that is, they are not specified by labels or discussed in specific terms in discourse, but still function, often normatively, in organizing the community's activities. An analyst can identify such implicit concepts and conceptions by identifying regularities in activity, including discourse, that are not labeled but that are expected by the participants and, if an action departs from such a pattern, participants are likely to mark it as deviant. For example, the class may regularly interact in the discourse pattern called Initiation-Response-Evaluation (IRE) so that an analyst would say that they knew and followed the IRE concept, but this would not be tantamount to their knowing a label for that pattern or having systematic discourse about it.

Practices differ in the degrees to which individuals and groups are entitled and expected to understand concepts and contribute to discourse involving conceptual explanations or justifications of actions or meanings of concepts and methods. Individuals and groups within a community are differentially entitled and expected to participate in these sense-making aspects of activity. We use Pickering's (1995) distinction between conceptual and disciplinary agency in our thinking about this issue. Acting with disciplinary

agency involves following accepted procedures and terminology with authority vested in the discipline so that a positive contribution depends only on its correspondence with established procedures. Individuals or group members are evaluated by whether they perform correctly. Acting with conceptual agency involves selection, adaptation, and critical judgment about the appropriateness, utility, relevance, and meaning of alternative understandings, strategies, concepts and methods in a domain of activity so that a positive contribution can result in choosing or adapting a method for use in solving a problem or better understanding of a problem or concept.

Conceptual growth by a community or group is change in the concepts and conceptions it uses in communicating, understanding, reasoning, solving problems, and making decisions, or in the distribution of participation in these activities across members of the community or group. For example, we believe that if a group such as a classroom changes so that more of its student members participate productively in its discourse involving a concept or conception, that change counts as a form of conceptual growth by the classroom community as well as by those individuals whose productive participation regarding that concept or conception increased.

Like other cognitive achievements, conceptual growth can be analyzed at the level of a community or group, or at the level of any individual's or subgroup's participation in a single community or group, or in an individual's participation in activity systems that span different communities or groups. Conceptual growth can be limited to capabilities involving disciplinary agency, but growth in capabilities for rich sense-making and innovation, involving conceptual agency, is especially valuable.

An example of conceptual growth by a community was provided by Engeström (2001), in an intervention and study of practice in a health care system. The health care professionals recognized a problem. Children who were diagnosed in the primary health care center and referred by the primary care center to specialists in the affiliated hospital often were referred to and treated by a series of specialists, and the primary care center was not notified or consulted for extended periods. This conflicted with the intended functions of the primary care clinic, which was supposed to be responsible for coordinating the children's care.

Engeström's intervention involved organizing sessions in which practitioners from the primary care clinic and from the hospital were present. The nature of the problem was emphasized by having the groups view video records of interviews of parents of children whose experience in the system was unsatisfactory. Members of both groups recognized that there was a serious problem, but they did not understand how their own participation contributed to the difficulties. Through discussion, in which the groups participated with significant conceptual agency, the groups recognized contradictions in their practices, reaching new conceptual understandings of ways in which their practices made lack of

coordination between the agencies likely to occur. They considered ways to change their practices and developed a concept, a care agreement, a form of boundary object that they agreed to incorporate into their practices.

Another example was provided in research by Nersessian and her associates (Nersessian, 2005; Nersessian, Kurz-Milcke, Newstetter, & Davies, 2003), who studied activity in a bioengineering laboratory that had the goal of developing an artificial blood vessel. This community's conceptual ecology included artifacts that they had developed. Conceptions included histories of researchers' interactions with the devices, in a form that Nersessian et al. (2003) called "cognitive partnerships." Conceptions were characterized as distributed mental models, constituted in interaction of scientists with devices. For example, a device that played an important conceptual role in the laboratory was a flow loop, which emulates shear stresses on cells within blood vessels. The flow loop had a rich history of use in the laboratory, being reengineered repeatedly to serve purposes of a succession of research projects. One aspect of conceptual growth that was observed was a transition by newcomers from understanding and interacting with devices as having a fixed design to understanding them as having histories of adaptation and potential for modification to afford different kinds of interaction.

There also have been studies of conceptual growth in school learning, with classroom communities or groups of students as the primary unit of analysis. In these studies, conceptual growth is evaluated by analyzing the contents of students' discourse, identifying more advanced versions of understanding in ways that concepts are utilized in reasoning and problem solving. For example, Engle (2006; also see Greeno, Benke, Engle, Lachapelle, & Wiebe, 1998) showed that students who read texts and prepared reports about endangered species changed their understanding of the conception of habitat, including multiple factors and graded effects in their evaluations of hypothetical habitats for designated species. Bowers et al. (1999) analyzed the development of a representational practice in an elementary-grade mathematics class, where students' understanding of arithmetic addition and subtraction was developed in use of an interactive interface that represented operations on quantities of candy in packages of 1, 10, and 100 pieces along with operations on numeral representations. Stenning, Greeno, Hall, Sommerfeld, and Wiebe (2002) showed that students who constructed models of population growth and decline developed understanding of predation that enabled them to include it as a factor in a complex model in support of a proposal to solve a hypothetical problem involving predator and prey populations.

Our bridge to the cognitive approach should include a way to include accounts of individuals' conceptual knowing, understanding and conceptual growth, and it does. We attribute understanding in a specific interaction to an individual according to her or his contribution to the group's discourse.

The first level of a situative analysis infers information structures involved in a group's discourse, including knowledge that is inferred to be in the distributed knowing that supports the understanding that is constructed in its interaction (e.g., Greeno et al., 1998). At another level, inferences can be made about knowing by individual participants in the interaction. These inferences can be developed and evaluated for explaining information and ideas that different individuals introduce into the conversation and evidence that different individuals give of understanding the contributions that others have introduced. Evidence of learning by individuals can include changes in the contents of their participation in discourse, including interviews and other activities that provide opportunities for them to display their understanding in interactions where their individual knowing and understanding can be assessed. For example, in Rosebery, Warren, and Conant's (1992) and Boaler's (2002) classic studies, evidence of significant conceptual growth by individual students during their extended learning activity in classroom projects was obtained from individual interviews. Bowers, Cobb and McClain (1999), Engle (2006), and Greeno et al. (1998) provided evidence both from analyzing discourse by groups and from examining the participation of individual students in group discourse and individual interviews.

### Conditions for Conceptual Growth

Toulmin (1972) contributed an account of conceptual growth in intellectual disciplines. He proposed a general Darwinian form for historical analysis. As Darwin hypothesized about biological evolution, Toulmin hypothesized that conceptual growth occurs through a combination of two general kinds of process, one that produces variation and the other that produces selection. In conceptual domains, variation involves generating proposals for alternative explanatory concepts and methods. Selection occurs in forums of debate, where alternatives are evaluated competitively.<sup>2</sup>

Adapting Toulmin's account to conceptual growth in school, we hypothesize that practices that facilitate conceptual growth should support the two processes of producing variation and selecting more valuable and valid alternatives. In examining episodes of interaction that provide opportunities for conceptual growth, we have identified features of interaction we call *problematizing* (Engle & Conant, 2002; Stenning et al., 2002) and *resolving* (Greeno, 2003). Problematizing occurs when an aspect of the group's current conceptual common ground, or of a proposed contribution, is

---

<sup>2</sup>Subsequent writers, including Strike and Posner (1982), have cited Toulmin's discussion in developing a biological metaphor for conceptual change, but have focused their discussions on changes in individuals' understandings, for example, by identifying a person's conceptual ecology with her or his relevant background of knowledge, beliefs, and motivations. These important ideas have much merit, but they do not continue Toulmin's efforts to understand changes in conceptualizations in intellectual communities.

questioned or challenged, and an alternative contribution is proposed and considered.

Resolving occurs in a process of negotiation in which the group settles on a conceptual understanding that is adopted in their common ground. Our hypothesis about this process adapts Clark's (1996) theory of conversational interaction. Clark assumed that conversations are processes of joint action in which participants collaborate to add information to their common ground. A contribution to discourse (Clark & Schaefer, 1989) includes someone presenting information (an assertion, opinion, proposed action, question, etc.). That information can be accepted as being mutually understood by the participants of the conversational group, or it can be questioned or challenged, sometimes by indicating lack of understanding, leading to some negotiation. The information eventually added to common ground can be acceptance of what the initiator first presented, or denial of that, or some modified version of it. Problematizing occurs when alternative assertions, proposed actions, or other items are understood to be in the participants' common ground and the participants understand that they need to resolve the difference in some way, perhaps by settling on one of the alternatives.

The negotiation that occurs when a presentation is questioned or challenged can focus on the information that was presented directly, or on other information that the presenter presupposed, including aspects of the presenter's perspective. Brennan and Clark (1996) hypothesized that use of a single referring term includes commitment to a conceptualization, for example, identifying an object as a member of some category. The conceptualization intended by the presenter is a kind of presupposition, and the participants need to reach mutual understanding of the conceptualization sufficient for their communicative purpose in their activity. If the presenter's intended conceptualization is specified insufficiently, or if a responder's understanding differs from the presenter's in a way that results in a conflict, the presenter and other participant(s) can engage in further exchanges that can result in mutual acceptance and understanding of a conceptualization. The term and its reference to a conceptualization that participants accept constitutes a conceptual pact, which tends to become part of their common ground for subsequent use.

### INCLUDING PERSPECTIVES IN ACCOUNTS OF CONCEPTUAL UNDERSTANDING AND CONCEPTUAL GROWTH

In our efforts to understand conceptual understanding and learning in interaction, we have concluded that our analyses should include hypotheses about the perspectives of participants in the processes. We are working to develop an account of knowing, using, and learning conceptions based on a view of cognition that emphasizes perspectival understanding. Following Fauconnier (1985), Rommetveit (1987),

Tomasello (1999), and especially MacWhinney (2005), we adopt, as a framing assumption, that cognition is inherently perspectival—that is, it always has a point of view, and understanding the cognitive aspects of an activity requires taking its point(s) of view into account.

In our perspectival view, a person's or group's knowing and understanding a conception is their ability to construct perspectival understandings that are situated in activity and that are organized according to principles that are taken as defining the conception. We define a perspectival understanding to be a cognitive arrangement of entities and some of their properties, organized in relation to each other,<sup>3</sup> with a point of view. The viewer may be enmeshed in the perspective (enactive/projective) or the viewer may be viewing from outside, representing and operating on the entities in the perspective (depictive/descriptive). Construction of a perspectival understanding is a process of constraint satisfaction.<sup>4</sup> The most general constraint, we hypothesize, is coherence, in the sense developed by Thagard (2000). More specifically, understanding of a conception corresponds to satisfaction of constraints that constitute that conception's meaning. Understanding, in this sense, may be explicit if it includes contributions to discourse that refer to the conception and to constraints that are constituents of its meaning, or it may be implicit if actions are constrained and afforded by constituents of the conception's meaning without their being referred to in discourse (Greeno, 1995).<sup>5</sup>

Taking our perspectival view, we hypothesize that Brennan and Clark's (1996) hypothesis of conceptualizations and conceptual pacts applies to perspectival understandings, which include conceptualizations of single referring terms, but also involve larger arrangements of information and meaning. In this view, a presentation, which may be an item

---

<sup>3</sup>Perspectives function at many levels. Our focus in this article is on what we might call "informational perspectives." Analogous to the concept of perspective in a painting or photograph, we focus on arrangements in which constituents of a scene are arranged in some way in relation to each other, rather than some other way that they could be interrelated. Another sense of perspective, also in common use, associates perspectives with broad aspects of a person's or group's social, cultural, ethnic, gender, economic, or organizational identity. We have only vague premonitions of how the ideas we are developing concerning perspectival understanding of problems and situations relate to broader issues of differing perspectives between people differing in identity.

<sup>4</sup>A process of constraint satisfaction generates candidate contributions to achieving a task and evaluates whether they satisfy a set of constraints. The configuration of information or actions that succeeds need not be known in advance. In this way, constraint satisfaction is a more general process than processes that depend on knowledge of a schema that is instantiated when the task is achieved.

<sup>5</sup>An example is young children's conceptual understanding of number. We follow Gelman and Gallistel (1978) and Greeno, Riley and Gelman (1984) in attributing conceptual understanding of number to children whose performance of counting tasks complies with principles such as a stable order of numeral terms, one-to-one correspondence of numerals with objects counted, and assignment of the last numeral of a count as the cardinality of the counted set of objects.

of information or an opinion or a proposal for action or a question, presupposes a commitment to a perspective, and aspects of that perspective that are relevant in the participants' activity are part of the conceptual pact that the participants accept when they accept the presentation or some modification of it.

We hypothesize that occasions in which perspectives are problematized can provide especially valuable opportunities for conceptual growth. Such problematizing occurs when the perspective of a group's current common ground, or of a proposed contribution, is questioned or challenged, and a contribution with a different perspective is proposed and considered.

