CONCEPTUAL LEARNING

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Educators generally want students to understand the concepts and principles of the domains they study, rather than only acquiring routine, low-level knowledge and procedural skill. While much research has focused on individuals learning rules or definitions for classifying stimuli (classically, for example, by Bruner, Goodnow & Austin (1956), Shepard, Hovland & Jenkins (1961); for a recent review, see Murphy (2002)), we consider conceptual learning and understanding more generally, taking a view developed initially by Wittgenstein (1953/2001), as participation in the activities of
In general terms, learning by an individual in a community involves progress from peripheral to fuller participation (Lave & Wenger, 1991). An important part of full participation is knowing the concepts a group uses in coordinating activities, deciding on goals and plans, evaluating and explaining actions, instructing newcomers, and communicating with each other. Communities of practice share conceptual systems that constitute figured social worlds (Holland et al., 1998) or discourses (Gee, 1996), which are socially and culturally constructed realms of activity and interpretation in which the meaning and significance of actions are interpreted and evaluated. Newcomers are limited in their ability to participate in discourse partly by not fully sharing in the understandings that more experienced participants have of the meanings and significance of concepts. Learners in the community increase their understanding of this aspect of the group’s common ground (Clark, 1996). Learners develop identities as full participants in the community as they come to share and appropriate patterns of interaction and interpretation afforded by the community’s practices.

Research on conceptual understanding in communities of practice has led to the idea that representational infrastructure in some disciplinary practice supports conceptual understanding by providing a material and social environment for understanding and purposeful activity. Representational infrastructure is an aspect of practice that is itself something to be learned, and in many cases, this infrastructure develops further through learning activity. Any social or cultural activity, including technical or scientific activities that are the focus of much formal instruction, depends upon shared representational resources—classification systems, devices that support decision making and memory,
and use conventions—for doing and communicating about that activity. For example, Bowker & Star (1999) studied how large-scale classification systems in medicine have changed with the introduction of new information technologies, with consequences both for medical practitioners and their clients. In routine use, representational infrastructure can be invisible, even though people learn by participating in activities supported by that infrastructure. But representational infrastructure is not always a stable background for processes of learning. When that infrastructure breaks down, when new forms of technology are introduced (or required), or when people set out to improve how they work together, there are processes of learning that change both participants in and the infrastructure for social or cultural practices.

Most activities in classrooms are intended to foster students’ learning information, skills, and understandings that constitute knowledge in established academic disciplines. Students show that they have become proficient in the domain by participating successfully in discourse activities—often by performing well on tests, but also by providing other evidence such as conducting projects, carrying out analyses, making presentations and writing reports in which concepts, information, and procedures of the discipline are utilized and discussed.

In nonschool settings, learning is often instrumental for some other specific purpose in the community. The most immediate goal of much school learning is to prepare students to show what they have learned, rather than to participate in some other activity. As a result, students’ understanding and use of the concepts they learn in school are often limited to the narrow set of activities in which they learned and displayed their ability to perform school tasks.
Learning and Developing Concepts Out of School

Several research studies have provided important information about conceptual learning and development in practices other than school learning. We present examples that illustrate three general principles. First, in the situative view that considers conceptual understanding as participation in the practices of communities, learning concepts is critical for individuals to progress from peripheral to more full participation. Second, concepts and their meanings are developed and evolve in settings of practice and are maintained in practices because they are useful for the community in conducting their activities. The local history of discourse involving the development and use of a concept in a community is an important part of the concept’s meaning in that community. Third, concepts can migrate from one community to another, and significant tailoring of a concept’s meaning can occur as a community adapts the concept to its practices.

Concepts Are Learned Through Participation in Practices

Participating successfully in a social practice requires understanding the meanings of concepts at multiple levels. Many concepts are in the contents of the community’s activity, referring to categories of material and products of the community’s work, to properties of situations, or to methods or procedures that are performed, including discourse activities such as conducting analyses and writing reports. Some concepts are central for organizing and understanding the community’s practices and can refer to fundamental aspects of character and identity. For example, in scientific practice concepts of evidence and explanation are crucial, as are aspects of identity such as being a careful and accurate experimenter and a truthful reporter of empirical results.
A case involving fundamental conceptual understanding and identity was contributed by Cain (1991; discussed by Lave and Wenger, 1991 and Holland et al., 1998). In this case conceptual learning was central in newcomers’ learning, that is, in their transition from peripheral to full participation in the community. The community was Alcoholics Anonymous, in which becoming a full participant involves a fundamental change in conceptual understanding of the person’s identity. Individuals who join and stay in AA come to understand alcoholism as an illness and to develop an identity of being an alcoholic person. Like other alcoholics, they are incapable of controlling their consumption of alcohol unless they completely avoid taking even one drink. To achieve this they become non-drinking alcoholics, practicing sobriety.

Cain (1991) found that to support members in their practice of sobriety, AA had a powerful representational infrastructure that included telling of personal stories and recognizing the durations of abstinence from drinking. Attaining the identity of a sober alcoholic requires adopting two fundamental beliefs, that alcoholism is an incurable disease, and that control of one’s drinking requires turning over one’s will and life to a Higher Power. The personal story is well established in AA practice, and new members experience its components when they converse with individual old timers and when they attend meetings. The stories include a progression in which the teller identifies herself or himself as having had problems while drinking, but they believed that drinking did not cause the problems. At some point the individual “hit bottom” and then turned to AA and became a different person, a nondrinking alcoholic. The elements of the story afford new members, who identify with experiences of formerly drinking alcoholics, with the prospect of achieving a similar transformation. Learning to participate fully in AA
includes becoming adept at telling one’s story about previous drunkenness and one’s conversion to sobriety, thereby providing a model for more recent members. Cain documented ways in which newcomers’ participation in meetings and interaction with more senior members of AA resulted in changes in the newcomers’ telling of their life stories, which corresponded to learning this key aspect of AA’s representational infrastructure. The representational infrastructure of AA also included collecting tokens (poker chips) as public acknowledgement of individual members’ persistence in sobriety.

In the large literature on cognitive development, many studies have focused on conceptual growth (e.g., Murphy, 2002, Chap. 10). Findings of these studies have generally been interpreted as showing how children develop mental structures that correspond to more sophisticated understanding in domains such as classification, conservation of material, and number. Conceptual growth can also be interpreted as progress in participating in the discourse practices of communities of practice in a culture. Of course, conceptual growth involves more than advancing purely linguistic aspects of discourse; discourse practices also include representational infrastructure, such as ways of organizing information, attending to significant aspects of situations, and making inferences based on relations between concepts that correspond to regularities in the material and social world. The important point, we believe, is that children’s development of understanding in general conceptual domains occurs in the social and cultural environment that they inhabit and occurs as children grow in capabilities for communicating with other people. We expect that general conceptual growth in early childhood depends on rich representational infrastructures that are available, in unfortunately very different degrees, to young children. In conversational interaction,
children experience things to have conversations about, including toys to be described and animated in narrative play, books to be read, elaborated, explained, and related to their experience, games to be played with older peers and adults, learning environments such as museums, zoos, and parks, photographs of their families, friends, and themselves, video entertainments, and materials and guidance for learning to draw and write (Bransford, et al., 2005; Rogoff et al., 2003).

**Concepts Evolve in the Activities of Communities**

Communities maintain practices that include stable meanings of the concepts that they use. At the same time, communities change aspects of their practices, including introducing new concepts and changing the meanings of concepts. This can happen as a community adapts to changes in societal conditions in which it operates, or through efforts to improve the effectiveness of its activities. Some communities have as a main goal the improvement of conceptual understanding or innovations in technology that necessarily change the meanings of concepts.

Nersessian et al. (2003) studied activity in a bioengineering laboratory, where the primary goal was development of artificial blood vessels that could be implanted in humans to repair circulatory functioning. To accomplish this, the laboratory activity system would need to develop a device that was beyond current scientific understanding, and such a device would involve concepts they did not yet possess. Nersessian et al. referred to this laboratory, and others they studied, as evolving distributed cognitive systems. They were distributed in the sense that cognitive activity was a joint product of the several human participants interacting with each other and with the material systems that they developed in their research. They were evolving in the sense that artifacts and
the bioengineering researchers’ understandings were continually changing through their activity.

Viewed as part of this distributed cognitive system, concepts functioned in the laboratory to organize activities, goals, and evaluations of progress. The lab’s representational infrastructure, including meanings of concepts, was embedded in patterns of interaction of persons, material, apparatus, and measuring instruments. These were continuously changing, as devices were modified and new versions were designed and constructed. Newcomers to the lab, often undergraduate assistants, understood devices more superficially than experienced researchers, focusing more on difficulties of making them work (which all lab members experienced). Experienced researchers understood the functional uses of a device and knew some of the history in which the design of a device evolved as the nature of its behavior in simulating biological material became better known. The experienced researchers also were positioned with what Pickering (1995) called conceptual agency. They designed devices and formulated experiments to test their capabilities; whether the devices then behaved successfully was determined by the devices and materials used in the tests, which Pickering called material agency. This relation was understood well, for example, by a researcher, some months after joining the lab, who saw “a device as an in vitro site for ‘putting a thought [his thought] into the bench top and seeing whether it works or not.’” (Nersessian et al., 2003, p. 6.).

Engeström (2001) studied a case involving two communities of practice in health care, medical professionals in a primary pediatric care facility and specialists in a hospital to which the primary care professionals referred children for treatment by specialists. In
interviews with providers and parents of these children, Engeström found that there were problems in coordinating the treatment children received. When a child was referred to a specialist, that physician might refer the child to another specialist, and multiple diagnoses and treatments could proceed without the knowledge of the primary care department. This was not optimal care, and it was inconsistent with the primary-care department’s responsibility.

Engeström organized and studied an intervention in which members of the two professional communities designed a practice that addressed the problem. Their new practice was a result of their conceptualizing the problem in a way that differed from their previous (disparate) understandings, and included a concept of coordinated care that they generated in their discussions. In Engeström’s theoretical analysis, problems can arise in a practice because of contradictions in its underlying assumptions. Here, assumptions about efficiency in treatment contradicted assumptions about maintaining coordination of patients’ care. Engeström brought members of the two professional communities together to discuss the problem, showing them videos of parents’ voicing their distress regarding their children’s care. The result was a design for a new practice, amending their representational infrastructure, which included constructing treatment plans for children that would provide information for both groups of practitioners to better understand conditions of medical care.

**Concepts Migrate Between Communities, Adapting to Practices**

Concepts and the representational infrastructure through which they are learned and used change over time, both within the activities of a work group and through the identification and resolution of conflicts between work groups within an organization.
Concepts also migrate across work groups, with consequences for their local practices, through active processes of borrowing and adapting representational infrastructure. Hall and colleagues (Hall, Wieckert and Wright, 2008; Hall, Wright & Wieckert, 2007) have studied processes of learning, teaching, and generalizing statistical concepts when statisticians advise clients across different research domains (e.g., the community ecology of social insects, the epidemiology of infectious disease). Consulting meetings between research clients and statisticians involve purposeful efforts to displace some aspect of the client’s existing infrastructure for representation and modeling with another way of working. Thus, consultations are a disruption in the client’s project timeline, and within the meeting, different ways of assembling the client’s future work are created and compared.

In a consultation between a biostatistician and entomologists (Hall, Wright & Wieckert, 2007), the clients were attempting to borrow uses of cluster analysis (CA) from published literature in order to identify new termite species. A senior research client proposed using CA to confirm insect groups they had already observed. However, the consulting biostatistician pointed out that CA finds clusters, regardless of their meaning, so could not be trusted in this epistemic role. Instead, another senior researcher proposed that they use CA to discover insect groups, which could later be confirmed using independent field and laboratory data. This seemingly simple, narrative repair in how CA should be used in the client’s work avoided a logical error and, once adopted in the group’s work practices and described in journal articles, was borrowed by other research groups to become a standard method for identifying insect group structures. As a critical part of this larger migration of concepts, consulting meetings involved basic discursive
processes of narrative assembly that ordered objects in the client’s work, people on the project as human labor and spokespersons for objects, and statistical techniques or concepts.

