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Article *in* Review of Educational Research · June 1993

DOI: 10.3102/00346543063002167

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Review of Educational Research
Summer 1993, Vol. 63, No. 2, pp. 167–199

Beyond Cold Conceptual Change: The Role of Motivational Beliefs and Classroom Contextual Factors in the Process of Conceptual Change

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Conceptual change models of student learning are useful for explicating the role of prior knowledge in students' learning and are very popular in the research on learning in the subject areas. This article presents an analysis of a conceptual change model for describing student learning by applying research on student motivation to the process of conceptual change. Four general motivational constructs (goals, values, self-efficacy, and control beliefs) are suggested as potential mediators of the process of conceptual change. In addition, there is a discussion of the role of classroom contextual factors as moderators of the relations between student motivation and conceptual change. The article highlights the theoretical difficulties of a cold, *or overly rational, model of conceptual change that focuses only on student cognition without considering the ways in which students' motivational beliefs about themselves as learners and the roles of individuals in a classroom learning community can facilitate or hinder conceptual change.*

Research on student cognition has demonstrated that students' prior conceptual knowledge influences all aspects of students' processing of information from their perception of the cues in the environment, to their selective attention to these cues, to their encoding and levels of processing of the information, to their search for retrieval of information and comprehension, to their thinking and problem solving (Alexander & Judy, 1988; Alexander, Schallert, & Hare, 1991; Pintrich, Cross, Kozma, & McKeachie, 1986; Winne & Marx, 1989). These cognitive models are relevant and useful for conceptualizing student learning, but their reliance on a model of academic learning as cold and isolated cognition (Brown, Bransford, Ferrara, & Campione, 1983) may not adequately describe learning in the classroom context. In particular, cognition-only models of student learning do not adequately explain why students who seem to have the requisite prior conceptual knowledge do not activate this knowledge for many school tasks, let alone out-of-school tasks. In this article, we will discuss both individual

A portion of this manuscript was presented in a symposium entitled "Beyond Prior Knowledge: Issues in Comprehension, Learning, and Conceptual Change" at the Annual Meeting of the American Educational Research Association, San Francisco, April 1992. Special thanks to our colleagues, Phyllis Blumenfeld, Karen Wixson, Marty Maehr, and Phil Winne, for their thoughtful and incisive comments on earlier drafts of this manuscript. In addition, we thank four anonymous reviewers for their comments, which were very helpful in revising the manuscript for publication.

differences in motivational beliefs as well as classroom contextual factors that may contribute to this problem.

The failure to activate or transfer appropriate knowledge can be attributed to purely cognitive factors including automatization, encoding, and metacognitive and self-regulatory processes (Schneider & Pressley, 1989), but it is likely that motivational and contextual factors also play a role (Garner, 1990). Models that focus only on cognition tend to avoid including constructs such as an individual's goals, intentions, purposes, expectations, or needs (Pintrich, 1990; Searle, 1992). This cognition-only strategy is useful for investigating the general cognitive competence of compliant subjects in an experimental setting where they are provided with a relatively clearly defined problem or task, but the model loses some utility when applied to students' actual cognitive engagement in classroom academic tasks. Students can and do adopt different goals and purposes for their school work, and becoming cognitively engaged in the myriad of classroom academic tasks is really a choice they can make for themselves. In addition, their level of engagement and willingness to persist at the task may be a function of motivational beliefs (Pintrich & De Groot, 1990a, 1990b; Pintrich & Schrauben, 1992).

These three aspects of an individual's behavior—choice of a task, level of engagement or activity in the task, and willingness to persist at the task—are the three traditional behavioral indicators of motivation. Almost all motivational research has been directed at explaining these three aspects of behavior and has invoked a number of motivational constructs as precursors of motivated behavior. Given general cognitive models that assume an active learner who selectively attends to information, activates prior conceptual knowledge, and monitors comprehension, then cognitive engagement in academic tasks may be a good representative of motivated behavior. However, there has been little research or theory development that attempts to link motivation and cognition (Winne & Marx, 1989). Accordingly, it seems important to begin to build the connections between the motivational and cognitive components of student learning.

Besides the intraindividual links between motivational and cognitive components of learning, the actual classroom context may influence students' motivation and cognition and, most importantly, interaction between these two constructs. For example, the tasks that students confront in a classroom are often not as structured conceptually or procedurally as they might be in the experimental setting of a psychology laboratory (Blumenfeld, Mergendoller, & Swarthout, 1987; Blumenfeld, Pintrich, Meece, & Wessels, 1982; Doyle, 1983). Given that these classroom tasks are often not clearly defined, students must often define the tasks for themselves, providing their own goals and structure. Students may not perceive the tasks in the same way that teachers do and may not understand what cognitive resources are appropriate for different tasks (Marx & Walsh, 1988; Newman, Griffin, & Cole, 1989; Winne & Marx, 1982). At the same time, other classroom tasks (e.g., drill and practice worksheets) may be so overstructured and repetitive that very little cognitive engagement is required for satisfactory performance (Doyle, 1983). In addition, the overall classroom structure and organization can influence students' perceptions of what is considered learning as well as their actual cognitive engagement (Stodolsky, 1988). However, this contextual analysis still leaves a role for the active individual. As Lave (1989) points out, in many contexts, not just schools and classrooms, individuals often have to make choices about whether they have a problem or not, then make choices about the specification of what constitutes the problem, and finally decide how they will go about solving it in that context. Again, given that this is a choice that individuals make, motivational constructs such as goals and agency beliefs can play a role in helping describe the factors that influence individuals' ability to recognize a problem, define it, and attempt to solve it.

The purpose of this article is to present a *conceptual analysis* of the relations between motivational factors and student cognition as well as an analysis of classroom contextual factors that may condition the relations between student motivation and cognition. There are many models of student cognition derived from a variety of theoretical perspectives, but we focus on a model of conceptual change that is important for describing how students' prior knowledge may facilitate or impede actual learning. Of course, there are other perspectives on knowledge change and development, such as nativist views on the origins of knowledge (e.g., Spelke, Breinlinger, Macomber, & Jacobson, 1992) and network models based on associationism and connectionism (e.g., Singley & Anderson, 1989), but we focus on conceptual change because of its relevance to conceptual understanding in schools (Gardner, 1991). In addition, conceptual change models have become very popular and useful in research on learning in the subject areas (science, mathematics, social studies; e.g., West & Pines, 1985). At the same time, in contrast to work on students' cognitive learning strategies which has examined the role of motivational beliefs (see Pintrich & De Groot, 1990a, 1990b; Pintrich & Schrauben, 1992), research on students' conceptual change has never explicitly examined the role of an individual's motivational beliefs. Accordingly, the purpose of this article is not to present a comprehensive review of the research, given that there is virtually none on motivation and conceptual change, but rather to develop an argument for the importance of examining motivational beliefs as mediators and classroom contexts as moderators of conceptual change. As part of this argument, we suggest a conceptual framework for future research in this area that includes the interactions between cognitive and motivational constructs as well as classroom factors. We begin with a brief examination of the general conceptual change model as it might be amenable to a motivational analysis, then discuss how different motivational beliefs and classroom contexts may facilitate or impede conceptual change, and suggest directions for future research.

Definition and Description of Conceptual Change

The conceptual change model of learning has been thoroughly described by Posner and his colleagues (Hewson & Hewson, 1984; Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1985; Strike & Posner, 1992). Conceptual change models generally rely on an organismic metatheoretical position (Pepper, 1942) and are similar in many ways to Piagetian theory, although conceptual change models take a more domain-specific view of individuals' conceptions or schemata in contrast to the more global, formal structures and operations of Piaget. This standard individual conceptual change model assumes that ontogenetic change in an individual's learning is analogous to the nature of change in scientific paradigms that is proposed by philosophers of science. There are, however, disagreements between philosophers, historians, and sociologists of science about the nature of change in scientific paradigms. It is beyond the scope of this article to address all the issues related to these disagreements, but there are two issues that are relevant to the argument of this article.

First, there is disagreement about the nature of scientists' judgments and evaluations of differing paradigms along a continuum from rational (being driven solely by logic and scientific findings, a *cold* model) to irrational (being driven by personal interests, motivation, and social/historical processes, a *hot* model, often described as a naturalist position; Giere, 1988). Second, there is disagreement over whether the actual content of scientific theories or just the process of doing scientific research (including developing new ideas and theories) can best be described as rational or irrational. Ever since Kuhn (1962), there has been some agreement that the process of scientific research is influenced by psychological, sociological, and historical factors, but, more recently, sociologists of science, particularly the social constructivists (e.g., Knorr-Cetina, 1981; Latour, 1987) have argued that the actual substantive content of scientific models and theories is influenced by these irrational factors (Cole, 1992). In contrast, other philosophers of science (e.g., Thagard, 1992) and sociologists of science (e.g., Cole, 1992) counter that, while the process of scientific research may be influenced by these irrational factors, the ultimate acceptance of substantive content, in particular the core knowledge in an area, is determined by empirical and logical factors.

In terms of mapping these different positions onto individual conceptual change, we take the constructivist position that the process of conceptual change is influenced by personal, motivational, social, and historical processes, thereby advocating a hot model of individual conceptual change. At the same time, while we accept the position that within natural scientific communities the actual substantive content of theories that is accepted as core knowledge is often determined by logical and empirical factors (Cole, 1992; Thagard, 1992), we believe that, in terms of individual conceptual change in the classroom, the classroom community does not generally operate in the same fashion as the scientific community. Accordingly, we believe that the actual content of students' theories and models is influenced by personal, motivational, social, and historical factors, as shown by the existence and persistence of students' misconceptions in science. These assumptions underlie our analysis of how students' motivational beliefs and the classroom context influence the process of individual conceptual change. We begin our analysis with a brief description of the traditional model of individual conceptual change.

Basically, the standard individual conceptual change model describes learning as the interaction that takes place between an individual's experiences and his or her current conceptions and ideas. These conceptions create a framework for understanding and interpreting information gathered through experience. Current conceptions held by the learner can result in problems resulting from discrepancies between experience and current beliefs, but current conceptions also provide a framework for judging the validity and adequacy of solutions to these problems. Thus, a paradox exists for the learner; on the one hand, current conceptions potentially constitute momentum that resists conceptual change, but they also provide frameworks that the learner can use to interpret and understand new, potentially conflicting information.

The process of learning in a conceptual change model depends on the extent of the integration of the individual's conceptions with new information. If he or she knows little about the topic under study, new information is likely to be combined easily with his or her existing ideas; the process that accounts for this event is what Posner et al. (1982) refer to as assimilation. On the other hand, the individual may have well-developed concepts about the topic under study. Often, these concepts may conflict and be contrary to what is understood as true by experts in that domain; such individual ideas are often referred to as alternative frameworks, and studies have shown these to be highly resistant to change (Champagne, Gunstone, & Klopfer, 1985; Nussbaum & Novick, 1982; Osborne & Freyberg, 1985). Overcoming these frameworks requires a more radical transformation of individual conceptions. This process is what Posner et al. (1982) refer to as accommodation. The processes of assimilation and accommodation are guided by the principle of equilibration whereby individuals seek a relatively stable homeostasis between internal conceptions and new information in the environment (cf. Chapman, 1988; Piaget, 1985).

This contrast between assimilation and accommodation presents another face of the paradox described above. That is, learners with relatively little prior conception of content to be learned have few barriers to learning new content. However, the literature is replete with studies showing the beneficial effect of prior knowledge on new learning. This body of literature also demonstrates that content learned in a disconnected fashion—that is, unintegrated with prior knowledge—is less meaningful and useful (Anderson, 1990). Thus it is clear that prior knowledge can be useful in learning new content. However, prior knowledge can be organized in such a way that the concepts connecting this knowledge compete with concepts understood by a discourse community (e.g., a scientific field). Given that the scientific discourse community can influence the school curriculum (e.g., in terms of what is taught, how it is organized, what is in the textbook and curriculum materials, etc.) in such a situation, students' prior conceptions can serve to resist the development of the more veridical conceptions that are represented in the curriculum.

Clearly, the process of accommodation is critical for the continuing educational development of learners. Without the process of accommodation working on prior conceptions of content, little conceptual growth would occur. Not surprisingly, then, most work on conceptual change has focused on what processes encourage or drive accommodation. To explain how current conceptions influence how an individual will view new information, Posner et al. (1982) use the metaphor of a conceptual ecology. Several assertions are implied by this metaphor. One is the systemic assumption that concepts exist in interrelated networks and that a change in one concept will affect how other concepts are viewed. Conceptual change in one area often leads to anomalies in the individual's conceptual ecology. This system view of learning suggests that considerable forces can be present that can have important consequences for whether conceptual change occurs or not. A second assertion is that individuals hold certain commitments and beliefs about the nature of knowledge. These epistemological beliefs are used by an individual as bases for determining what can or cannot be true or what is or is not a valid explanation of a problem raised in the effort to incorporate new experiences and information into that individual's conceptual ecology. Finally, there is the possibility of ideas competing for the same conceptual niche; this is particularly important for accommodation. In such cases, the idea that wins out will most likely be the one that successfully resolves anomalies and conforms to the individual's beliefs about the nature of knowledge and truth—a survival-of-the-fittest ideas and concepts. The metaphor begins to exhaust itself at this point. Ecosystems are not purposeful, but individual learners and communities of scholars can and do have goals, purposes, and intentions, thereby suggesting a role for an individual's motivational beliefs. It is not clear how competing ideas in a purposeful ecosystem of the mind might behave differently from organisms and populations in a biological ecosystem.

In conjunction with the idea of a conceptual ecology, the conceptual change model states four conditions that must be fulfilled for accommodation to occur. These conditions are borrowed from an analysis of change in scientific paradigms, but they have been applied to individual learning by conceptual change theorists (Posner et al., 1982). The first condition is that of *dissatisfaction* with current conceptions. This suggests that, the less dissatisfied an individual is with his or her current understandings and ideas, the less likely he or she will be to consider a radical change of view. The second condition is that a new conception be *intelligible*. In order for an individual to consider a new concept as a better means of explaining experience than his or her current conception, he or she must be able to understand it. The third condition is that the new concept be *plausible*. While the learner might be able to understand the new concept, he or she may not see how it can be applied or may deem the new concept too inconsistent with other understandings to merit further consideration. Finally, the new concept must appear *fruitful;* that is, it must have explanatory power and/or suggest new areas for investigation.

This description of the four conditions necessary for conceptual change provides an interesting model of how learners might come to change their beliefs about academic subject matter. It presumes a very rational process of cognitive change, paralleling Brown, Bransford, Ferrara, and Campione's (1983) assertion that academic learning is "cold and isolated" (p. 78) cognition. That is, it suggests that learners behave very much like scientists in that, when they become dissatisfied with an idea, they will then search out new intelligible, plausible, and fruitful constructs which will balance their general conceptual model. However, there are both theoretical and empirical reasons to believe that academic learning is not cold and isolated. For example, there is empirical evidence that more affectively charged motivational beliefs, such as students' self-efficacy beliefs, and their goals for learning can influence their cognitive engagement in an academic task (see Pintrich & Schrauben review, 1992). Accordingly, individual students' motivational beliefs may influence the process of conceptual change. In addition, there is a great deal of theoretical and empirical research to suggest that individual learning in classrooms is not isolated but greatly influenced by peer and teacher interactions (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Marx & Walsh, 1988; Palincsar & Brown, 1984; Resnick, Levine, & Teasley, 1991; Tharp & Gallimore, 1988). Besides the influence of individual beliefs then, the conceptual change process may be influenced by being situated within different classroom contexts and shaped dramatically by the nature of the interactions between students and the teacher.

The assumption that students approach their classroom learning with a rational goal of making sense of the information and coordinating it with their prior conceptions may not be accurate. Students may have many social goals in the classroom context besides learning—such as, making friends, finding a boyfriend or girlfriend, or impressing their peers (see Wentzel, 1991)—which can short circuit any in-depth intellectual engagement. In addition, even if the focus is on academic achievement, students may adopt different goals for or orientations to their learning. For example, it appears that a focus on mastery or learning goals can result in deeper cognitive processing on academic tasks than a focus on the self (ego-involved) or a focus on performance (grades, besting others), which seems to result in more surface processing and less overall cognitive engagement (Dweck & Leggett, 1988; Nolen, 1988; Pintrich & De Groot, 1990a, 1990b; Pintrich & Schrauben, 1992). Finally, Kruglanski (1989, 1990a, 1990b) has suggested that individuals' epistemic goals—that is, their motivations toward knowledge as an object—will influence their information processing and knowledge acquisition. Accordingly, an individual student's goals for knowledge, learning, and for classroom life in general may have a significant impact on the conceptual change process.

In addition to this individual goal issue, the conceptual change model uses a metaphor of the individual student as scientist, engaging in rational inquiry and attempting to understand the natural and social world through the use of such devices as theories, models, experiments, and data. Scientists attempt to make sense out of results from research studies and coordinate these results with their prior theoretical beliefs and conceptual models. At the same time, the individual scientist is part of a larger scientific community which emphasizes the search for meaning and understanding and the importance of coherence and consistency in theories, models, and data. Although scientists may be members of a community that sets and enforces this norm of commitment to understanding and most scientists internalize this norm as a personal goal, it is doubtful that students in classrooms are members of a community that operates with this goal of understanding or that individual students will internalize this goal. In fact, Reif and Larkin (1991) have argued that individuals' goals for everyday life lead to a type of satisficing in terms of developing adequate explanation and prediction for phenomena that help them lead "a good life" and are not supportive of the optimal explanation and prediction that scientists typically adopt as goals for their work. Given that the classroom context may not create or support a community committed to understanding, the metaphor of scientific change may not be readily applicable as a model for ontological change in the classroom. Of course, the call for the creation of classrooms as a community of inquiry (Sarason, 1990) seeks to address this problem.

In our view, there are serious limitations to the power of existing conceptual change theory to explain learning in classrooms. We have shown that two of the greatest problems are the lack of theoretical reasoning about the way that: (a) individual motivational beliefs about the self as learner influence learning in classrooms and (b) the role of the individual in a learning community supports or resists instructionally guided conceptual change. In fact, in a recent revision of their original theory, Strike and Posner (1992) have stated that:

> A wider range of factors needs to be taken into account in attempting to describe a learner's conceptual ecology. *Motives and goals and the institutional and social sources of them need to be considered.* The idea of a conceptual ecology thus needs to be larger than the epistemological factors suggested by the history and philosophy of science. (Italics added, p. 162)

Given these problems with the conceptual change model, there needs to be an integration of motivational constructs and an attention to classroom contextual factors in elaborating the model. The remainder of this article presents an argument for how motivational constructs like goals and beliefs may influence conceptual change in the classroom context and how the social and institutional characteristics of the classroom context may influence students' motivation and cognition.

Table 1 displays an overview of our analysis. We have displayed the factors by columns and broken them into cognitive, motivational, and classroom factors (see Table 1), but we assume that the the relations between these three general factors and the four conditions necessary for conceptual change are interactive and dynamic and that there is not necessarily a linear, one-to-one relation between the four columns. We assume that the four basic conditions of conceptual change (dissatisfaction, understanding, plausibility, and fruitfulness) are dependent on a variety of cognitive factors (see Table 1). It seems likely that in order for students to engage in the type of cognitive accommodation for integrating their original beliefs with new ideas that is required by the conceptual change model they would have to be very active, generative learners and engage in a number of cognitive processes (Osborne & Wittrock, 1983). Although there are any number of different conceptualizations of the cognitive factors, there is beginning to be a remarkable consistency at a macrolevel of analysis in that the cognitive factors that influence learning include knowledge, cognitive learning strategies, problem solving or thinking strategies, and metacognitive and self-regulation strategies (see Bereiter, 1990; Perkins & Simmons, 1988; Pintrich, 1992; Snow & Swanson, 1992). In terms of linking these cognitive factors to conceptual change, there are a variety of paths a learner might follow. For example, selective attention to the new information would be required. If students are to become dissatisfied with their original ideas, they would have to attend to the discrepant information. If students have to encode the new concepts to make them understandable and plausible, then they might have to use various deeper processing cognitive strategies such as elaboration (paraphrasing, summarizing) and organizational strategies (concept mapping, networking) which have been shown to facilitate encoding and learning (Weinstein & Mayer, 1986). In the same manner, they would have to activate and utilize their prior knowledge in order to integrate it with the new information in a coherent and logical manner, rather than as just separate bits of new information to recall (Reif & Larkin, 1991). The conditions of dissatisfaction and fruitfulness also could depend on students' ability to find or become aware of problems (Arlin, 1986) as well as their actual problem solving ability (Perkins & Simmons, 1988). As part of this problem solving process, students would have to engage in metacognitive reflection, rethinking their old beliefs and comparing them with the new ideas in order to judge the new ideas as more plausible and fruitful. In addition, students

TABLE 1
Classroom contextual, motivational, and cognitive factors related to the process of conceptual change

Classroom contextual factors	Motivational factors	Cognitive factors	Conditions for conceptual change
Task structures	Mastery goals	Selective attention	Dissatisfaction
Authentic			
Challenging			
	Epistemic beliefs	Activation of prior knowledge	Intelligibility
Authority structures			
Optimal choice	Personal interest		Plausibility
Optimal challenge		Deeper processing	
		Elaboration	
	Utility value	Organization	Fruitfulness
Evaluation structures			
Improvement-based	Importance	Problem finding and solving	
Mistakes as positive			
Classroom management	Self-efficacy		
Use of time		Metacognitive evaluation and control	
Norms for engagement			
	Control beliefs		
Teacher modeling		Volitional control and regulation	
Scientific thinking			
Scientific dispositions			
Teacher scaffolding			
Cognition			
Motivation			

would have to use various metacognitive strategies such as self-testing or self-questioning to determine if the new ideas are intelligible to them given their prior knowledge. Finally, all these types of cognitive engagement often require more effort and persistence on the learner's part, which can make volitional and self-control strategies important as students attempt to manage their effort in the face of challenging tasks (Corno, 1986, 1993; Corno & Kanfer, 1993).

A second assumption of our model is that these various cognitive processes can be influenced by students' motivational beliefs (see Table 1). This is not a new assumption. In fact, Piaget (1954/1981) noted that cognition and affect were inseparable and proposed that affect—specifically, interest—was related to the energizing of all action, including cognitive activity, and that the speed of cognitive development would be facilitated by interest (Chapman, 1988). Besides interest, there are a number of other motivational beliefs that may influence the quality, not just the speed, of students' cognition. Our list of motivational beliefs is derived from a social cognitive perspective on motivation that highlights the important role that students' beliefs and interpretations of actual events play in motivational dynamics (Weiner, 1986). The discussion of motivational beliefs includes several different constructs that have been generated by different theoretical models (e.g., attribution theory, self-efficacy theory, goal theory, intrinsic motivation theory), but we have organized the beliefs around two general motivational factors. These two factors concern students' motivational beliefs about their reasons for choosing to do a task (value components that include goal orientation, interest, and importance) and their beliefs about their capability to perform a task (expectancy components that include self-efficacy, attributions, and control beliefs). Finally, this social cognitive perspective on motivation assumes that students' motivational beliefs are more situation or context specific in contrast to older, traditional personality models of motivation that proposed that student motivation was a stable personality trait (e.g., students were high or low in need for achievement). Given this assumption, it is important to discuss how these motivational beliefs are created, shaped, and constrained by various aspects of the classroom context (see Table 1).

Goal Orientation Beliefs and the Process of Conceptual Change

Goals are cognitive representations of the different purposes students may adopt in different achievement situations. Like general intentions and purposes, in motivational theory these goals are assumed to guide students' behavior, cognition, and affect as they engage in an academic task (Dweck & Elliott, 1983). There are a variety of different conceptualizations of academic achievement goals, but the main distinction is between an intrinsic, mastery, and task-involved orientation and an extrinsic, performance, and ego-involved orientation (cf. Ames, 1992; Dweck & Leggett, 1988; Harter, 1981; Nicholls, 1984). Students who adopt a mastery orientation are assumed to focus on learning, understanding, and mastering the task while those who adopt a performance orientation are assumed to focus on obtaining a good grade or besting others. There have been a number of studies that have shown that these two different types of goal orientation can lead to different patterns of cognitive engagement (Pintrich & Schrauben, 1992).

For example, Pintrich and his colleagues in a series of correlational classroom studies (e.g., Pintrich, 1989; Pintrich & De Groot, 1990a, 1990b; Pintrich & Garcia, 1991) have shown that junior high and college students who adopted an intrinsic goal for learning focused on understanding were more likely to report using deeper processing strategies like elaboration as well as more metacognitive and self-regulatory strategies (e.g., planning, comprehension monitoring, regulating). Meece, Blumenfeld, and Hoyle (1988), in a correlational study of elementary science classrooms, found that students who adopted a general intrinsic orientation to learning as well as task-specific mastery goals were more likely to report using more cognitive and metacognitive strategies. Nolen (1988), in a laboratory study of text comprehension, found that junior high school students who adopted a task orientation focused on learning and understanding were more likely to use both deeper and surface processing strategies, while those with an ego orientation (a focus on the self and besting others) were more likely to use surface processing strategies. In addition, in both the Pintrich et al. studies and the Nolen study, the motivational variables only had an indirect relationship to actual academic performance through their link to the use of cognitive and metacognitive strategies and deeper cognitive engagement (as suggested in Table 1). Graham and Golan (1991), in another experimental study of elementary students' memory and depth of processing, found that an induced motivational state (task- or ego-focused) did not differentiate students' memory performance when shallow processing was required by the memory task (recall of rhyming words), but, when required by the task to remember meaningful words from sentences, students who were more task focused performed significantly better. Taken together, these results suggest that when students are required to process material in a deeper fashion, as would be expected in a classroom focused on conceptual change, students who are focused on the task with a learning/mastery orientation are more likely to process the information in a way that increases the probability that the four conditions necessary for conceptual change will occur. As Reif and Larkin (1991) and others (Cole, 1992; Thagard, 1992) have pointed out, scientists may have a number of goals operating as they engage in research, but they almost always have a goal of understanding the phenomena under study. In a parallel fashion, students who adopt a mastery goal orientation focused on learning and mastery should be more likely to engage in the type of cognitive processing necessary for conceptual change to occur.

Although the link between students' mastery goal orientation and their cognitive engagement seems to be relatively robust, it is important to note that most goal theorists assume that individuals' goal orientations are dependent on and situated within a classroom context (Ames, 1992; Blumenfeld, 1992). There seem to be several important dimensions of classrooms that can influence the adoption of a mastery goal orientation. First, the nature of the tasks that students are asked to accomplish can have an impact on students' goals. It appears that tasks that are more challenging, meaningful, and authentic in terms of actual activities that might be relevant to life outside school can facilitate the adoption of a mastery goal (Ames, 1992; Brophy, 1983; Lepper & Hodell, 1989; Meece, 1991). However, many, if not most classrooms, do not offer students the opportunity to work on authentic tasks (Gardner, 1991), thereby decreasing motivation and the opportunities for transfer of knowledge learned in school to other contexts. At the same time, the authority structures in classrooms often do not allow students much choice or control over their activities, which decreases the probability of a mastery orientation being developed in students (Ames, 1992; Ryan, Connell, & Deci, 1985). Finally, evaluation procedures that focus on competition, social comparison, and external rewards can foster a performance goal orientation where the learner focuses on besting others rather than gaining a conceptual understanding of the content (Ames, 1992; Elliott & Dweck, 1988; Grolnick & Ryan, 1987).

This research supports the assumption that the classroom context can influence the adoption of a mastery goal orientation, which in turn can influence the nature of students' cognitive processing and potential for conceptual change. These linkages between context, motivational goal orientation, and cognition suggest that it may not be enough for teachers to present new information in a conceptual change instructional format that creates disequilibrium or dissatisfaction on the students' part (see Osborne & Freyberg, 1985). It appears that teachers must consider how the instruction is embedded in the task, authority, and evaluation structures of their classrooms. If teachers use a conceptual change instructional model without changing the traditional task, authority, and evaluation structures of the classroom, then students still might adopt a performance goal orientation to the new instructional method. In turn, this performance goal orientation would tend to undermine the teacher's attempts to have the students engage the material in a deep and thoughtful manner. Accordingly, teachers may have to change not just their general instructional strategies for teaching for conceptual change but also their tasks, authority, and evaluation structures to focus the students on mastery and understanding goals (Blumenfeld, Mergendoller, & Puro, 1992).

At the same time, the changing of these classroom structures creates additional demands on the classroom management system. For example, discovery and inquiry methods, which are suggested as potential ways to teach for conceptual change, often use *authentic* tasks (e.g., real science experiments), decrease the role of the teacher's authority, and change how students are evaluated, yet they can create many management problems. Science education reform efforts in the 1960s often failed because they were difficult to manage for many teachers in traditional classrooms (Blumenfeld et al., 1991). As Doyle (1983) has pointed out, challenging and different tasks can create ambiguity and risk for both teachers and students. Students who are accustomed to tasks (e.g., worksheets) that require rather minimal or passive involvement may resist the teacher's attempts to engage them in more complicated and ambiguous tasks by negotiating the task downward to a rather simple level or by acting out when given more responsibility. Accordingly, the changes suggested by goal theorists (e.g., Ames, 1992) to the task, authority, and evaluation structures of the classroom must be considered in light of both management and curriculum concerns (Blumenfeld, 1992). As McCaslin and Good (1992) have argued, it is important to develop authoritative management systems that help students become active, self-regulated learners who are engaged in problem solving and meaningful learning not just passive obedience, as in an authoritarian system, or unfocused freedom, as in a laissez-faire management system. In summary, the classroom contextual factors of task, authority, and evaluation structures as well as of the general management system can influence students' motivation and cognition and can either facilitate or hinder the potential for conceptual change.

Besides these goals for learning that focus on the self, Kruglanski (1989, 1990a, 1990b) has suggested that individuals might have different goals or motivations about knowledge as an object. He terms this motivation towards knowledge *epistemic motivation*. Most of the empirical work that supports his lay epistemic theory has been concerned with social cognitive issues such as attitude change, person perception, and attributional beliefs. Nevertheless, the model assumes that individuals are active processors of information who develop and test hypotheses about their knowledge of themselves, other people, and the social world. This assumption of lay epistemic theory is identical to the assumption in conceptual change theory that individuals act as scientists as they try to understand the natural world. In contrast to conceptual change models, however, in Kruglanski's model this process of developing and testing hypotheses is explicitly a function of both cognitive and motivational processes. The cognitive factors that influence hypothesis generation and testing are the availability and accessibility of knowledge. *Availability* refers to all possible knowledge structures an individual can potentially access, and *accessibility* refers to the actual knowledge structures that the individual activates in the specific context. This general model is not unlike many cold cognitive models regarding the role of knowledge. However, Kruglanski argues further that individuals often do not test hypotheses all the time. Epistemic motivations provide the psychological mechanisms for the initiation, guidance, and cessation of the cognitive work involved in hypothesis development and testing.

In his lay epistemic theory, Kruglanski posits two general dimensions of epistemic motivation, seeking or avoiding closure and specificity or nonspecificity. Kruglanski uses the metaphor of *freezing or unfreezing* of cognition to illustrate the potential influence of epistemic motivations. Freezing of cognition refers to the process where the individual does not attempt to develop or test new ideas or entertain new hypotheses. The individual basically does not seek out new information or discounts relevant information that might contradict already established beliefs or knowledge structures that are activated in that situation. In contrast, unfreezing refers to the individual actively seeking new information, questioning old beliefs, entertaining new ideas and hypotheses, and trying to solve problems or resolve discrepancies. It seems clear that Kruglanski's use of the term *unfreezing* shares many features with the cognitive processes that are assumed to go on when individuals have to accommodate new information in conceptual change models.

The epistemic motivation of seeking closure refers to an individual's attempts to obtain an answer to a question or resolution to a problem, thereby bringing to an end the hypothesis generation and testing process. In contrast, at the other end of the continuum, when operating under the avoiding closure goal, individuals will delay premature or early resolution of a problem in favor of continued information search and hypothesis generation and testing. The goal assumed to underlie this process of avoiding closure is assumed to be a need for accuracy which can then lead to the use of appropriate beliefs and strategies for reasoning (Kunda, 1990). These two aspects of the closure dimension can be combined with the other dimension which refers to the specificity of the answer. Specificity refers to the individual seeking one answer, whereas nonspecificity refers to the individual being satisfied with any answer. The need for a specific answer also has been categorized as a directional goal which leads to the use of beliefs and strategies that will most likely produce the desired answer (Kunda, 1990). Individuals may seek nonspecific closure where they will actively seek to end their cognitive activity by finding any answer to their question. Children in classrooms may be operating with this combination of epistemic motivations most frequently (i.e., find any answer as quickly as possible, Anderson, Brubaker, Alleman-Brooks, & Duffy, 1985). In contrast, individuals seeking specific closure will engage in cognitive activity until they have obtained a particular answer. Kruglanski points out that cognitive activity is not only initiated and concluded by these epistemic motivations but that, when operating under a goal of specificity, an individual's processing of information will be guided in certain directions (i.e., towards the specific answer; cf. Kunda, 1990).

