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ABSTRACT

This paper takes the position that logical knowledge is distinct from conceptual and procedural knowledge and can make a unique contribution to the understanding of knowledge acquisition. This view of logical knowledge departs from the traditional Piagetian view of stages and the overriding view of logic as the sole means of constructing new knowledge. Logical knowledge is compared to and contrasted with conceptual and procedural knowledge. The interrelationships among the three aspects of knowledge during knowledge acquisition are discussed. An extensive list of bibliographical references is attached. (Author/JAZ)

Studying Knowledge Acquisition:

Distinctions Among Procedural, Conceptual and Logical Knowledge

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Running Head: Knowledge Acquisition

Abstract

This paper takes the position that logical knowledge is distinct from conceptual and procedural knowledge and can make a unique contribution to the understanding of knowledge acquisition. This view of logical knowledge departs from the traditional Piagetian view of stages and the overriding view of logic as the sole means of constructing new knowledge. Logical knowledge is compared to and contrasted with conceptual and procedural knowledge. The interrelationships among the three aspects of knowledge during knowledge acquisition are discussed.

Studying Knowledge Acquisition:
Procedural, Conceptual, or Logical Knowledge?

At one time the term cognitive development was nearly synonomous with the study of Piaget's theory of intellectual development. Cognitive developmentalists sought to study the existence of general, logical structures of thought that developed through a series of universal stages. While the issue is not settled, the tide in recent years has moved away from the Piagetian position. The acquisition of logical structures has been treated both as an example of conceptual knowledge (e.g., Markman, 1978, 1979; Chi, 1985) and as an example of procedural knowledge (e.g., Siegler, 1979; Klahr, 1984). Further, Gelman (1985) has argued that logical structures exist implicitly for very young children, and merely become more flexible and generalized as children's theories of the world change and as they acquire metacognitive skills. While this shift in focus represents in part a dissatisfaction with Piaget's logical formalism as a way to characterize the structures of the human mind; evidence suggests that children's thinking may well progress through orderly, stage-like changes (Fisher, 1983; Case, 1985). Piaget's goal of identifying structures or principles that unify knowledge within and among domains must not be abandoned (Beilin, 1983, 1984). The study of knowledge acquisition will be most fruitful if logical, conceptual, and procedural knowledge are considered three distinct but interrelated aspects of knowing.

The argument to be presented here is that logical knowledge has properties that distinguish it from conceptual and procedural knowledge. Briefly, logical knowledge refers to the abstract, lawful principles or structures that organize thinking in all domains. Conceptual knowledge refers to the accumulated content knowledge about the world. Like logical knowledge, conceptual knowledge is used to construct knowledge and shows qualitative change. The major difference is that the conceptual structures are domain specific, and consequently do not show stage-like development. Procedural knowledge refers to the task specific rules, skills, actions and sequences of action employed to reach goals. It shares no features with logical knowledge except occasional qualitative change. Each serves a unique role in knowledge acquisition. Table 1 shows the points of similarity and difference to be expanded upon in the text.

Insert Table 1 about here

An example

Each of the three aspects of knowledge is relevant to the acquisition of counting. Procedural knowledge mediates what is known conceptually (e.g., the number word sequence) and the counting task at hand. For example, the physical actions first employed to count (such as tagging each item only once, or maintaining a one-to-one correspondence between the number words and the items) mediate the goal of counting a set of objects and the conceptual knowledge of the number word sequence and the counting principles (Gelman & Gallistal, 1978). Siegler and Robinson (1982) propose a model of the counting act that emphasizes procedural knowledge.

The procedures children use to count may also reflect the completeness of their conceptual knowledge of the number sequence. Fuson, Richards and Briars (1982) describe children's initial number word sequence as a verbal string which does not differentiate individual words. This string is gradually elaborated as the individual words are differentiated and the links between them become strengthened as an associative chain. They argue that the "counting on" procedure to solve simple addition word problems is impossible until the relations among the words are strengthened enough so the child can access them at any point, not just from the beginning. Gelman and Gallistel's (1978) five counting principles--stable order, one-to-one correspondence, abstraction, order irrelevance, and cardinality--are examples of implicit conceptual knowledge which may guide and structure children's counting behavior. Greeno, Riley and Gelman (1984) propose a model of counting that integrates conceptual and procedural knowledge.