In a second discourse practice common in consulting meetings, statisticians told parables that offered clients alternative subject positions in stories about statistical inference and data modeling. These stories had highly evaluative outcomes, depending on which position a client took. In the case of entomologists seeking to borrow CA from previously published studies, the statistician compared their situation to using blood type shown on a California driver’s license. The lead entomologist initially responded from the position of a harried Type O blood donor (i.e., dealing with constant requests to give blood), but later realized that in the statistician’s completed parable, he would grant licenses on the basis of blood type (i.e., blood type is a real structure, but it has nothing to do with obtaining a driving license; similarly, CA might discover structures that had little relevance for insect classification).

A third, recurring discourse practice found in Hall et al.’s comparative analysis was the use of analogy to borrow and modify statistical methods or approaches to modeling that appeared in prior publications, sometimes out of field for research clients. Findings here are similar to Dunbar’s (1995) studies of scientific research groups, but in Hall et al.’s cases, consulting statisticians worked as brokers (Star & Griesemer, 1989; Wenger, 1998; Tuomi-Grohn, Engestrom, & Young, 2003) to map and evaluate analogies that were brought into consulting meetings by research clients. In a case where research epidemiologists were seeking to estimate the number of young children hospitalized with influenza (Hall, Wieckert & Wright, 2008), the lead researcher borrowed a capture-
recapture estimate from prior publications in epidemiology, but made an overly narrow assumption about matching hospital days for two screening procedures. The consulting statistician advised that matching days were not required, yet the client was not convinced, posing an extreme case in which a 1 day screen would be incorrectly (he thought) combined with a 7 day screen. After further discussion and illustrative calculations, the statistician was able to convince the client to use all screening days, and the resulting, published estimate of children with influenza was more robust. In the same consultation, the statistician convinced epidemiologists at a national public health agency that screens with quite different coverage could be combined, as long as there were no dependencies among them. As a result, new studies and a national influenza monitoring program for adults were undertaken, using the client’s extreme negative case (1 versus 7 screening days) as a feature of the new health surveillance system.

These case studies of learning and developing concepts out of school show that conceptual systems are implemented as representational infrastructures that support the activities, learning, and communication of participants from multiple generations within a work group. But these cases also show how concepts and supporting infrastructure evolve in and across the activities of communities, either through processes of experimentation and incremental refinement, or through interventions specifically designed to identify and work through contradictions within an organization’s mission. In still other cases, concepts are borrowed and adapted across work groups or organizations, sometimes with the help of brokers whose professional activities span different disciplinary contexts and work groups. Thus, in the cases of statistical consultation studied by Hall and colleagues, conceptual development in activity systems appeared to advance along two dimensions at
once. Work practices—including what needs to be learned by newcomers, what counts as a finding or argument, and how to communicate about these things—changed to accommodate borrowed conceptual structures within the local history of a work group. But at the same time, for brokers like the consulting statisticians, local problems and adaptations required for borrowing conceptual systems provided rich material for the extension of existing concepts or the discovery of new concepts that might prove useful across the different purposes and local work settings of particular clients. In this sense (see also Engestrom, 2007), disrupting representational infrastructure to work more effectively in the future involves both aspects of horizontal (within local work groups) and vertical (across groups) conceptual development.

Several structural features of concept learning and development in these out of school case studies bear further discussion. The temporal duration of conceptual change in these cases is diverse, ranging from days or weeks in interactions between a small number of people (e.g., the consultation over use of capture-recapture methods to count cases of child influenza), to multiple years and interactions between members of larger work groups (e.g., the refinement of artificial vascular tissue media or adopting cluster analysis as a method to discover structure in field entomology). Processes at different levels of analysis and different timescales contribute to conceptual change in these cases, and these processes appear to involve aspects of human agency and interaction that have typically been attributed to individual mental processes operating at smaller scales in time, place, and participation. In summary, the components of representational infrastructure are more diverse and productive for activity than a narrow view of notational systems and their proper use might suggest. This diversity includes forms of
narrative description that compare the consequences of alternative ways of using the concept (e.g., using cluster analysis to confirm versus discover candidate structures) or efforts to borrow and adapt concepts that expand the meaning of the concept within and across work groups (e.g., adapting prior use of a statistical concept to cover a new situation, or developing new statistical methods that cover multiple, particular consultations).