Besides these two-way interactions between closure and specificity, Kruglanski also predicts that the level of prior knowledge may influence cognition when combined with the epistemic motivations. For example, students who have low prior knowledge in an area and have a need to seek nonspecific closure would engage in an intense cognitive search (unfreezing) for an answer, any answer. Once this answer is obtained, then the cognitive activity would be concluded. In the same way, a student who has a high level of knowledge in an area and has a need for nonspecific closure would be unlikely to engage in further elaborate cognitive activity because he or she already has an answer based on prior knowledge. The process works basically the same way for students with a need to seek a specific closure in terms of the freezing or unfreezing of cognitive activity. However, the need for specific closure would influence the direction of the cognition by maintaining cognitive activity until a particular answer is found. Accordingly, students with low knowledge who are seeking specific closure might engage in cognitive activity longer than students with low knowledge who are seeking nonspecific closure in order to obtain information that fits the specificity criteria.

Kruglanski (1989) also notes that the need to avoid closure might be particularly strong when there are costs associated with being wrong. Students with low prior knowledge would be unlikely to engage in cognitive activity when they are also trying to avoid closure. In this case of an ignorance-is-bliss orientation, students would not want to seek new knowledge that would lead to some type of answer. In contrast, students with high knowledge in a domain but also a need to avoid closure would be likely to engage in cognitive activity to seek out new information that might contradict or lead to change in their knowledge structures. In addition, given their relatively high level of knowledge, they might be less threatened by new information, and, because they are trying to avoid closure, they would be likely to engage in cognitive activity.

The four different epistemic motivations are assumed to be more situation specific than traits, although the need for closure may have some trait-like characteristics (Kruglanski, 1989, 1990a, 1990b). In his empirical work, Kruglanski has shown that all four of the different epistemic motivations can be activated by certain features of the environment. For example, setting time constraints and heightening the time pressure or instructions that stress the need for clear, definite answers usually lead to the seeking of closure. Stressing the costs of being wrong and the creation of evaluation apprehension by suggesting that responses will be compared to others seems to lead to fear of invalidity and the need to avoid closure (Kruglanski, 1989). These features seem readily applicable to many of the common aspects of the classroom context. Most classrooms have time constraints operating, but teachers can increase the time pressure by stressing the importance of finishing academic work within the allocated time period. This would tend to create a need for closure with the concomitant decrease in cognitive activity. Efforts at school reform that seek to increase the time available for students to work on extended projects would help set a classroom context whereby the motivational mechanism of need for closure would be lessened and cognitive activities such as hypothesis generation and testing increased. In the same way, if the teacher stresses that the products of student work (answers in a discussion, lab results) should have one correct answer, then a need for closure would be created, and students would be less likely to become cognitively engaged. In fact, in the science education literature there is evidence that many science labs are verification, not problem solving, exercises and are seen as something to complete and to get the right answer on, rather than as a process by which one might learn something new (Hofstein & Lunetta, 1982; Walberg, 1991). Accordingly, classroom activities that are designed to be more open-ended and create a need to avoid closure in students may be more likely to facilitate cognitive activity and conceptual change. In addition, the issue of need to avoid closure may be less of a problem in classrooms, given their overwhelming press for closure.

In summary, classroom organization and the nature of many classroom academic tasks may encourage students to get it done, not think it through, so it may be important to create types of authentic tasks or projects (Blumenfeld et al., 1991) without one right answer and with longer periods of time for completion in order to help stave off seeking closure and facilitate more cognitive activity and conceptual change. Epistemic motivations and students' general goal orientation to learning provide a psychological mechanism to explain how and why these more authentic tasks may lead to more cognitive activity.

There are a great many avenues for further research on the role of students' goal orientations in the classroom context and conceptual change. First, there is a need for research on the actual empirical links between students' goals (mastery, performance, social, and epistemic) and students' cognition and conceptual change. Although the links between mastery motivational goals and students' cognition are fairly well documented, the next link to actual conceptual change has not been documented. In addition, the research on goal theory has tended to ignore other potential goals (e.g., social and epistemic) to focus on mastery goals, and there is a need for an examination of how these other goals could complement, compensate, or conflict with mastery and performance motivational goals. In addition, epistemic goals have not been examined in younger students in classroom contexts, so it is not even clear whether we can assess epistemic goals in children and whether they are related to the learning process in classrooms. Kruglanski (1990a) suggests that the need for closure may be more trait-like, but it seems clear that this would be a trait that would develop over time through experience. It may be that certain types of classroom experience increase the likelihood of the adoption of need for closure, but there is a need for research on how this pattern may develop over time in classroom settings. The research that examines the interaction of these different types of goals, cognition, and conceptual change should focus on domain-specific measures and link them to students' cognition and conceptual change for very specific types of cognitive tasks and content, not use omnibus measures of goals that may not be related to the more specific knowledge and strategies in different domains.

In addition, there is a need for research on how the different classroom contextual variables moderate and condition the relations between students' goals, cognition, and conceptual change. It seems clear that the different structural characteristics of classrooms (see Ames, 1992) can influence students' mastery and performance goals, but it is not clear how they may be related to social and epistemic goals. In addition, the work on goal theory has tended to examine the structural characteristics of task, authority, and evaluation structures without considering how the management system and the teachers' instructional behavior may interact with these more structural features to enhance or undermine students' adoption of mastery goals. For example, can the teachers' modeling of scientific thinking and a scientific disposition create an epistemic goal of avoiding closure that can override the adoption of a performance goal orientation that is fostered by the task, authority, and evaluation structures of the classroom? It is important to note that we do not assume that research that examines these issues will be able to isolate the different classroom characteristics along separate dimensions as in an analysis of variance model but rather that the classroom characteristics may coalesce in different patterns of classroom structure, management, and instruction which will have differential effects on students. In the same manner, we do not assume that the different student goals and other motivational beliefs will necessarily be orthogonal to one another but rather that they may be assembled in different patterns or *modules* (see Bereiter, 1990) that are activated in different classroom contexts. In this sense, traditional analysis of variance models may not be the most useful to examine these questions. Cluster analysis or multidimensional scaling techniques may be more useful, as will more qualitative analyses (cf. Blumenfeld, Mergendoller, & Puro, 1992; Pintrich, 1992; Salomon, 1992).

Interest and Value Beliefs and the Process of Conceptual Change

Although goals and goal orientation beliefs are related to students' choice of tasks and the quality of their engagement, there are other motivational constructs that also are related to students' reasons for engaging in tasks. These constructs are not the same as goals and goal orientations, albeit they also are related to the quality of students' engagement in tasks. These constructs include students' interest and value beliefs which are somewhat more affective or attitudinal in nature and which may be more stable and personal in comparison to the more cognitive and situational representations of goals. In this sense, interest and value beliefs may be at a different level of analysis than goals and goal orientations. It may be that students could have multiple goals operating due to differential interest and value beliefs. In fact, interest researchers (e.g., Krapp, Hidi, & Renninger, 1992) have suggested that the effects of interest on learning may be generated by different interest and value beliefs that influence the types of motivational goal orientation that students adopt in classrooms and that then influence learning. For example, students may be intrinsically interested in a topic area, but they may also value it because of its importance for future career options. These differential interest and value beliefs could give rise to both mastery (intrinsic interest generating a mastery goal) and performance (importance generating a concern for grades) goal orientations. Pintrich and Garcia (1991) have made a similar argument and shown that students can have both mastery and performance goals that operate at the same time and that interact to influence students' cognitive engagement. Accordingly, interest/value beliefs and goals may be operating at different theoretical levels of analysis (see Krapp et al., 1992) but may be linked to one another in important ways as well as to students' cognitive engagement.

It is important to note that interest and value beliefs are assumed to be personal characteristics that students bring to different tasks, not features of the task itself. In contrast, concepts like situational interest refer to environmental features (e.g., text features that make a text interesting) that induce interest in almost all students who experience the task (Hidi, 1990). We will focus on the individual difference and the personal variables that are activated in the situation. Eccles (1983) has proposed that there are three general interest or value beliefs. Interest simply refers to the student's general attitude or preference for the content or task (e.g., some students just like and are interested in science). Utility value concerns the student's instrumental judgments about the potential usefulness of the content or task for helping him or her to achieve some goal (e.g., getting into college, getting a job). Finally, the importance of the task refers to the student's perception of the salience or significance of the content or task to the individual. In particular, the importance of a task seems to be related to the individual's self-worth or self-schema. If a student sees himself or herself as becoming a scientist—that is, a scientist is one of her possible selves (Markus & Nurius, 1986; Markus & Wurf, 1987)—then science content and tasks may be perceived as being more important, regardless of his or her mastery or performance orientation to learning.