We consider this account of conceptual understanding as a generalization of the theory of schemata. We understand the concept of a schema to refer to a previously learned pattern that organizes some aspects of a situation into an information structure, as Rumelhart (1980) wrote, "a schema is *instantiated* whenever a particular configuration of values is bound to a particular configuration of variables at a particular moment in time" (p. 36).<sup>6</sup>

To illustrate the distinction between constructing a perspectival understanding and applying a schema, consider an example studied by Clement (1993), involving Newton's third law. Clement asked students to consider a situation where a book is resting on a table, asking whether the book exerts a force on the table, and whether the table exerts a force on the book. A mature physicist knows a schema to apply to such situations, that at equilibrium forces are balanced, so the answer to both questions is "yes." Physics students, however, are likely to answer "yes" about the book's force on the table, but "no" about the table's force on the book. An explanation of this could hypothesize that before they learn a schema of equal and opposite forces, students have learned a schema for the force of gravity pulling objects toward the earth, and apply that schema to answer the question.

Lacking the schema for equal and opposite forces, how could a student learn to understand the situation of a book resting on a table in accord with physics? Clement reported that an instructional method he called "a bridging analogy" was effective. He asked a student to consider a book resting on a spring that was partially compressed by the book, which is being pulled downward by the earth's gravitational force. Most students understood that the partially compressed spring exerted an upward force on the book. Then Clement discussed the stiffness of the spring as a variable, with the

idea that a stiffer spring would be compressed less, but still exert an upward force on the block. Finally, Clement invited the students to think of the table as a very stiff spring, compressed microscopically, but still exerting an upward force equal to the force of the book pressing down.

We offer a perspectival account of Clement's instructional use of a bridging analogy. We hypothesize that the students' initial perspective views the book and the table asymmetrically, with the book pulled downward by the earth's gravity, thereby exerting a force on the table, but with the table simply being the recipient of that force. The perspective needed for a more advanced physical understanding views the book and table as an interacting system, exerting forces on each other to maintain their stable positions in space. We hypothesize that the perspective involving interaction was induced by the spring analogy. If the book was removed, the spring would return to its greater length, just as removal of the table would result in the book falling.

We conjecture that effective bridging analogies may be understood generally as supporting learners in constructing perspectival understandings that they need to learn new conceptions. We recognize that the line between constructing a perspectival understanding and applying a schema can be hard to draw empirically, at least in relatively simple cases such as Clement's spring analogy. It would be plausible to hypothesize that students have a schema involving agents pushing against each other in equilibrium, and they apply that schema in understanding a book on a spring and learn to apply that schema to a situation with a book on a table. The example we discuss in a later section, involving an algebra problem, is more definitive in this regard, where we propose that the data rule out a hypothesis that the understanding that participants achieved resulted from their applying a single schema.

We assume that instantiating a schema is a special case of constructing a perspectival understanding. That is, we assume that schema-based constructions are perspectival, that is, they have points of view that result from their functions in activity. We also hypothesize that if a person or group knows a schema that they can apply in the situation and they take to be relevant in their activity, they will apply it. If more than one applicable schema are recognized, some negotiation will occur to settle on a perspective.

The strength of schema theory also creates a major limitation. What if the participant or participants have not learned or do not recognize an applicable schema that is sufficient for their task? Then constructing an understanding requires more work and is more complicated than instantiating a schema and requires another process. Our proposal is that he, she, or they can work on constructing a perspectival understanding, through a process of constraint satisfaction. Schema-based structures of information are generally included as parts of a perspectival understanding. The hypothesis that participants construct perspectival understandings by constraint satisfaction, then, can provide a basis for accounting for reasoning

---

<sup>6</sup>We believe that Bartlett's (1932) concept of schemata was more general and can be interpreted in modern terms as a theory of constraint satisfaction. An example that he used to illustrate the concept was a physiological postural schema that explains how we mobile animals maintain our balance. Our suggestion that Bartlett's view is compatible with the modern concept of constraint satisfaction, rather than patterns stored in memory, is at odds with what Bartlett wrote in his autobiography (Bartlett, 1936, quoted by Brewer, 2000), but perhaps Bartlett was not entirely consistent on this point.

and understanding that occur in spite of participants' not having schemata that are sufficient for coherent representations.<sup>7</sup>

Constructing a perspectival understanding requires conceptual agency that is not required for simply applying a schema. If an individual or group is positioned with agency that is limited to actions that are well specified and taken as established in the discipline, he or she will be able to construct understandings of parts of a problem or situation, but the integration of those parts requires initiative that goes beyond what has been explicitly learned. Applying a known schema is a constructive cognitive action that requires authority, but constructing a perspectival understanding that integrates component schemata involves greater initiative and authority by an individual or group to construct relations that are not justified by familiar disciplinary procedures.

### Aspects of Conceptual Growth

Conceptual growth, in this view, is an increase of capability to construct perspectival understandings that use the constraints and affordances that constitute the meanings of concepts. Conceptual growth can include learning of schemata. We hypothesize that a pattern of information that occurs in perspectival understandings can be learned in a kind of crystallization. After learning a schema, the learner(s) can organize information into its pattern easily, depending only on recognizing the potential of a situation for the pattern to be applied.

Our main proposal is that when one or more participants in an activity have not learned a sufficient prefabricated schema for understanding a situation, a process of constructing a coherent understanding by constraint satisfaction can occur, and that achieving perspectival alignment is an important aspect of such constructive understanding. This suggests a conjecture about conceptual growth; that patterns that are constructed in perspectival understandings can be learned. That is, learning a schema can result from constructing perspectival understandings in which information is organized according to the schema, and the schema can be learned by a kind of crystallization.

---

<sup>7</sup>Developmental theorists, especially Case (e.g., 1991) and Fischer (e.g., Fischer & Bidell, 2006) have developed and evaluated hypotheses about conceptual growth that are more flexible than standard schema theory. We believe our hypotheses of perspectival understanding may be consistent with Case's hypothesis that development involves coordination between understandings of initially separate dimensions, and Fischer and Bidell's hypothesis that development involves increasing elaboration and integration of conceptual structures in the form of developmental webs. Another information-processing proposal to address the limitation of schema theory was by Schank (1982), who extended his theory of text understanding beyond schema-based structures with a concept he called "memory-operating packets" (MOPs), which are schemata that organize parts of the information about a situation and need to be combined to form a coherent representation. We differ from this proposal by formulating the constructive process as constraint satisfaction, and, of course, by assuming that understandings incorporate points of view that are crucial in their functioning.

Although this conjecture will require considerable development to provide an adequate account of conceptual growth, it has the merit of providing a framework in which a difficulty sometimes called the "learning paradox" might be avoided. The learning paradox results from the assumption that information is organized according to schemata. But if a schema is needed to organize information, it is questionable how a new schema can be learned. Hypotheses have been proposed, notably Piaget's concept of accommodation, in which new schemata result from resolving incoherencies in understanding achieved with current schemata. By hypothesizing a process of organizing information in cases where an adequate schema is not known, our conjecture allows for conceptual growth that occurs through accumulation of component understandings and is therefore more aligned with views such as diSessa's (1993), involving conceptual development from "knowledge in pieces," than with views that emphasize systematic misconceptions that need to be replaced (cf. diSessa, Gillespie, & Esterly, 2004).