**Learning Concepts of Disciplines in School**

In school, students learn concepts and methods that have been developed in intellectual disciplines and that are considered generally valuable for educated members of society. Teachers, textbooks, and other resources represent disciplinary communities. Goals include having students learn to participate in practices that are valued in the society, including practices that are preparatory for further disciplinary learning. By considering concepts as aspects of activity, we are led to question the kind of activities in which students typically learn concepts in school. Important aspects of these activities should include opportunities for pursuing generality with conceptual agency, if school learning is to have value beyond its specific learning context.

**Concepts Are Learned Through Participation in Practices**

Curricula can be designed so that concepts are learned in activities where they function and can thereby be understood as resources for practice. Jurow (2004) studied middle school students participating in project-based activities designed to teach them about the mathematics of population modeling (Greeno & MMAP, 1998; Stenning,
Greeno, Hall, Sommerfeld, & Wiebe, 2002 Her studies started with the observation that representational systems for modeling—like tables or graphs of fish population growth—operate by conventions that have already been designed to record and summarize multiple, concrete instances. Thus, in conventional use, these systems provide powerful resources for generalizing (Latour, 1990). For example, looking at a graph of population values over time, a skilled reader sees an ordered progression of values and can make inferences about intervening events, trends, and what might happen to the population in the future. However, students must learn these conventional uses in order to use representational systems to generalize about population dynamics. In the cases studied by Jurow, several representational systems (i.e., tables, graphs, and constraint networks coordinated in a computer interface) provided means for asking and answering functional questions about population models that spanned multiple contexts (e.g., How large must a student-designed “tank” be to accommodate a growing population of fish; Then later, how many fish could live within the carrying capacity of a larger stream reach). In Jurow’s study, these “what if” questions, either embedded in the curriculum or asked by the teacher, prompted students to engage in two basic discursive processes: linking one context with another (e.g., current and future fish populations, in different habitats) and conjecturing about what might happen in alternative models (e.g., a predator/prey model of interacting fish populations, with and without human intervention). Both processes involved conversations where representations were treated as models of population growth, and students took up positions either as makers or users of alternative models. As interactive environments for learning, episodes of linking and conjecturing structured students’ participation (Erickson, 2004) in increasingly sophisticated ways of using
representations as models.

In this sense, linking and conjecturing provided opportunities for students’ learning about the representational infrastructure of modeling. However, Jurow also found that what students counted as adequate participation varied across contexts of assessment. For example, some students stopped with the first answer they felt would earn credit on daily worksheets, while others anticipated giving explanations in later classroom discussion, and thus continued to seek alternative or more convincing population models. Different expectations about assessment produced tensions within student groups regarding what was to be learned, and these tensions influenced how students engaged with instructional activities. In another study of project-based learning, Engle (2006) specifically asked what might lead to transfer of causal explanations in classroom activities designed to support inquiry learning (Brown & Campione, 1994). A group of students studying why some whale species are endangered spent several weeks constructing a multi-causal explanation, in which relatively low birth rates (whales give birth every few years) combined with intense pressure from human hunting would decrease the whale population to the point of endangerment. Through a careful retrospective analysis of group activities, Engle demonstrated that while the content of this explanation was made available to group members, their learning was substantially enabled by their teacher’s efforts to establish links across contexts in which such an explanation would be useful or relevant. Specifically, the teacher framed student activities as extending across instructional contexts, alerting students to how a causal explanation might be relevant across time (e.g., linking past instructional activity with current and future activity) and how their participation in inquiry might span wider social
contexts (e.g., students were framed as authors of causal explanations that would be relevant in whole class discussions). In this way, the teacher’s framing regularly broadened the participation structure of students’ learning, and by Engle’s argument, encouraged them to use their explanations in ways that were generative outside the original context of learning. This provides a situative explanation for transfer of learning that combines aspects of content (e.g., texts describing endangered species) and the interactional contexts in which that content is engaged by students (e.g., linking current and past inquiry to conversations anticipated in the future).