Hidi (1990) has discussed issues related to the role of interest and its influence on learning. She summarizes the research on interest by concluding that both personal interest and situational interest have a "profound effect on cognitive functioning and the facilitation of learning" (Hidi, 1990, p. 565). In particular, she suggests that personal interest influences students' selective attention, effort and willingness to persist at the task, and their activation and acquisition of knowledge. In addition, Hidi (1990) notes that interest may not necessarily result in more time spent processing information—rather, depending on the nature of the task (complex vs. simple), students may take more or less time to perform the task. The difference lies in the quality of the processing, not the quantity of processing or time spent on the task (Hidi, Renninger, & Krapp, 1992). Similarly, using both experimental and correlational designs, Schiefele (1991, 1992) has shown interest to be related to a variety of cognitive measures. For example, college students' ratings of their interest in their course material were positively related to their self-reported use of elaboration strategies, the seeking of information, and their engagement in critical thinking. Also, interest was negatively related to the use of rehearsal strategies (a surface processing strategy) and most strongly related to self-reports of investment in time and effort. In an experimental study where interest was manipulated and reading and strategy behavior were observed, interest was correlated with underlining and note taking and strongly related to the use of elaborative strategies. Pintrich and his colleagues (Pintrich, 1989; Pintrich & Garcia, 1991) also have shown that college students who report that their course material is more interesting, important, and useful to them are more likely to use deeper processing strategies like elaboration and metacognitive control strategies.

The effects of interest on cognitive engagement have not been limited to studies of college students. For example, Renninger and Wozniak (1985) demonstrated the effects of interest on the processes of attention, recognition, and recall for young children. After first determining objects of interest for each of sixteen 3- to 4-year-olds through naturalistic observations, they showed in subsequent experimental studies significantly higher levels of both initial attentional fixation and numbers of attentional shifts toward objects of interest than toward comparison (control) items, all within a 3-second exposure period. Additionally, children were not only better able to both recognize and recall objects of interest but also more likely to recognize and recall objects of interest first, before comparison items. Not only were there strong and varied focuses of interest in children this young, but this interest, from initial attending on, influenced memory performance. More recently, Renninger (1992) has shown that fifth and sixth graders' reading and math performance were influenced by individual interest. Tasks that included high interest or value contexts (e.g., interesting reading passages or math word problems) resulted in more competent performance. It is important to note that this study showed that the high value context did not necessarily result in students' use of the prerequisite cognitive skills but that it did result in longer persistence at a task. In another study that assessed students' beliefs about value, Pokay and Blumenfeld (1990) found that high school students' beliefs about the value of geometry did not directly predict performance on tests but that value was predictive of use of general cognitive strategies, specific geometry strategies, metacognitive strategies, and effort management strategies. These findings for task value support the view that perceptions of the value of a task do not have a direct influence on academic performance but they do relate to students' choice of becoming cognitively engaged in a task or course and to their willingness to persist at the task. Taken together, these studies suggest that personal interest and value beliefs are aspects of a self-generated context that interacts with the task features to support learning by increasing attention, persistence, and the activation of appropriate knowledge and strategies (cf. Renninger, 1992). To the extent that conceptual change requires students to maintain their cognitive engagement in trying to understand alternative views, to accommodate to the new, conflicting information, these value beliefs may mediate the process.

Most of these studies have focused on students' personal beliefs and the interest that they bring with them to the task. Situational interest is influenced more by classroom, task, and text features and is, therefore, more amenable to teacher control. At the classroom and task level, there are a number of features that could increase students' situational interest—such as, challenge, choice, novelty, fantasy, and surprise (Malone & Lepper, 1987). In the text-processing literature, many of these same features have been shown to influence situational interest and students' cognitive engagement (Garner, Brown, Sanders, & Menke, 1992; Hidi, 1990; Hidi & Anderson, 1992; Wade, 1992). To the extent that classrooms, tasks, or text materials have these features, we would expect students to be more or less interested in the content of the lesson with concomitant levels of cognitive activity. Again, the features of the classroom context are important moderators of the relationship between student motivation and cognition. Classrooms that stress conceptual change and disequilibrium-inducing material but that do not have some of these other motivating features may undermine the conceptual change process because students will not be interested enough to attend to the new information. In addition, most of the work on challenge and intrinsic motivation (see Malone & Lepper, 1987) stresses the importance of optimal levels of challenge, keeping novelty, difficulty, and surprise within the capabilities of the student. Instruction that is designed to foster conceptual change but that goes beyond the students' range of knowledge and capability (or alternatively, zone of proximal development) will likely short-circuit the change process. In such a situation, assimilation processes are more likely to operate than accommodation processes, thus limiting the possibility that conceptual change will take place.

In contrast to the research on goal orientation, there is much less research on interest and value beliefs and students' cognition (see, however, Renninger, Hidi, & Krapp, 1992). It is becoming clear that, although goals are important, interest and value beliefs might help shape goal adoption and that interest can be related to cognitive engagement independent of goals. At the same time, the research on interest is not as far along as that on goal theory in specifying clearly the nature and definition of the construct of interest. Accordingly, future research on interest, cognition, and conceptual change will have to address carefully the theoretical differences between constructs in the interest research. Nevertheless, there are directions for research on interest and conceptual change that should be productive. For example, although it seems intuitive, there is a need for research on the links between interest and value and conceptual change. That is, are personal interest and value for a particular domain necessary for conceptual change in that domain? It may be that students can show conceptual change without being interested in or valuing the domain. On the other hand, while not necessary, interest and value beliefs may increase the probability that conceptual change will occur. If so, what are the mechanisms by which this effect occurs; is it strictly a function of spending more time in the domain, or are other more cognitive mechanisms at play (activation of prior knowledge, accommodation, deeper processing, etc.)? Beyond personal interest, are text or classroom features that create situational interest sufficient for conceptual change? It may be that situational interest results in more attention to the text on the part of the student, but, if the text is still not structured for facilitating conceptual change (cf. Roth, 1990), then situational interest may not be sufficient. Accordingly, there is a need for more research on both the motivational features of texts as well as the conceptual change features of texts. In the same manner, classroom features (see Malone & Lepper, 1987) that increase interest may not lead directly to conceptual change unless students have the requisite prior knowledge and skills. There is a need for more research that examines the interactions of classroom features that heighten interest and students' cognitive capabilities.

Self-Efficacy Beliefs and the Process of Conceptual Change

Goals, interest, and value beliefs represent students' reasons for engaging in different tasks. However, another important aspect of motivation is students' beliefs about their capability to accomplish the task. *Self-efficacy beliefs* have been defined as individuals' beliefs about their performance capabilities in a particular domain (Bandura, 1986). In an educational context, self-efficacy beliefs refer to students' judgments about their cognitive capabilities to accomplish a specific academic task or obtain specific goals (Schunk, 1985). Self-efficacy beliefs are assumed to be relatively situation-specific, not global personality traits or general self-concepts. In a conceptual change model of learning, self-efficacy beliefs could be construed in two ways. First, in the bulk of the research on self-efficacy, the construct is used to represent students' confidence in their ability to do a particular task. In applying this construct to conceptual change, this could translate into students' confidence in their own ideas and conceptions. In this case, higher levels of self-efficacy or confidence in one's own beliefs would be a hindrance to conceptual change. That is, the more confidence students have in their own beliefs, the more resistant they would be to new ideas and conceptions. In fact, much of the conceptual change literature is based on the notion of destabilizing students' confidence in their beliefs through the introduction of conflicting data, ideas, or theories. A second way to conceive of the relation of self-efficacy to a conceptual change model is the confidence students have in their capabilities to change their ideas, to use the cognitive tools necessary to integrate and synthesize divergent ideas. Following the scientific paradigm and scientist metaphor of conceptual change, self-efficacy would be the students' confidence in using the research methods of thinking (hypothesis testing, gathering evidence, considering alternative arguments, etc.) to effect a change in their own conceptions. In this sense, self-efficacy would refer to students' confidence in their own learning and thinking strategies.