In addition to procedural and conceptual knowledge, mature counting also involves an understanding of the logical relationships that exist among numbers (Labinowicz, 1985; Kamii, 1985). For example, seriation underlies an understanding of the ordinal relationships among numbers, that is, each number is one more than the number preceeding it. Further, classification is a basis for understanding cardinality or the "manyness" of the set. Cobb (1984) argues that part-whole structures seem necessary for certain addition strategies based on counting. For example, students who solve "27 - 8 = 19" can solve "27 - 11 = ____" by operating on the part of the first problem, "- 8," and the part of the second problem, "11," to produce "8 is 3 more than 11." They then operate on the answer such that "19 - 3 = 16," so the answer to "27 - 11" is 16. The logical knowledge, in effect, underlies the more advanced counting procedures.

The purpose of this framework is to distinguish the kinds of knowledge children acquire during learning and to clarify the different perspectives on "what develops." The remainder of this paper will discuss the nature of logical knowledge, including departures from the traditional Piagetian view and differences with conceptions of procedural and conceptual knowledge prevalent in the literature.

Logical and Infralogical Knowing

Logical knowledge is the ability to reason logically according to lawful, self-regulated structures, most notably, the logical structures proposed by Piaget. These include transitivity, seriation, class inclusion, multiplication of classes, the operations of number and measurement, the infralogical operations of space and time, as well as the formal operations such as proportional reasoning or combinatorial reasoning.

Consistent with traditional Piagetian theory, logical structures are presumed to become more complex and integrated with development, beginning with individual schemes, and later, operations and systems. Schemes are the simplest structures, particularly characteristic of the sensorimotor period. They are defined as that part of an action that is common to each repetition, generalization, or differentiation of the action. They serve an interpretative or constructive function. Schemes are building blocks for more complex structures. At the sensorimotor level they are combined into more complex structures such as the permanent object. At the more advanced levels of concrete and formal operations, they can be transformed into higher order operations.

Operations are internalized, reversible actions that are integrated into more complex structures. They are internalized because they are carried out in thought. They are reversible in the sense that the inverse or negation is implied by the direct action. In other words, it forms a conceptual whole characterized by logical necessity. It is this logical necessity that distinguishes operative thought (Inhelder, Sinclair and Bovet, 1974; Murray and Armstrong, 1976; Murray, in press). Operations, then, become integrated into structures.

Structures are systems of transformations that are self-regulated and lawful, with properties unique to the whole. Self-regulated means that the use and modification of structures is controlled by an "endogenous motor" rather than environmental stimuli. Wholeness means that the total system has properties that are not entailed in any of the components, much like water having properties that are not characteristic of either hydrogen or oxygen. Lawful means that the outcomes of the transformation are defined by the system. Structures are integrated into increasingly complex systems analagous to the integration of cells, tissues, organs and systems of the human body. These structures are constructed by the mind as the individual acts on his environment and assimilates new information to the structure and the structure accommodates. The person structures or interprets external events in terms of what he already knows (Furth, 1981). Logical structures are a means to interpret a task and determine the form of its solution, but not implement the solution (c.f., Vuyk, 1981; Piaget, 1970b).

Positing logical knowledge as a separate aspect of knowing is controversial. One reason is that the characteristics of the stages of logical development outlined by Flavell (1971) continue to have either mixed support or no support. For example, the concurrence dimension, that all structures develop at the same rate in all domains, is clearly not true. The construction of logical knowledge appears to follow the same trajectory in all domains.

In fact, Vuyk (1981) writes that Piaget had abandoned the "structure d'ensemble," as a useful description of logical development in favor of the notion of a spiral of development. In this view, structures are reworked at higher and higher planes. Feldman and colleagues offer another alternative view in which a stage is treated as a description of the modal level of logical ability (Snyder and Feldman, 1977, 1984; Feldman, 1980a, 1980b). In this view, an individual may use logical structures of higher and lower levels because the logic is constructed as the individual encounters domain content and demands. Nevertheless, the pattern of these qualitative changes is common to many conceptual domains, while progress through them may be uneven. Thus a strong form of stage theory does not characterize the data available, nor is it consistent with recent formulations of Piaget's theory.

This does not diminish the importance of logical knowledge. