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ABSTRACT

This paper proposes the construct of metacognition as a potential bridge between the concerns of educators and the concerns of researchers who study cognitive development. In so doing, it highlights, as another bridging construct, the phenomenon of transfer, or, more precisely, the absence of transfer. The difficulty of achieving transfer of learning from one context to another is a problem that cognitive development researchers and educational practitioners are both aware of and appreciate as fundamental to their respective concerns. The two constructs are connected, in that a key to transfer lies in metacognition. In inquiry learning research, students display the intra-individual variability in strategy use that microgenetic studies have found to be the norm. Development consists of shifts in the frequencies with which different strategies are chosen for application. To explain developments, it is necessary to turn to the meta-level of functioning. If nothing has been done to influence the meta-level, new behavior will quickly disappear once the instructional context is withdrawn and students resume meta-level management of their own behavior. The growing reliance on standardized testing of basic skills poses a grave danger to the quality of education. Better definitions are required of what it means to be an educated person. The skills of inquiry should be central to such definitions, and these skills need to be understood as not just as performance tools, but with respect to their meta-level structure. (Contains 1 figure and 24 references.) (SLD)

Metacognition and Critical Thinking

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They have their differences to be sure, but educational practitioners and the academic theorists and researchers who concern themselves with education would likely agree on a broad goal: to develop in students the conceptual skills that will prepare them to contribute to a democratic society. Academics are inclined to decry the growing emphasis on "objective" standardized tests and to endorse "education for understanding" (Gardner, 1999) and development of the learning and thinking skills that will equip students to thrive in tomorrow's society (Bereiter, 2002; Kuhn, forthcoming). Practitioners have long appeared to be of the same mind. The mission statement of the school district in which one of us was recently a teacher reads, ". . . our students will graduate with the knowledge, skills, and values necessary to be successful contributors to our democratic society." These educational goals can be traced back at least as far as Thomas Jefferson, who proclaimed, "I know no safe depositary of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion by education."

THE GREAT DIVIDE

The challenge comes, of course, in trying to implement these lofty goals, and here we find academics and practitioners navigating largely unconnected paths. Academics pursue their agendas isolated from the demands of the classroom, while practitioners are pressed to find methods that work, and quickly. Even if they had the time and energy to seek them out, research findings are not disseminated in a way that facilitates practitioners' consumption of them. And practitioners are unlikely to have much motivation to do so, having acquired the attitude, conveyed from their preservice training onward, that research is not going to be of any direct help – research findings, they learn, are both inconsistent and far removed from classroom realities. Scant attention in the preservice curriculum to educational research, and to the tools needed to evaluate it, is perhaps the strongest meta-level message to practitioners as to its value.

Bereiter (2002) makes the case that this state of affairs needs to change dramatically. Teachers must become collaborators in the research enterprise, in close contact with knowledge building in their field, seeing themselves and being accepted as part of the endeavor. Educational reformers, Bereiter says, ". . . are likely to fail in even their immediate objectives if they do not become more deeply engaged with the unsolved problems of pedagogy" (p. 421).

One of these major "unsolved problems of pedagogy is identifying more precisely the higher-order thinking skills that will equip students to participate in modern democratic society. Practitioners traditionally have skirted the question. "We all know good thinking when we see it," their attitude has been, "so let's get on and focus on finding effective techniques to foster it." Increasingly, it is becoming clear that this stance will not suffice. We cannot effectively teach cognitive skills in the absence of very clear and precise understandings of what those skills are (Kuhn, 1999, forthcoming). Educators must collaborate with researchers in achieving these understandings, creating the need for a different kind of collaborative role for the academic researcher. In the past, when educators have turned to academics for assistance, the role the academic has been asked to play is that of technician: Here is the knowledge we want students to have; can you advise us of the most efficient means to help them acquire it? Instead, both practitioners and academics need to collaborate not just with respect to devising means but also in better defining ends – the nature of the intellectual skills that need to develop, and the patterns and mechanisms that characterize this development.

Still, the challenge of meaningful collaboration remains a formidable one. The goal is a long way from being realized. Reflecting the extent of the challenge is the obstacle of the two different languages the two groups speak. Educators commonly talk about critical thinking as an objective. Indeed, critical thinking skills appear as objectives in state and national standards across the entire range of the curriculum. Academics, in contrast, have largely avoided the term critical thinking, preferring to focus their studies on constructs that can be more precisely defined and measured.