A second aspect of conceptual growth, in this view, is becoming attuned to constraints and affordances that are included in the meaning of a concept. By becoming better attuned to constraints and affordances in a domain, people become more capable of constructing perspectival understandings in situations for which they do not have sufficient schemata. Becoming attuned to constraints and affordances can happen implicitly, as an individual or group participates in a practice in which the constraints and affordances function normatively for others whose behaviors serve as models for the learner and with whom the learner adjusts his or her behavior in interaction, or there can be explicit discussion of the constraints and affordances. The constraints and affordances that are learned can include aspects of theoretical discourse, directly about the meanings and justifications of concepts and methods, or aspects of activity for which the constraints and affordances are instrumental for participation that is consistent with practices of a community. For example, in Clement's instruction with a bridging analogy, there was explicit reference to opposing forces between a book and a spring, and between a book and the table. In contrast, important aspects of participating in discourse involving turn taking often are not prescribed explicitly. In classrooms, expectations for when it is appropriate for students to ask questions, and for the kinds of answers they should give, are often taken for granted, to the disadvantage of students whose cultural patterns of interaction are at variance from those that are normative in school (e.g., Philips, 1972).

A third aspect of conceptual growth involves positioning in activity. A group's practice can shift in the direction of individuals and the group having increased conceptual agency, that is, being entitled to greater initiative in interpreting, adapting, questioning, criticizing, and modifying concepts and methods in its subject-matter domain. In our situative view of interaction, increasing the conceptual agency of an

individual's or group's participation constitutes important conceptual growth.

Whether and how problematizing and resolving—especially problematizing and resolving of perspectival understandings—are encouraged and supported are aspects of classroom practice that involve the distribution of conceptual agency. In practices that vest teachers and students with conceptual agency, they are entitled and expected to question, challenge, and adapt concepts and methods of the subject-matter domain for purposes of their activity and understanding. We hypothesize that such practices can provide significant opportunities for learning that involve conceptual growth, that is, the development of schemata, attunements to conceptual constraints and affordances, and positioning with conceptual agency.

### Processes of Constructing Perspectival Understanding

A process of constructing perspectival understanding in the absence of a single, sufficient schema is more complicated than instantiating a single schema, at least in the sense that perspectival construction includes finding ways to relate components of information that a schema already has specified. The process is especially complicated when one or more of the participants has an established perspective that undergoes fundamental reorganization.

The idea that successful understanding and problem solving can require a shift in perspective was established in research by gestalt psychologists, especially Duncker (1945) and Wertheimer (1959), who emphasized perspectival processes such as restructuring and recentering. Use of concepts from recent cognitive science of schemata, constraint satisfaction, and discourse patterns, along with perspectives, can provide a more comprehensive account of reasoning and understanding than gestalt psychologists were able to give.

Evidence that an episode of interaction involves constructing perspectival understanding is provided when participants express significant uncertainty or disagreement about the meanings of each others' communications and relations between ideas and proposals that are presented. The participants' efforts to understand each other provide information about the distribution of knowing in the group, including concepts and information in their common ground and constraints of the subject-matter and of general communicative practices that they are attuned to.

We draw two conclusions from episodes that we have analyzed. One is that a process more general than schema instantiation is needed to explain the activity. We hypothesize that the process is one of constraint satisfaction.

The second conclusion involves a property of activity that seems to be required for success in constructing perspectival understanding. We have labeled this property constructive listening. In the episodes we have studied, one

or more of the participants were attempting to understand the perspective of (an)other participant(s). That is, there were one or more inquirers and an informant. The effort on the part of the inquirer(s) was significant, involving active questioning of the informant, careful attention to the informant's statements including inferences of his or her meaning, and substantial work in finding relations between elements contributed by the informant to construct a coherent organization of ideas and information. The communicative interactions in these episodes were not symmetrical—the inquirers and the informants contributed different functions to the interaction. Even so, they were highly cooperative and mutually effortful, with the informants attending to the inquirers' questions and providing information and suggestions helpfully.

### An Example: Teacher's and Two Students' Joint Construction of a New Perspectival Understanding

We present an analysis of an episode of classroom interaction that involved conceptual discovery and, therefore, an opportunity for conceptual growth. The example involves a conception of algebraic representation, including variables, expressions, and equations that occurred in an eighth-grade algebra class.

To summarize the episode and our interpretation of it:

The class was continuing work on a problem that they had begun the day before. The teacher, whom we call Ms. Sanchez, had a plan she expected to convey in class discussion, but when she invited the class to provide a key piece of information, assignment of a variable, they were unresponsive. However, a student, whom we call Gillian, offered a different assignment of variables. Ms. Sanchez did not see immediately how Gillian's proposal could lead to a solution of the problem. We infer that Ms. Sanchez was committed to a perspectival conceptualization, in Brennan and Clark's (1996) sense, in which Gillian's proposal would not fit. Ms. Sanchez did not insist on her own perspective; instead, she pressed Gillian to elaborate on her proposal. In their subsequent interaction, Ms. Sanchez, Gillian, and another student, whom we call Hannah, constructed a perspectival understanding that differed significantly from the one Ms. Sanchez had initially, and Ms. Sanchez authorized this conceptual pact for the class to use in solving the problem.

This episode exemplifies the process that we call "constructing perspectival understanding" unusually well. It provides an example in which participants constructed a perspectival interaction in joint action. It is evident that their understanding was not in common ground initially, and neither of the two central participants, Ms. Sanchez nor Gillian, had the understanding initially that they developed with Hannah. (Hannah also may have developed that understanding in the episode, but we cannot tell whether her contributions reflected understanding of partial solutions or a

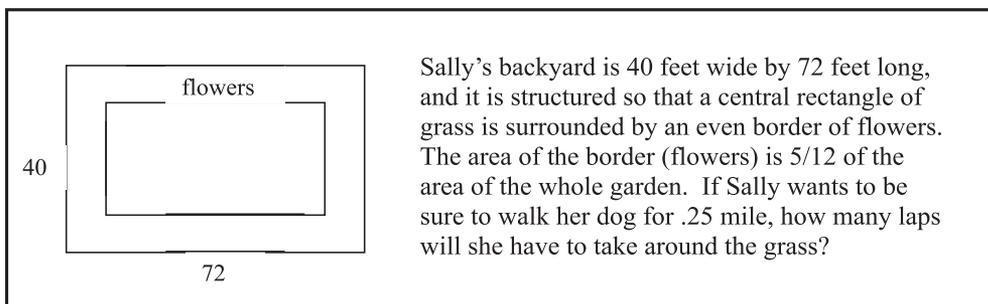


FIGURE 1 The garden border problem.

complete plan.) Their construction of understanding developed in several stages of partial understanding, which were evident because they were communicating in discourse. The episode illustrates a pattern of interaction that we expect occurs often when a perspectival understanding is constructed, with one of the participants functioning as an inquirer and (an)other(s) as the primary informant(s). In this example, the inquirer, Ms. Sanchez, expended much effort in achieving perspectival common ground with Gillian and Hannah. This is instructive in illustrating the kind of cognitive difficulty that can be involved in achieving a perspectival understanding that requires reorganization of one's initial understanding.

*Data<sup>8</sup> and interpretation.* In the episode we discuss the class worked on a problem they had begun the previous day. The problem is in Figure 1. In the previous session, the class had determined that the area of the flowered border is 1,200 square feet, and the area of the inner rectangle is 1,680 square feet. Figure 2 is a facsimile of the diagram Ms. Sanchez drew on the white board to begin the class's next session of work.

After she reminded the class of its previous work, Ms. Sanchez said,<sup>9</sup>

Ms. S: ...we want to also be able to write equations that will hopefully help us be able to solve problems like this. So, to have an equation, we need to have a variable to write the equation. So, in this problem—I kind of gave it away—what I wrote, oh well, umm, what would my variable be? (*pause during which students were silent*)

Ms. S: Oh, not all at once. What would my variable be in this? What am I trying to figure out here?

We infer that Ms. Sanchez invited the students to identify the (even) width of the border as her variable. (She “kind of gave it away” by indicating the horizontal and vertical widths with question marks.) The variable would have a label; call it  $w$ . Then, according to this plan, construct a quadratic equation,  $(72-2w)(40-2w) = 1,680$ . Solve this equation, and with the value of  $w$  that accords with the problem situation, calculate the length and width of the inner rectangle, then its perimeter, and divide that into the number of feet in a quarter mile to find the number of laps.

The next exchange between Gillian and Ms. Sanchez was initiated by Gillian and was a departure from Ms. Sanchez's plan:

G: You're trying to find out the two lengths of the inside square, or the, (*hand motion in the air*)

Ms. S: The two lengths? What do you mean “the two lengths?”

G: Of the inside square, like (*hand motion toward the diagram*)

Ms. S: (*indicated length and width of the inner rectangle at the white board*)

G: Yeah. You could put them as  $x$  and  $y$ .

Ms. S: (*labeled the vertical length “ $x$ ” and the horizontal length “ $y$ ”*)  $x$  and  $y$ . Ok.

Gillian began her statement as a response to Ms. Sanchez's question, “What am I trying to figure out here?”

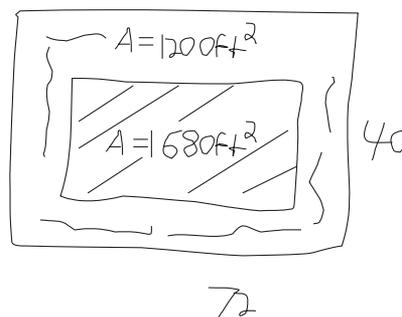


FIGURE 2 The problem as it appeared on the classroom white board at the start of the episode.

<sup>8</sup>These data were presented previously at the AERA symposium that originated this special issue (Greeno & van de Sande, 2005) and at the International Conference of the Learning Sciences (van de Sande, 2006).

<sup>9</sup>In the transcriptions, Ms. S is Ms. Sanchez, G is Gillian, and H is Hannah.

Gillian's proposal to define variables that refer to those dimensions was not part of Ms. Sanchez's plan. She asked Gillian, "What do you mean, 'the two lengths?'" She chose this option, rather than challenging Gillian's proposal to consider two quantities, which she could have taken by saying something like, "No, we only want one variable." By asking Gillian to clarify her proposal, she opened the conversation to considering information that was not part of Ms. Sanchez's initial perspectival understanding, which turned out to lead to a plan that differed from the one she had intended, and, we hypothesize, rested on a different perspectival understanding.

After Ms. Sanchez wrote "x" and "y" in appropriate locations on the diagram, references to the length and width of the inner rectangle were in common ground between Ms. Sanchez and Gillian, and at least some of the other students. This was not sufficient, though, for Ms. Sanchez to construct a perspectival understanding of the problem that would support a plan for solving it. She continued:

Ms. S: So, is there any way I can write an equation for this?

Gillian responded, somewhat haltingly, with expressions for the (even) border width  $(72-y)/2$  and  $(40-x)/2$ . Ms. S. said, "you're trying to get what?" and Gillian responded, "Cause remember how you said that we were trying to get what this is" (the top border dimension). Ms. S. asked, "I don't have enough numbers to get it though, do I?" After some further interchanges, and after Gillian added the equation  $x \times y = 1,680$ , Hannah, said, "So now you have two, two equations and two variables." Ms. Sanchez responded, "Ok, so I see one equa -"

Although the board only had one equation (along with the terms of another, not yet stated as an equation), Hannah had referred to two equations. Ms. Sanchez added the equal sign to form the equation  $(72-y)/2 = (40-x)/2$  along with  $x \times y = 1,680$ . Ms. Sanchez explained that this involved a different perspective from her initial understanding, "a completely different way than I looked at it." The class discussed the relation between this understanding and the question marks that Ms. Sanchez had placed in the diagram. Ms. Sanchez and the class sketched a plan for finding the number of laps after finding the length and width of the inner rectangle and pointed out that they could proceed by solving the pair of equations.

*Summary and discussion.* The understanding that Ms. Sanchez, Gillian, and Hannah achieved in these exchanges was constructed of at least three constituents that we can identify in their discourse. First, they focused on two quantities, the length and width of the inner rectangle and defined variables, x and y, that referred to them. Next, they constructed expressions in these variables that referred to other quantities, the widths of the horizontal (top and bottom) and

vertical (right and left) borders of the diagram. These were presented and recorded by Gillian as expressions, not an equation, but Ms. Sanchez and Hannah may have recognized that they could be used to form an equation. Third, they constructed a second equation in x and y, for the area of the inner rectangle, with the numerical value of that quantity from previous work on the problem.

We contend that these data support two claims about the construction of understanding that occurred. First, explanation of their understanding requires a process that does not depend entirely on application of schemata. The process we propose is constraint satisfaction. Second, construction of the understanding required significant effort by Ms. Sanchez, which we explain by hypothesizing a need for her to reorganize her understanding of the problem; she had to develop a perspective that was different from one she had initially. The interactional process we propose for accomplishing this is constructive listening.

Regarding the first claim, Ms. Sanchez's interactions with Gillian provide evidence for us (as they did for each other) of their achieving understanding of the constituents—the definition of x and y, the expressions in x and y for the border widths, and the equation for the area of the inner rectangle. We hypothesize that schemata were involved in the participants' understanding of these three constituents. They almost certainly knew a schema for representing the area of a rectangle as the product of two variables that refer to its length and width, and for declaring variables with these referents. Constructing expressions in x and y, respectively, for the border widths was probably more complicated. A plausible account could include a schema for the additivity of spatial distances along lines across the garden diagram, each of which would include two segments corresponding to the border widths and, respectively, the length and width of the inner rectangle.<sup>10</sup> The total length of a line had a given numerical value (72 or 40), and subtracting the inner rectangle dimension would leave the combined lengths of the two border widths. (Gillian gave an explanation of the expressions essentially like this.)

It is very unlikely, however, that the participants knew a schema that had, as one of its main components, an equation for the area of a rectangle and, as its other main component, an equation of two expressions that relate the rectangle's dimensions to dimensions of a different rectangle. We argue, therefore, that it is likely that a process different from simple schema application is needed to account for the understanding that Ms. Sanchez, Hannah, and Gillian achieved. Our candidate includes applications of schemata that provide constituents of an understanding, operating in a general constraint-satisfaction process. We hypothesize that in this case, one constraint was a requirement of constructing equations and, with two variables, two equations were required.

<sup>10</sup>This schema also would have been a constituent of Ms. Sanchez's perspectival understanding of the plan we infer she had intended initially.

Our second claim involves our assumption that understanding is perspectival, and a hypothesis that a conflict between perspectives was a cause of Ms. Sanchez's difficulty in reaching the understanding that was constructed in the episode. According to our hypothesis, supported by Ms. Sanchez's reintroduction of the problem to the class, her initial perspective had the width of the border as its main focus, referred to explicitly by a variable (although it was designated by question marks in her diagram). The length and width of the inner rectangle were represented implicitly. That is, there were expressions in the solution that referred to those quantities, but they were not labeled explicitly. The understanding the participants constructed had variables that referred explicitly to the length and width of the internal rectangle, and the referents to the border width were implicit. We hypothesize that the two understandings involve different perspectives, with the border width and its variable in the foreground of Ms. Sanchez's initial perspective, and with the dimensions of the inner rectangle in the foreground of the perspective of the understanding that was constructed in the episode. In the sequence of activity of solving the problem, in Ms. Sanchez's initial plan, the quadratic equation would be solved to find the numerical value of the border width, which would be used to calculate the inner-rectangle dimensions. The constructed understanding supported a plan in which the inner-rectangle dimensions would be found directly by solving equations, and an explicit value of the border width was not required.

If our hypothesis of conflict between perspectives is accepted, the episode provides an informative example of the kind of effort that can be required for someone to construct a perspectival understanding that requires reorganizing a perspective. Ms. Sanchez, Gillian, and Hannah engaged in an effortful process that we call "constructive listening." When Gillian proposed variables that departed from Ms. Sanchez's plan, Ms. Sanchez took on the role of an inquirer. She asked questions in a way that invited Gillian to explain her proposals. She seems to have acted on the presupposition that Gillian's contributions could be developed into a coherent perspectival understanding, without assuming that this would be aligned with her own initial perspective. She asked for explanations of constituents of the understanding that was eventually achieved and constructed an understanding that included those constituents, even though the relations between the constituents in this understanding were not consistent with the perspectival understanding she had initially. Gillian responded cooperatively, and Hannah contributed with understanding of both Gillian's perspective and Ms. Sanchez's questions.

This episode also illustrates the positioning of students as the authors of a perspectival understanding, thus providing them an occasion of conceptual agency. When Gillian offered the possibility of assigning variables to the dimensions of the inner rectangle, Ms. Sanchez positioned herself as a person seeking to understand what Gillian (and, then,

Hannah) had figured out about solving the problem. She named Gillian as the author/initiator of the way they were to set up the problem, which is what we characterize as a perspectival understanding.

The evidence for significance of perspectives includes Ms. Sanchez's own metaphorical commentary, "This is a completely different way than I looked at it." It also comes from a question by another student, "are we looking for the question mark or the  $x$  and  $y$ , or are we looking for both?" These comments indicate that the understandings involved different ways of organizing the information in the problem and focused on different quantities and their representations, which is what we mean by different perspectives.

## CONCLUSION AND IMPLICATIONS

Developing a theory of perspectives in understanding and reasoning is part of the broader research program that seeks to develop bridges between sociocultural and individual cognitive concepts and methods in the study of cognition and learning. Our effort to contribute to this program, as we discuss in the introduction of this article, takes a situative perspective, that is, we adopt an analytic focus primarily on the level of activity systems and consider cognitive achievements as being accomplished through interaction of their human participants and their material and informational constituents. In this situative perspective, concepts are characteristics of discourse in communities, used by members to coordinate, plan, and evaluate their activities and to instruct newer members and others to support their fuller participation in the community's practices (Greeno, 1995). Conceptual understanding and conceptual growth, like other cognitive achievements, are considered as accomplishments of activity systems. (Studying conceptual understanding and conceptual growth at the level of activity systems and communities of practice does not preclude focusing on individual participants and members, and analyses that integrate those levels are needed.)

This article develops an extension of the theory of conceptual understanding in interaction, emphasizing the importance of alignment between perspectives of participants. We consider the theory of perspectival understanding as a generalization of schema theory. Most of the understanding achieved in groups and communities is supported by schemata that the participants have in common ground and jointly activate to construct mutual understanding in their activity. There are occasions, however, in which one or more of the participants in an interaction do not know a schema that is sufficient to organize relevant information adequately for their understanding. In those cases, efforts to reach mutual understanding may fail. But if they succeed, we propose that the success can often be explained by hypothesizing a process of constraint satisfaction resulting in the construction of a perspectival understanding. Regarding conceptual growth,

we have proposed three conjectures: that schemata can be learned based on patterns of information that are constructed in perspectival understandings; that learners can become attuned to constraints and affordances in a domain so that they become more capable of constructing perspectival understandings in the domain; and that learners can become positioned with greater authority, accountability, and conceptual agency in their group or community of practice so that they are more fully entitled and expected to engage in the cognitive activity of constructing perspectival understandings that go beyond the schemata they have been taught.

We have presented a single example of interactive construction of perspectival understanding in some detail. We hope that this strategy succeeds in establishing an existence proof for two claims. First, there are cases in which explanation of the understanding that people achieve requires hypothesizing the constructive process that we call constructing perspectival understanding, which is more flexible and general than application of a schema. Second, we propose that there are cases in which perspectival understanding is achieved in interaction, where one or more of the participants reorganize an understanding they had initially, and that such an interactional achievement of constructing perspectival understanding can require a process of effortful constructive listening.