There has been very little research on students' self-efficacy for thinking and using sophisticated strategies for problem solving. In one of the few studies, Strike and Posner (1992) reported that high school students' learning attitudes (a single factor which was composed of three constructs that we have kept separate in our model: self-efficacy, mastery goal orientation, and deeper processing strategies) were positively correlated with conceptual change in physics. However, there have been a variety of other studies linking students' self-efficacy beliefs for an academic task to their cognitive engagement in those tasks. For example, Schunk (see reviews in 1985, 1989, 1991) has consistently shown in experimental studies that changing self-efficacy beliefs can lead to better use of cognitive strategies and higher levels of academic achievement for math, reading, and writing tasks. Other correlational studies have supported this view. Paris and Oka (1986) found that elementary school students' perceptions of competence were positively related to performance on a reading comprehension task, metacognitive knowledge about reading, and actual reading achievement. Pintrich and De Groot (1990a) also found that junior high school students' use of cognitive and metacognitive strategies was positively correlated with self-efficacy judgments. Shell, Murphy, and Bruning (1989) found that college students' self-efficacy beliefs about their reading and writing skills were related to their performance on a reading comprehension task and an essay writing task. Pintrich and his colleagues (Pintrich & Garcia, 1991; Pintrich, Smith, Garcia, & McKeachie, in press) have found that college students' self-efficacy beliefs about their performance in a college course are strongly related to their use of cognitive and metacognitive strategies in the course, as well as their actual performance as measured by course grades. The use of these cognitive and metacognitive strategies should result in deeper processing of course material and should increase the probability of conceptual change. As Strike and Posner (1992) suggest in their revised *interactionist* model of conceptual change, students that have confidence in their ability to understand science, value science, and approach science learning with a focus on understanding should show more conceptual change.

This suggests that instructional strategies must be developed that increase students' efficacy in their capability to accomplish the tasks as well as their efficacy for using the appropriate cognitive and metacognitive strategies to facilitate understanding. In this sense, it is not useful for teachers to create tasks that increase the opportunities for cognitive conflict and then leave students entirely to their own devices to resolve the conflict. Students must be assisted in learning how to resolve cognitive conflict through both modeling and scaffolding. In his work on how to increase students' self-efficacy as well as cognitive skill, Schunk (1989) has suggested a number of instructional strategies that may be useful. Verbalization and modeling of appropriate strategies by both the teacher or other students seem to be helpful to students' efficacy and learning. In addition, there is experimental evidence that students observing a coping model, who initially has difficulty with a task and then eventually masters it, increase their efficacy and learning more than students who see a mastery-only model (Schunk & Hanson, 1985). In scaffolded instruction or other classroom instructional models that rely on a great deal of in-depth interaction between teachers and students, the possibility that students will see other students having difficulty is increased. This should then have positive effects on the observers' efficacy and learning. Of course, this presupposes that the task is eventually mastered by some of the students in the instructional group. The complexity of classroom instruction and, in particular, the role of peer models as representations of successful learners highlight the need for conceptual change instruction to introduce tasks that may induce cognitive conflict but not at a level that is beyond the students' actual capabilities to master the task or beyond their efficacy beliefs about what they can master. In this sense, the learner's contribution to the zone of proximal development can be seen to have three essential features: prior knowledge and conceptual understanding of the subject matter, cognitive strategies and tools for mastering new learning, and motivational factors such as self-efficacy beliefs that serve to mediate the student's attempts at learning new and potentially difficult material. The activation of appropriate self-efficacy beliefs may widen the zone of proximal development by providing students with the confidence they need to sustain their effort and persistence at more difficult levels of the task as well as the willingness to activate relevant knowledge and strategies (Paris & Cross, 1988; Renninger, 1992).

Future research will need to examine both students' confidence in their preexisting beliefs and their perceptions of efficacy to learn science as they might interact in the process of conceptual change. In addition, there needs to be research on students' perceptions of efficacy for using the various cognitive, metacognitive, and self-regulatory strategies often used by scientists and research on how these beliefs interact with other self-efficacy beliefs. It may be that students do not have confidence in their actual beliefs, but at the same time they do not feel efficacious in using the tools of thinking and hence will be less likely to become cognitively engaged in the task. On the other hand, they may feel very strongly about their preexisting beliefs and may not feel any need to change them, even if they do have confidence in their ability to think scientifically. Although Eccles and her colleagues (see Eccles, Adler, & Meece, 1984; Wigfield & Eccles, 1992) have shown that expectancy beliefs (e.g., self-efficacy and control beliefs) are more related to actual achievement and that value beliefs (e.g., goals and interest) are more related to choices of tasks in which to become engaged, there is a need for research that examines the interaction of these different motivational beliefs in the context of students' conceptual change. At the same time, this research must be embedded in the classroom context where various aspects of classroom structure, management, and teacher behavior (see Table 1) might have differential effects on self-efficacy as well as value beliefs, with complementary or conflicting results for conceptual change.

Control Beliefs and the Process of Conceptual Change

Most social cognitive theories of motivation include some construct that refers to individuals' belief about how much control they have over their behavior or the outcome of their performance. Self-efficacy theory distinguishes individuals' perceptions of their capability to perform a task (self-efficacy) from their outcome expectations which refer to their beliefs that the environment is responsive to their actions on that task. For example, a student may have a relatively strong belief in his or her efficacy to do chemistry problems but a low outcome expectation for his or her grade on a chemistry exam because the grading curve in the class is set at a very difficult level. Intrinsic motivation theorists also have proposed that control beliefs are an essential aspect of an intrinsically motivated learner. For example, Connell (1985) has proposed that there are three general control beliefs: internal control, external control, and unknown control. He has shown that students who believe that they have internal control over their own learning and performance, in contrast to students high in external control or unknown control, perform better in school. Skinner and her colleagues (e.g., Chapman, Skinner, & Baltes, 1990; Skinner, Chapman, & Baltes, 1988a, 1988b; Skinner, Wellborn, & Connell, 1990) also have proposed that students' beliefs about perceived control have important implications for motivation and academic performance. They make a distinction between three types of perceived control beliefs: Agency beliefs refer to students' perceptions that they can perform the appropriate behavior for the task (this is congruent with self-efficacy from social cognitive theory: e.g., "I can use this strategy."); means-ends beliefs parallel the outcome-expectancy belief construct from social cognitive theory and involve the belief that there is a contingent relation between performing a behavior and the outcome (e.g., "If I use this strategy, I will learn better."), and control beliefs are a generalized expectancy for a relation between the agent and the outcome (e.g., "I can learn; I can get good grades.").

Although there are an overwhelmingly large number of studies on the relations between control beliefs and just about any behavior of interest (e.g., Baltes & Baltes, 1986; Lefcourt, 1976), including academic achievement (e.g., Findley & Cooper, 1983; Stipek & Weisz, 1981), research on its relation to students' cognitive engagement is fairly recent. For example, Pintrich (1989) found that internal control beliefs were positively related to college students' use of deep processing and metacognitive strategies and their actual performance on class exams, lab reports, and papers, as well as in final grade in the course. Fabricius and Hagen (1984) found that early elementary students' memory performance and use of memory strategies were positively related to attributions to internal ability. Kurtz and Borkowski (1984) also found that attributing memory performance to controllable factors had a positive relation to the subsequent use of memory strategies on transfer and generalization tasks. In studies with upper elementary and junior high students, there is evidence that beliefs regarding the importance of effort (an internal and controllable attribution) are related to metacognitive knowledge, actual memory strategy use, and performance (Borkowski, Carr, Rellinger, & Pressley, 1990; Schneider, Borkowski, Kurtz, & Kerwin, 1986). In contrast, some studies have not found positive relations between control beliefs and memory performance (Chapman, Skinner, & Baltes, 1990; Weed, Ryan, & Day, 1990), general engagement (Skinner, Wellborn, & Connell, 1990), or general academic performance (cf. Findley & Cooper, 1983; Stipek & Weisz, 1981). It appears that these relationships may vary depending on the age of the student, the definition of the construct, the types of measures employed, and the timing of the assessments of the motivational beliefs. It is unclear at this time what psychological mechanisms might underlie these empirical irregularities. However, the theoretical mechanisms thought to be central to conceptual change are good candidates for exploration.

Students' perceptions of how much control they have over their own learning may have implications for the process of conceptual change. Bereiter (1990) has recently argued for a more global construct for the development of learning theory, which he labeled the *intentional learner*. This construct includes the idea that individuals assemble into modules the knowledge, skills, goals, and affect (for both task and self-related factors) that are then used in a specific context for guiding and directing learning. In a conceptual change model, self-related beliefs about control over learning could direct the level of accommodation or assimilation to new information. If students did not see themselves as intentional learners with some control over their learning, they might be less willing to try actively to resolve discrepancies between their prior knowledge and the new information. Instead, they might regard the discrepancies as something beyond their understanding, something that takes place in the classroom but not under their control. In contrast, intentional learners who believe they do have some control over their learning may actively try to resolve the discrepancy in some fashion. This does not mean that it will be resolved in favor of the scientifically acceptable answer, only that students may be more willing to engage in thinking through some of the issues. Accordingly, control beliefs may be more related to the initiation of cognitive engagement, but they may not specifically influence the direction of thinking. This nondirectional effect is in contrast to the need for specificity in epistemic motivation which would direct the content of students' thinking.