A key question that can be asked, then, is "How might we connect the construct of critical thinking to modern research on cognition and learning?" We propose here the construct of metacognition as a potential bridge between the concerns of educators and the concerns of researchers who study cognitive development. In so doing, we also highlight, as another bridging construct, the phenomenon of transfer, or, more precisely, absence of transfer. The difficulty of achieving transfer of learning from one context to another is a problem that cognitive development researchers and educational practitioners are both aware of and appreciate as fundamental to their respective concerns. The two constructs are themselves connected, as we will claim that a key to transfer lies in metacognition.

METACOGNITION AND CRITICAL THINKING

Definitions of critical thinking are numerous and wide-ranging, but one perhaps non-controversial claim we can make about critical thinking is that it entails awareness of one's own thinking and reflection on the thinking of self and others as objects of cognition. Metacognition, a construct that is assuming an increasingly central place in cognitive development research, is defined in similar terms as awareness and management of one's own thought, or "thinking about thinking." In cognitive psychology, these kinds of cognitive functions are most often examined under the heading of "executive control."

Whatever its exact label, the management of one's own cognition is crucial, as both researchers and practitioners have become aware. It is usually not difficult to teach a child to perform a particular procedure in a particular context. But it is the meta-level of operations that determines whether the child will continue to exercise this skill in other settings once instruction is withdrawn and the child resumes meta-level control of his or her own behavior. In our work, we have conceptualized the connections between the performance levels and meta-levels of knowing as shown in figure 1 (from Kuhn, 2001).

Procedural meta-knowing (left side of fig. 1) includes metatask and metastrategic understanding and management of the task and the strategies one has available to apply to it, and thus governs how the knowledge acquisition strategies of inquiry, analysis, inference, and argument are deployed. The epistemic understanding depicted on the right side of fig. 1 figures most prominently in determining whether these strategies are executed at all. As depicted there, epistemic understanding informs intellectual values with respect to each of the phases of knowledge acquisition, and values in turn affect disposition to action. Epistemological understanding of what knowing consists of progresses through three broad levels (Hofer &

Pintrich, 1997; Chandler, Boyes, & Ball, 1990). At the absolutist level, the products of knowing are *facts* that are objective, certain, and derive from an external reality that they depict. This absolutist conception is replaced by a multiplist conception of knowledge as *opinions*, freely chosen by their holders as personal possessions and accordingly not open to challenge. Only at the most advanced, evaluativist level is knowledge seen to consist of *claims*, which require support in a framework of alternatives, evidence, and argument. The cognitive task underlying this evolution is the coordination of the objective and subjective components of knowing. The evaluativist reintegrates the objective dimension of knowing, by acknowledging uncertainty without forsaking evaluation. It is only at this level that justification of claims becomes a meaningful enterprise. If facts can be ascertained with certainty and are readily available to anyone who seeks them, as the absolutist understands, or, alternatively, if any claim is as valid as any other, as the multiplist understands, there is no point in expending the intellectual effort that the justification and debate of claims – the heart of critical thinking, by most definitions – entails.

There is much more, then, that must develop than the procedural skills themselves that enable students to construct new knowledge. It is the overarching structure portrayed in fig. 1, a structure in which procedural skills are but one component, that needs to develop. In contrast to the cognitive development that occurs routinely in the first decade of life, full development of this structure represents a developmental potential that may or may not be realized. In fostering the development of these higher-order knowing capabilities, the concerns of cognitive development researchers and the concerns of educators clearly converge.

THE EXAMPLE OF INQUIRY LEARNING

To illustrate our broader claim, we can consider the more specific case of inquiry learning. A wide variety of activities, of varying quality, have come to be regarded under the heading of inquiry learning. If inquiry learning amounts to nothing more than being assigned a question and asked to search for answers (whether on the traditional shelves of a library or the electronic pages of the internet), it is likely to have no more impact than the typical homework assignment. Or if inquiry learning entails nothing more than a science teacher's "hands on" demonstration of well-established phenomena, it may elicit at most momentary interest and be quickly forgotten, never having been connected to anything else the student knows.