We offer a conjecture that growth of ability to construct perspectival understandings is an important aspect of conceptual growth in a domain. If this conjecture about conceptual learning is correct, or even close, it has two important implications for the design and conduct of learning activities. First, it could be beneficial to analyze ways in which learning resources can facilitate students' construction of perspectival understanding when they have not yet developed an appropriate schema for a task or activity. We suggest that one such resource might be a bridging analogy of the kind studied by Clement (1993). The goal would be to have resources in activity settings that support success in tasks along with support for constructing understanding in perspectives that are aligned with concepts and principles of the subject-matter domain that students need to develop.

The second implication is a possibility of formulating learning goals for students to become more proficient in constructing and explaining perspectival understandings in situations where standard schemata do not support successful problem solving and reasoning. We expect that proficiency in constructing perspectival understandings depends on both cognitive capabilities and positioning. Cognitive aspects include knowing concepts, principles, and methods of the subject-matter domain in ways that support correct execution of disciplinary agency and flexible reasoning in support of conceptual agency in novel situations, as well as capabilities of explaining one's perspectival understanding to others who are trying to understand but who need to construct an understanding with a perspective they have not yet understood. The positioning aspect involves students being entitled and

expected to use resources of the domain with conceptual agency, adapting concepts, principles, and methods for purposes of their activity and understanding. Findings of studies such as Boaler's (2002) and Rosebery, Warren, and Conant's (1992) are consistent with the conjecture that positioning students with conceptual agency, providing opportunities to learn in a domain through inquiry that develops their understanding of concepts and methods of the domain, can result in their developing significant capabilities of constructing perspectival understandings of novel problems.

In the classroom example we discuss in this article, we identified a process of constructive listening, an effortful kind of interaction that requires perspectival reorganization by one or more of the participants. If a goal is adopted to strengthen students' capabilities to construct perspectival understandings, that goal may need to include providing occasions and guidance for them to learn to listen constructively to develop capabilities of appreciating and constructing understandings with perspectives different from those they have initially in a situation. This point was made by Barron (2000), who studied characteristics of groups of students who differed in their success in solving an open-ended problem collaboratively. A major differentiating factor was the extent to which a group's members attended to and picked up on the presentations of valuable proposals from its members. The point was also made in a conversation between Giyoo Hatano and James Stigler (personal communication with both parties) about an unsuccessful attempt to appropriate a discussion-oriented method of science instruction that was successful in Japanese schools (Hatano & Inagaki, 1991) in an American classroom. Hatano suggested that American students are not taught effectively to listen. Stigler wondered whether that is true, because they participate in show-and-tell and in presenting solutions to problems publicly. Hatano asked whether American students are required to use information they obtain when other students are presenting in these activities, and Stigler responded that they almost never are. Hatano said, "Then you teach your students to sit quietly and wait their turn. We teach our students to listen."<sup>11</sup>

Creating conditions for the kinds of knowing and positioning in classrooms required for constructing perspectival

---

<sup>11</sup>When Giyoo Hatano received a draft of this article, he responded with the following cautionary message: "I like the Stigler-Hatano episode in your [article] but would like to point out that we should be careful about emphasizing the cultural differences—I now think we might characterize the situation as follows: for the HEI method to work, students have to be good listeners, and because of the earlier participation in instructional activities, the American students may have underdeveloped listenership. This implies that, if we introduce some effective activities for listenership prior to the use of the HEI method, it will work in the United States as well; to put it differently, many Japanese teachers introduce such activities in the classroom." We believe that Giyoo Hatano concurred with our interpretation of the difference in the two outcomes being attributed to differing participation in activities encouraging constructive listening and wished to forestall a possible inference involving cultural differences that some might attribute to the finding.

understanding departs fundamentally from standard didactic practice. Developing students' potential for flexible, innovative thinking is a goal that many, but not all, people profess. This ideal for education depends on an ideal for society that departs from much prevalent social practice. As Toulmin stated the problem,

The broader conditions within which men's (sic) reflective curiosity will give rise to authentic science—i.e., to a continuing disciplinary-cum-professional tradition of critically controlled speculation about Nature—have existed only rarely. Taking human history as a whole, heresy-hunting or intellectual conformism has been the rule, tolerance of free conceptual innovation the exception. (Toulmin, 1972, p. 220)

Our scientific proposal could support the design and conduct of learning that would prepare students for opportunities to exercise their reflective curiosity productively. We hope that aspects of practices and institutions of society that encourage these functions can be maintained and strengthened, and that scientific work along these lines can contribute to that aim.

#### ACKNOWLEDGMENT

This research was supported by Grant No. 200300029 from the Spencer Foundation.

We are grateful to Gale Sinatra and anonymous reviewers for constructively critical comments.