**Concepts Evolve in the Activities of Communities**

The second general principle that we consider is that concepts and their meanings evolve in the activities of groups and communities. Our situative account emphasizes that meanings and uses of concepts have important aspects that are local, including the histories of their local development and use. The examples of this principle that we discussed from out of school, Nersessian et al.’s (2003) study of a bioengineering laboratory and Engeström’s (2001) study of two groups involved in medical care, illustrate the principle of local evolution and inclusion of local history in meanings of concepts in professional communities.

When this principle of conceptual learning is recognized in school, the learning communities of classrooms function as constructors of concepts and their meanings, including representational infrastructures that embody and support their conceptual understanding. Students are positioned in these activities with conceptual agency, in Pickering’s (1995) sense. This can support students’ development of disciplinary identities in which they are entitled and capable of questioning, criticizing, and adapting
resources of the discipline, rather than only being able to use these resources mechanically.

The Algebra Project (Moses & Cobb, 2001) exemplifies this principle of classroom constructivism. Students engage in an activity, such as taking a trip together or learning a game, and their shared experience is then used to ground the development of mathematical concepts and methods. Moses designs learning activities in which classroom communities develop mathematical concepts and representations in discourse that Moses characterizes, following Quine (1981), as a regimented version of ordinary language. The concepts and representational infrastructure that they construct have meaning and significance in their practice, including a history in which the students have significant agency and authorship.

Godfrey and O’Connor (1995) studied the development of a representational practice in an Algebra Project classroom taught by Godfrey. The mathematical concept involved was difference between two quantities or numbers, which has both a magnitude and a direction. The class, led by the teacher but with significant content initiated by students, developed symbols that referred to both these properties for representing differences between the heights of individuals. One symbol illustrated the students’ role in authorship of representational infrastructure particularly well. One of the students proposed that the magnitude of a difference could be represented by a unit he called the handspan, meaning the distance between the tips of the fingers and the base of the palm. Other members of the class raised questions, including a difficulty because this use of the term “handspan” would conflict with its ordinary meaning of the distance between the ends of the thumb and smallest finger when the hand is spread. The class determined that
this was a significant issue, and settled on the term “vertical handspan.” In developing this representation, students discussed significant issues in the design of symbols, and thus had opportunities to learn important aspects of the concept of numbers that have signs as well as magnitudes, with their history of these considerations integral in their local version of the concept.

Engle and Conant (2002) analyzed an extended episode of learning in two fifth-grade classes organized according to principles of the Fostering Communities of Learners project (Brown & Campione, 1994). The classes conducted investigations of endangered species, with different student groups studying different species. Part of their representational infrastructure was a poster that was constructed midway through the unit to display what each group had found by that time. In the groups studying whales there was a controversy over whether it was appropriate to include orcas in their report, because on a field trip they had heard a staff person say that, although most people think killer whales are whales, they are really dolphins. They discussed this for 27 minutes, debating the significance of physical features in taxonomic classification, the authority of sources, and the linguistic convention that the animals are called killer whales. This discussion became an integral part of the group’s conceptual understanding, as indicated clearly during a report the group gave to a newly arrived student teacher, who was told that they had “a big ol’ argument” about the proper classification of orcas. Engle and Conant analyzed interactions in the class and hypothesized that the students’ productive disciplinary engagement, and the conceptual learning that they accomplished, were enabled and supported by practices that encouraged problematizing disciplinary issues, in which they had authority for resolving these issues, were accountable for supporting their
positions with evidence, and had access to resources that informed their development of positions on issues.

The local history of conceptual discourse shapes a group’s understanding and meaning of a concept. It also provides the group with resources that can benefit their learning. Schwartz and Martin (2004) studied ninth-grade students participating in a discussion of how to construct a numerical indicator of variability in samples produced by different baseball pitching machines. The samples differed both in average accuracy and variability. Following this activity, the students were given instruction in a standard index of variability, the average absolute deviation from the mean. The students who had previous experience with constructing an index learned more successfully than other students who had not had that experience. We interpret this as further evidence that conceptual learning in a community occurs more readily when the representational infrastructure through which the concept is understood is part of inquiry activities of the community, rather than just being presented as something to learn.