Interest in inquiry learning has escalated, and software developers have designed a number of innovative programs intended to offer students the opportunity to engage in genuine, self-directed inquiry (de Jong & van Joolingen, 1998). The problem is that we lack detailed knowledge regarding what students do with these materials and what cognitive skills are needed to utilize them effectively.

Cognitive development research related to inquiry learning was for some time narrowly focused on acquisition of the control-of-variables strategy as an isolated attainment (Case, 1974; Moshman, 1998; DeLoache, Miller, & Pierroutsakos, 1998). Available research on students engaged in self-directed inquiry suggests that the relevant skills are weak (de Jong & van Joolingen, 1998; Klahr, 2000; Kuhn, Black, Keselman, & Kaplan, 2000). This is not surprising given that mostschools offer students little or no opportunity to engage in genuine inquiry. But it does tell us that such skills cannot be taken for granted.

This conclusion is perhaps counterintuitive. To inquire is to ask a question. The questions of preschoolaged children often come in such a steady stream as to tax a caretaker's ability to respond. One might conclude that inquiry is a "natural" human activity that emerges of its own accord and does not need to be taught. If anything, some have suggested, the educator's challenge is merely to keep alive the natural inquisitiveness of the young child:

> Children are born scientists. From the first ball they send flying to the ant they watch carry a crumb, children use science's tools - enthusiasm, hypothesis, tests, conclusions - to uncover the world's mysteries. But somehow students seem to lose what once came naturally (Parvanno, 1990).

Empirical research has shown this view to be fundamentally incorrect. The so-called "natural" curiosity of the early years needs to be channeled and directed by intellectual tools that do not come naturally. We need to understand more about what they are, by undertaking detailed microgenetic observation (Kuhn, 1995) of students as they engage in inquiry learning over a sustained period.

We do know that, like even very young children, adolescents have constructed intuitive theories of how the world works that they bring to any new situation (Gelman & Wellman, 1998). Inquiry, then, consists not simply of searching out new facts to add to a knowledge repository. Rather, it involves a more complex process of coordinating existing theories with new evidence. Genuine inquiry, then, involves accessing a new body of information with the understanding that it may bear on what one believes to be true and with the intention of establishing what that bearing may be. Students must have the conviction that there is something to find out that bears on what they already think, if they are to engage in meaningful inquiry.

To do this skillfully requires keeping the two straight, that is, forming a mental representation of the data that have been accessed, distinct from a representation of the knowledge claim in question (one's theory), and then relating the two to one another. Preschoolers show little distinction between theory and evidence as their basis for knowing that an event occurred (Kuhn & Pearsall, 2000) and little awareness of the sources of their knowledge in general (Robinson, 2000; Taylor, Esbensen, & Bennett, 1994). These cognitive skills develop during childhood, but weaknesses linger through adolescence and into adulthood, with the result that a major obstacle to successful inquiry learning is that students are likely to confuse what they already believe with what they stand to find out.

Critical to effective inquiry is that one formulate a genuine question to put to the data being examined. Generating a hypothesis that the data are capable of disconfirming reflects a capacity for coordinating theory and evidence in the most essential sense. It reflects the epistemological understanding that the data I am examining have the potential to be analyzed and interpreted in a manner that will bear on my theories. This understanding is essential, for without it there can be little point to inquiry activities. At worst, inquiry is reduced to demonstration (of what one already knows to be true).

The studies our co-workers and I have conducted follow young and older adolescents and adults as they engage in self-directed inquiry, analysis, and inference regarding the factors that do and do not affect an outcome (Kuhn, Garcia-Mila, Zohar, & Andersen, 1995). Some make little progress because their preexisting theories entirely determine the data they choose to examine (often data incapable of disconfirming their expectations), as well as the (theory-consistent) interpretations they make of these data.

Our research (Kuhn et al., 2000) indicates limitations, until at least well into adolescence, in achievement of a mature mental model of multivariable causality, i.e., in conceptualizing multiple factors as additively affecting an outcome – a competency in fact required by most inquiry-based educational software. Most of children's inquiry activity is consistent with a co-occurrence mental model of causality: The co-occurrence of a level of one variable and an outcome is sufficient to explain that outcome. The potential causal influence of a second variable, therefore, need not be treated as additive. Instead, the second variable can be invoked as a different explanation for a later outcome, or the second variable can be discounted because the first feature explains the outcome (false exclusion, if the discounted variable has not been varied). Accordingly, then, the co-occurrence mental model treats causal influences as neither consistent nor additive.

Computing the consistent effects of multiple variables on an outcome rests on a different, more advanced model of causality. Identification of an individual effect ("Does X make a difference?") is only one step in explaining the causal structure of a domain. The broader task is to identify the effect of each of the varying features, and then -- a part of the task that has received little attention -- considering their additive (or possibly interactive) effects on outcome. Taking into account all such effects is of course the only way to achieve the goal of accurate prediction of outcomes. Doing so requires that a different mental model of causality replace the co-occurrence model, one in which multiple causes operate individually in a consistent fashion, simultaneously and additively producing an outcome. (Interactive effects require a further level of understanding.)

We have observed an association between the goal of identifying effects of individual features and use of controlled comparison as an analysis strategy (Kuhn et al., 2000), arguably because both rest on the mature additive mental model of causality. In the absence of this mental model, one's task goal is unlikely to be identification of the effect of each of the individual variables. Accordingly, neither attribute of the controlled comparison strategy will be compelling. The "comparison" attribute is not compelling, given it entails comparing the outcomes associated with different levels of an individual variable for the purpose of assessing the effect of that variable. And the "controlled" attribute is even less compelling, since it is the individual effects of other variables that need to be controlled. An immature mental model of causality, then, limits adoption of either the goals or strategies that make for effective scientific investigation.

In our inquiry activities, students display the intra-individual variability in strategy use that microgenetic studies have found to be the norm. Individuals have available a range of different strategies of differing levels of advancement and effectiveness (Kuhn, 1995; Siegler, 1996). Development consists of shifts in the frequencies with which different strategies are chosen for application. To explain development, we therefore need to turn to the meta-level of functioning, the level at which strategies are selected and their use monitored.

If nothing has been done to influence the meta-level, new behavior will quickly disappear once the instructional context is withdrawn and students resume meta-level management of their own behavior. This limitation applies to the many studies that have undertaken to improve scientific thinking simply by teaching strategies ("do this"), and, if meta-level understanding is addressed at all, by assessing children's knowledge that this is what they should do. The meta-level understanding that is critical, in contrast, is *why* this is what to do and why other strategies are less effective or wrong. In one of the most meticulously designed training studies, for example, Chen and Klahr (1999) taught 2nd-4th graders that comparisons were good comparisons if just one feature changed and bad comparisons if more than one feature changed. In posttests in new contexts, many children were able to choose a good comparison over a bad one and to justify it as good because only one feature changed. Indicative of their fragile meta-level knowledge (knowledge centering around *why* this is the better strategy), however, was the continued mixture of correct and incorrect strategies shown by a majority of children in conducting their own investigations.

It is something like the more complex structure portrayed in figure 1, then, that we are claiming needs to develop as a basis for effective inquiry. Something like it must be in place before students are likely to be productive in more complex, content-rich forms of inquiry that are likely to be involved when they generate questions of their own to investigate. Again, even more critical than the skills themselves is the understanding that there are important questions to be asked, that it is possible to seek and find evidence bearing on these questions at hand, and that I am someone capable of conducting such inquiry. Students must be disposed to invest the considerable intellectual effort that is involved in coordinating multiple theories with divergent bodies of evidence.

With the essential beliefs and values in place and the opportunities available to engage in increasingly more complex inquiry, the needed performance skills are in the best position to develop. If we can clearly identify what these cognitive skills are and how they develop, we are in the best position to learn how to promote understanding of their value. Thus, science educators need to base their efforts on a sound understanding of the entire complex of skills and meta-skills that have the potential to develop during the childhood and adolescent years. Educators who are informed developmentalists stand to bring the strengths of both traditions to the challenge that meaningful inquiry learning poses.