Instruction designed to foster conceptual change is likely to take place over larger units of time than more conventional didactic instruction, thereby providing somewhat different opportunities for control. For example, project-based learning in science is often designed so that students investigate a significant problem with a specific question that serves to organize and drive activities. The pursuit of these activities results in a variety of products, such as analyses of water quality in the local watershed, that eventuate in a final product that answers the driving question of the project (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). Conceptual change instruction, such as is implied by project-based learning, involves at least two venues for opportunities for student control.

First, students can exercise some control over what to work on, how to work, and what products to create in project-based learning. These features of project-based learning should increase students' perceptions of control. Given their choice over activities and how to do them, they should come to believe that they have some control over their own learning in project-based classrooms as suggested by intrinsic motivation researchers (Deci & Ryan, 1985; Malone & Lepper, 1987). This increase in control beliefs may lead to deeper levels of cognitive engagement. However, many research and instructional questions remain regarding the optimal degree of choice and control to be shared by teachers and students so that novices are not overwhelmed by the opportunities before they attain the requisite competence to use choice and control productively.

Second, a central feature of student control is the learning strategies they use to accomplish academic tasks. Control over learning strategies requires students to be metacognitive and self-regulating. Two aspects of metacognitive control are relevant to conceptual change instruction. One is tactical, relating to the moment-to-moment control of cognition; the other is strategic and pertains to more molar levels of control over larger units of thought. These two features of metacognitive control refer to different strategies for accomplishing academic tasks. Tactical control represents students' ability to monitor and fine-tune thought as they work through the details of particular tasks. This type of cognitive control enables students to remain focused on the goals of the activity while they struggle through the hard work required by conceptual change instruction. Learners with inadequate tactical control are likely to have difficulty sustaining mental effort in the moment-to-moment work of generating products in project-based learning. Strategic control represents the students' ability to engage in purposeful thought over what might seem to be disconnected elements of learning as the students engage in a variety of different activities in project-based learning. Students need to be responsible for guiding and controlling their own activities and focusing their work over a long period of time in this type of instruction. The capability of students to organize their mental effort in the service of these more long-term purposes depends on strategic metacognitive control. In this sense, both tactical and strategic control beliefs are necessary for successful project-based learning and at the same time should be fostered by project-based instruction.

Research on the role of control beliefs in conceptual change has many questions to address. First, there is a need for clarity regarding the different dimensions of control (cf. Connell, 1985; Skinner et al., 1988a, 1988b) and how they might interact with the various cognitive strategies to produce conceptual change. Moreover, as suggested above, there is a need for instructional research on the optimal levels of choice and control to provide students. It may be that increasing students' control beliefs through various instructional changes leads them to spend more time on topics where they have more prior knowledge and interest, which could lead to more confidence in their own preexisting beliefs and a discounting of new, more scientifically correct, information. Accordingly, research needs to look for both the potentially positive motivational effects of changing classrooms to give students more control and the potential possibility that there could be some subtle negative effects. It may be that it is important to have instruction that encourages students' control over their learning and the various cognitive and self-regulatory strategies but does not relinquish control over the content of the instruction, at least in conceptual change instructional models. Clearly, there is a need for more research on these various possibilities.

Conclusion

This article began with a brief review of the major theoretical features of conceptual change theory as it applies to learning in classrooms. As part of the this review, we discussed a number of unresolved problems with the conceptual change model. In particular, we argued that two of the most paramount problems are: (a) inadequate theoretical development of the way in which individual beliefs about the self as learner influence learning in classrooms and (b) how the role of the individual in a learning community sustains or hinders conceptual change through instruction. However, the literature is not moot with regard to these two major difficulties with conceptual change theory. Indeed, as we have shown, considerable theoretical and empirical work exists that can be brought to bear on these issues. What remains to be developed is a program of research that specifically investigates two critical features of the conceptual change model. These two features are the nature and functions of motivation and classroom contextual factors.

The structure of this article reflects our concerns and proposed remedies. The first major section outlined conceptual change theory and our critique of it. The second major section reviewed four areas of research on motivation and classroom learning that bear on issues of applying conceptual change models to classroom learning. Our intention was not to map particular motivational mechanisms uniquely to theoretical or instructional difficulties in using conceptual change models. Rather, we are proposing a range of theoretical entities in the field of motivational research that are possible candidates for incorporation in conceptual change theory and research. Our critique of the conceptual change model raised four issues.

First, prior knowledge plays a paradoxical role in conceptual change. This paradoxical role can be cast in at least two different ways. One is that prior knowledge can impede conceptual change when that knowledge is not veridical (at least with respect to the consensually held position of a discourse community) and it is part of a strongly held set of beliefs. Yet prior knowledge also forms a framework for judging the validity of new information to be learned and thus forms a procrustean bed for the development of new knowledge. The second cast to this paradox is that the conceptual change model would suggest that students who possess little prior knowledge in an area would have few barriers to learning new concepts, yet the literature on learning shows clearly the value of prior knowledge. Thus, prior knowledge may impede learning through the alternative frameworks that students possess, or it may facilitate learning by providing a basis for understanding and judging the validity of solutions to problems. The conceptual change model assumes, in the language of lay epistemic theory, that when faced with a discrepancy between a current framework and new, to-be-learned concepts a student would undergo an unfreezing of his or her cognition in order to seek specific cognitive closure—that is, the resolution of the discrepancy. However, the learner's motivational beliefs about his or her current knowledge or about the knowledge to be learned texture the nature of the discrepancy in such a way that resolution might take on a very different form than is predicted by conceptual change theory. We have described motivational constructs such as goal orientation, values, efficacy beliefs, and control beliefs that can serve as mediators of this process of conceptual change and are likely candidates for research on how assimilation and accommodation processes might operate in conjunction with student motivation in conceptual change instruction.

The second issue pertains to the implications and limitations of the conceptual ecology metaphor in the model. This metaphor depicts the balance of alternative conceptions within the learner's conceptual structure as analogous to the balance of biological and environmental forces in an ecosystem. We argued that this metaphor is limited as a depiction of ontological change in learners in as much as learners are purposeful while ecosystems are not. Learners do have intentions, goals, purposes, and beliefs that drive and sustain their thinking. In addition, these motivational beliefs can influence the direction of thinking as the students attempt to adapt to the different constraints and demands placed on them by the tasks and activities they confront in classrooms.

Third, the model states four conditions for conceptual change (dissatisfaction, intelligibility, plausibility, and fruitfulness). These four conditions are depicted as if they operated in a cold, rational manner that ignores the influence that motivational constructs might play regarding whether these conditions might be met. For example, both conceptual analysis and empirical research indicate that the condition of satisfaction will be influenced at least partly by affective variables and value beliefs. Students' personal interests as well as situational factors might determine whether they even attend to a discrepancy that could lead them to become dissatisfied with their conceptual understanding. The level of dissatisfaction might also be affected by the utility that the new concept would hold for them. Whether a new concept is intelligible or plausible is likely to be related to the depth of processing that students engage in; if they do not cognitively engage in the task, then it is unlikely that they will be able to understand the concept in an intelligent or plausible manner. In turn, depth of processing is related, at least in part, to motivational factors, such as whether learners have more of a mastery or a performance goal orientation, level of interest, and efficacy beliefs with respect to the content area and the learning strategies to be used with the content.

The fourth issue is the validity of the notions of the child as a scientist and the classroom as a community of scientists. Such notions assume that the goals and intentions of children and youth in school are analogous, if not identical to, the goals and intentions of scientists and scientific communities. Such an assumption also begs the question, what are the motivational orientations for scientists and their communities? These notions are difficult to argue in the face of overwhelming evidence that children in school work at school tasks with very different understandings of their role than the ones scholars and researchers believe their roles to be. Even if some students approach school learning as intentional learners with a goal of developing integrated and sophisticated understanding of a field of study, they might not believe that the goals of the schooling enterprise are to foster such understanding. That is, they might not think that schools and classrooms as institutions operate in a purposeful, goal seeking manner.

Thus, school and classroom contexts might be designed and operated in a way that contradicts the way in which a community of purposeful scholars might act (Gardner, 1991). There is abundant anecdotal evidence that much of what happens in school is driven by need to maintain bureaucratic and institutional norms rather than scholarly norms. Much research literature documents this interpretation; it is likely that many students hold similar views of schools and the instructional activities that take place there. To the extent that this is true then, it is unlikely that individual conceptual change will take place without restructuring classrooms and schools along lines that will foster the development of a community of intentional, motivated, and thoughtful learners.

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Received May 20, 1992
Revision received January 4, 1993
Accepted February 19, 1993

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