**Concepts Migrate Between Communities, Adapting to Practices**

Teaching a concept in school always involves migration of the concept across a boundary—actually, across several boundaries. Except for the occasional visits of practicing members of a discipline to classes, the route of a concept from a community of disciplinary scholars into classrooms includes adoption in communities of curriculum writers, teacher educators, and teachers, all of whom must adapt the function and meaning of the concept for use in their various practices. In a different set of practices, the teacher and students of a classroom community adopt some version of the concept in learning and displaying their knowledge.
For each of these adaptations, there is a concern that the adapted version of the concept be consistent with some important aspects of the concept’s meaning in the disciplinary community. There are disputes about which aspects of meaning should be preserved. Preserving correctness in recitation of facts and definitions and in performance of routine procedures is sometimes taken as sufficient for purposes of general education. But many educators and members of disciplinary professions advocate more ambitious educational aims, involving understanding and abilities to use concepts and methods of the disciplines that students study. Some efforts, usually focused on curricula, have worked to improve the accuracy of students’ understanding of concepts and principles. Alternatively, there also are efforts to change curricula and classroom practices so that students will have opportunities to learn to understand and reason with concepts in ways that are consistent with patterns of understanding and reasoning that are characteristic in disciplines (Brown, Collins & Duguid, 1989). These efforts are aimed toward students developing valuable habits of mind of the kinds that have evolved in disciplinary practice, which include ways that members of the disciplinary community formulate problems and questions, organize information, formulate and evaluate arguments, and assemble and evaluate evidence,

Whatever view is taken about which aspects of understanding and skill are important for students to learn, an important question is What kinds of learning environments and activities afford students’ developing the kinds of understanding and skill that are valued. The view that conceptual understanding is embedded in social practice emphasizes that different learning practices in classrooms provide opportunities for conceptual learning that reflect different aspects of understanding.
Boaler (1993/2002) studied mathematics teaching and learning in two secondary schools in England. Although the schools were virtually identical demographically, they taught in strikingly different ways over a period of three years. In one of the schools, students learned mathematics in a traditional practice where teachers described and explained a procedure and students did problem sets as seatwork and homework. In the other school, students learned mathematics by carrying out investigations, each of which lasted, typically, about three weeks. Teachers presented concepts and procedures when these could be used to understand and make progress on students’ projects.

Boaler’s (1993/2002) findings showed that adaptation of mathematical concepts to these different teaching practices resulted in striking differences in what students learned. In the school using mathematical investigations, students learned to appropriate mathematical concepts and methods in their projects and to apply them to generate information relevant to their own questions. In contrast, students participating in more traditional pedagogy learned to recognize cues for which procedure to use and how to perform procedures correctly. These students later understood mathematics to be about a collection of procedures one needed to perform correctly. Students participating in classroom investigations, in contrast, understood mathematics to be a collection of tools for use in solving problems and making sense of situations. Boaler concluded that students in these schools also developed different mathematical identities, with those from investigations classrooms displaying higher levels of conceptual agency in the mathematics they were learning (i.e., Pickering’s (1995) distinction between conceptual and material agency).
Conclusions

We have taken the general view, initially developed by Wittgenstein (1953/2001), that concepts are resources of social practice, and meanings are the ways that concepts function in activities of communities. We have considered three principles of conceptual learning that we understand as implications of this general view and discussed research studies in which these principles are exemplified. First, concepts are learned by individuals through their participation in the practices of a community, and conceptual learning is an integral part of learning in which individuals progress from peripheral to more full participation. Second, conceptual learning occurs in communities; concepts change as communities progress in their understanding and in developing practices and technologies that are increasingly effective. Third, conceptual learning occurs as concepts migrate across boundaries between communities, with adaptation of the concepts’ meanings to make them functional in the community that receives them.

This view of concepts as resources for communication, understanding, and reasoning in social practice contrasts with the understanding of concepts that has shaped most educational practice. In the prevailing view, learning concepts is assumed to be acquisition of knowledge structures, represented as schemata that contain (a) patterns of features that define and characterize examples of the concept and (b) procedures in which values of variables in the concept’s definition can be inferred or used to infer values of other variables that are related to the concept. Use of the concept involves recognizing the pattern of features that characterizes the concept, instantiating the variables in the schema with features of the situation, and carrying out procedures to infer values of other variables.
In this prevailing view of conceptual learning and understanding, much attention is given to the issue of transfer. Students may show evidence that they have learned a concept by giving correct answers about its meaning, identifying examples correctly, and/or performing inferential procedures correctly in a test. But when asked questions or given problems that differ from those used in instruction in some way, they often do not succeed. The problem, according to the mainstream view, is that they failed to transfer knowledge they had acquired to the novel situation. Perhaps the knowledge they acquired lacked the generality that it should have had, or perhaps they did not acquire needed procedures for instantiating their general schema in the kind of situation that was presented in the transfer test.

In the situative view that we take in this article, knowing a concept is not considered an abstraction from practice; instead, all knowing is assumed to be embedded in social practices. At the same time, social practices and individuals’ participation are understood to differ in ways that encourage or discourage generality of knowing. Knowledge of a concept is not assumed to be inherently general or specific. Instead, in activities that potentially could be informed by a concept, communities’ or an individual’s practices vary in their extent of affording use of that concept (or concepts) in a broad range of settings. In this situative view, generative use of any knowledge is always a constructive act, which often requires creativity and sometimes, moral courage.

Learning practices that are often used to teach concepts in school focus on the use of concepts primarily in taking tests. Although test items can be constructed to provide different informational contexts from those present during learning, testing unavoidably provides only a very limited kind of activity in which to apply one’s understanding of a
concept. Therefore, if we agree that conceptual understanding is knowing how to participate in activities that are informed by the meaning of a concept, testing provides a poor representation of the kinds of activities that most people would want to have students learn to participate in successfully. And school instruction that emphasizes successful test taking as the main goal of learning fosters a narrow form of understanding. Understandably, students do not expect that what they learn in school to be relevant to other activities.

We propose that to make school instruction for conceptual understanding more effective, curriculum design, teaching, and teacher preparation and development should attend to a range of activities and practices in which students could be prepared to use the concepts they are learning, and to the kinds of activities and ways of being positioned in learning through which conceptual understanding in practice can be fostered. This is not a recommendation to avoid explicit discussion of concepts and their meanings, or to necessarily depend on students’ processes of discovery to reach correct versions of disciplinary concepts. It is a recommendation that attempts to teach concepts that are inherently generative—that is, that contain the basis for their generality as a characteristic of their internal content—in ways that are more likely to succeed.

Consistent with research we have reviewed, two important factors contribute to students’ learning concepts that then become generative resources in their activity. One is that the activity in which concepts are learned uses them generatively, rather than only as information to be remembered or as procedures to be executed. The other is that students are positioned in learning activity with conceptual agency, that is, with agency to appropriate, adapt, question, and modify conceptual meanings in the discipline. Students
need to learn with conceptual agency in settings where the representational infrastructure supports more than narrow test performance.

At the same time, this research reveals why changing the leading activities of school learning to support generative use of concepts and conceptual agency in students’ participation is fundamentally challenging. Whether in the project-based teaching studied by Jurow (2004) or in the cycles of inquiry studied by Engle (2006), engaging tasks need to be organized in ways that build up functional relevance for mathematics or science, and students’ generative use of concepts needs to be made visible and available for conversation and refinement in culminating or benchmark activities. Designing instruction so concepts are learned through participation in activities that use them as resources also requires building participation structures in classrooms so students have significant conceptual agency. In short, the representational infrastructures used in classrooms need to be fundamentally reconstructed. Departing from the “grammar of schooling,” as Tyack and Tobin (1994) characterized it, incurs a heavy cost. Just as cultural expectations about language use can lack congruence (Erickson, 2004; Ladson-Billings, 1995), expectations about the representational infrastructure of schooling can lack coherence, and place barriers in the way of students’ learning. While overcoming these barriers can be difficult, we hope that the challenges of changing practices, including representational infrastructures, do not deter designers and other educational professionals from the effort to accomplish the changes that research shows are needed for students to succeed in meaningful conceptual learning in their school activities.
References and Further Readings