CONCLUSION

The growing reliance on standardized testing of "basic" skills, with higher and higher stakes, poses a grave danger to the quality of education. We need better definitions of what it means to be an educated person. The skills of inquiry, discussed here, and argument, discussed elsewhere (Kuhn & Udell, in press; Yeh, 2001), we believe, should be central to such definitions. If so, it is essential to understand more about these skills. But these skills need to be understood not just as performance tools – it is essential that the broader meta-level structure develop that reflects understanding of how, when, and why to use them. This is the critical thinking ability that educators (and researchers) want to see students acquire.

We have suggested here that cognitive development researchers and educators can and must collaborate in constructing these more adequate definitions of the ends toward which the educational enterprise is directed. Fewer and fewer cognitive development researchers remain content to preoccupy themselves with narrow agendas, while ignoring the larger, more difficult questions that the education of children poses. At the same time, educators for the most part are discouraged by the professional challenges facing them, would like to be part of the knowledge-seeking process, and appreciate the importance of evidence as a basis for policy (Feuer, Towne, & Shavelson, 2002). Without being naive [about the obstacles involved, we would conclude that both groups seem poised for meaningful collaboration.

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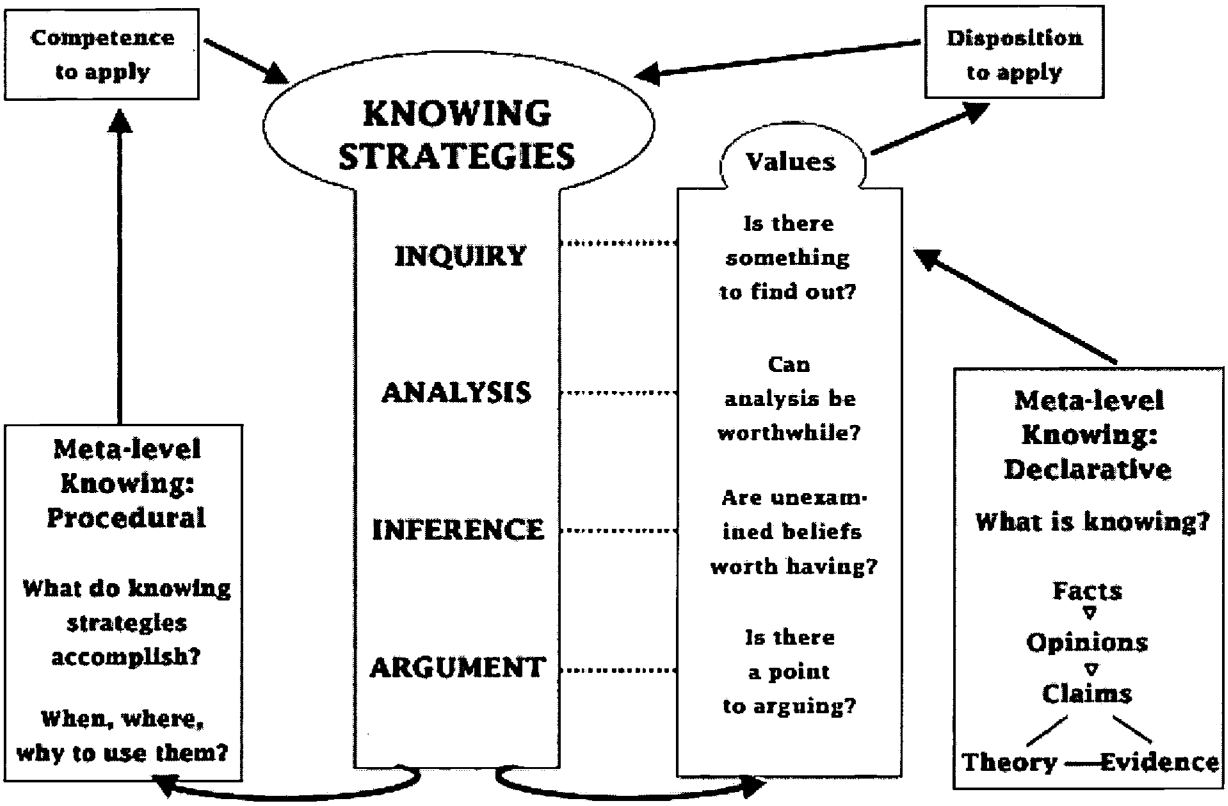

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