#### REFERENCES

- Barron, B. (2000). Achieving coordination in collaborative problem solving groups. *Journal of the Learning Sciences*, 9, 403–446.
- Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge, UK: Cambridge University Press.
- Bartlett, F. C. (1936). Frederic Charles Bartlett. In C. Murchison (Ed.), *A history of psychology in autobiography* (Vol. 3, pp. 39–52). Worcester, MA: Clark University Press.
- Barwise, J., & Perry, J. (1983). *Situations and attitudes*. Cambridge, MA: MIT Press/Bradford.
- Boaler, J. (2002). *Experiencing school mathematics: Traditional and reform approaches to teaching and their impact on student learning* (revised and expanded edition). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Bowers, J., Cobb, P., & McClain, K. (1999). The evolution of mathematical practices: A case study. *Cognition and Instruction*, 17, 25–64.
- Brennan, S. E., & Clark, H. H. (1996). Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 22, 1482–1492.
- Brewer, W. F. (2000). Bartlett's concept of the schema and its impact on theories of knowledge representation in contemporary cognitive psychology. In A. Sait. (Ed.), *Bartlett, culture, and cognition* (pp. 67–89). East Sussex, UK: Psychology Press.
- Case, R. (1991). *The mind's staircase: Exploring the conceptual underpinnings of children's thought and language*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Clark, H. H. (1996). *Using language*. Cambridge, UK: Cambridge University Press.
- Clark, H. H., & Schaefer, E. F. (1989). Contributing to discourse. *Cognitive Science*, 13, 259–294.
- Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching*, 30, 12141–12157.
- Devlin, K. (1991). *Logic and information*. Cambridge, UK: Cambridge University Press.
- diSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and Instruction*, 10, 105–225.
- diSessa, A. A., Gillespie, N. M., & Esterly, J. B. (2004). Coherence versus fragmentation in the development of the concept of force. *Cognitive Science*, 28, 843–900.
- Duncker, K. (1945). On problem solving. *Psychological Monographs*, 58(5), Whole No. 270.
- Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, 14, 133–156.
- Engle, R. A. (2006). Framing interactions to foster generative learning: A situative account of transfer in a community of learners classroom. *Journal of the Learning Sciences*, 15, 451–498.
- Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, 20, 399–483.
- Erickson, F., & Mohatt, G. (1982). Cultural organization of participation structures in two classrooms of Indian students. In G. Spindler (Ed.), *Doing the ethnography of schooling* (pp. 132–74). New York: Holt, Rinehart & Winston.
- Fauconnier, G. (1985). *Mental spaces*. Cambridge, MA: MIT Press.
- Fischer, K. W., & Bidell, T. R. (2006). Dynamic development of action, thought, and emotion. In W. Damon & R. M. Lerner (Eds.), *Theoretical models of human development. Handbook of child psychology, vol. 1: Theoretical models of human development* (6th ed., vol. 1, pp. 313–399). New York: Wiley.
- Gee, J. P. (1996). *Social linguistics and literacies: Ideology in discourses* (2nd ed). London: Falmer.
- Gibson, J. J. (1986) [1979]. *An ecological approach to visual perception*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Gelman, R., & Gallistel, C. R. (1978). *The child's understanding of number*. Cambridge, MA: Harvard University Press.
- Greeno, J. G. (1991). Number sense as situated knowing in a conceptual domain. *Journal for Research in Mathematics Education*, 22, 170–218.
- Greeno, J. G. (1995). Understanding concepts in activity. In C. A. Weaver III, S. Mannes, & C. R. Fletcher (Eds.), *Discourse comprehension: Essays in honor of Walter Kintsch* (pp. 65–96). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Greeno, J. G. (2003, November). *A situative perspective on cognition and learning in interaction*. Paper presented at "Theorizing learning practices" workshop, University of Illinois, Urbana-Champaign.
- Greeno, J. G., Benke, G., Engle, R. A., Lachapelle, C., & Wiebe, M. (1998). Considering conceptual growth as change in discourse practices. In M. A. Gernsbacher & S. J. Derry (Eds.), *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society* (pp. 442–447). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Greeno, J. G., Riley, M. S., & Gelman, R. (1984). Conceptual competence and young children's counting. *Cognitive Psychology*, 16, 44–143.
- Greeno, J. G., & van de Sande, C. (2005, April). *A situative perspective on conceptual growth*. Paper presented at the annual meeting of the American Educational Research Association, Montreal.
- Gresalfi, M. S. (2004). *Taking up opportunities to learn: Examining the construction of participatory mathematical identities in middle school classrooms*. Ph.D. dissertation, Stanford University.
- Hanks, W. F. (1996). *Language and communicative practices*. Boulder, CO: Westview Press.
- Hatano, G. (2005, April). *A cognitive-sociocultural view of conceptual change: A case study of understanding of photosynthesis*. Paper presented

- at the annual meeting of the American Educational Research Association, Montreal.
- Hatano, G., & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. In L. B. Resnick, J. M. Levine & S. D. Teasley (Eds.), *Perspectives in socially shared cognition* (pp. 331–348). Washington, DC: American Psychological Association.
- Holland, D., Lachicotte, W., Jr., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.
- Hutchins, E. (1995). How a cockpit remembers its speeds. *Cognitive Science*, 19, 265–288.
- Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge, UK: Cambridge University Press.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
- Levinson, S. (1983). *Pragmatics*. Cambridge, UK: Cambridge University Press.
- MacWhinney, B. (2005). The emergence of grammar from perspective taking. In D. Pecher & R. Zwann (Eds.), *The grounding of cognition* (pp. 198–223). Cambridge, UK: Cambridge University Press.
- Nersessian, N. J. (2005). Interpreting scientific and engineering practices: Integrating the cognitive, social, and cultural dimensions. In M. Gorman, R. Tweney, D. Gooding, & A. Kincannon (Eds.), *Scientific and technological thinking* (pp. 17–56). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Nersessian, N. J., Kurz-Milcke, E., Newstetter, W. C., & Davies, J. (2003). *Research laboratories as evolving distributed cognitive systems*. Proceedings of the Twenty-Fifth Annual Conference of the Cognitive Society. Mahwah, NJ: Lawrence Erlbaum Associates.
- Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.
- Philips, S. (1972). Invisible culture: Communication in classroom and community on the Warm Springs Indian Reservation. In C. Cazden, V. Johns, & D. Hymes (Eds.), *Functions of language in the classroom* (pp. 370–394). Prospect Heights, IL: Waveland Press.
- Pickering, A. (1995). *The mangle of practice*. Chicago, IL: University of Chicago Press.
- Rommetveit, R. (1987). Meaning, context, and control. *Inquiry*, 30, 77–99.
- Rosebery, A., Warren, B., & Conant, F. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences*, 2, 61–94.
- Rumelhart, D. E. (1980). Schemata: The building blocks of cognition. In R. J. Spiro, B. C. Bruce, & W. F. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 33–58). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Schank, R. C. (1982). *Dynamic memory: A theory of reminding and learning in computers and people*. Cambridge, UK: Cambridge University Press.
- Sinatra, G. M., & Pintrich, P. R. (Eds.) (2003). *Intentional conceptual change*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Stenning, K., Greeno, J. G., Hall, R., Sommerfeld, M., & Wiebe, M. (2002). Coordinating mathematical with biological multiplication: Conceptual learning as the development of heterogeneous reasoning systems. In M. Baker, P. Brna, K. Stenning, & A. Tiberghien, (Eds.), *The role of communication in learning to model* (pp. 3–48). Mahwah NJ: Lawrence Erlbaum Associates, Inc.
- Strike, K. A., & Posner, G. J. (1982). A revisionist theory of conceptual change. In R. A. Duschl & R. J. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147–176). Albany: State University of New York Press.
- Tall, D., & Vinner, S. (1981). Concept images and concept definitions in mathematics with particular reference to limits and continuity. *Educational Studies in Mathematics*, 12, 151–169.
- Thagard, P. (2000). *Coherence in thought and action*. Cambridge, MA: MIT Press/Bradford.
- Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
- Toulmin, S. (1972). *Human understanding: Volume 1, the collective use and evolution of concepts*. Princeton, NJ: Princeton University Press.
- van de Sande, C. (2006, July). *Perspectives and problem solving in an algebra classroom*. Paper presented at the International Conference of the Learning Sciences, Bloomington, IN.
- Wertheimer, M. (1959). *Productive thinking*. New York: Harper.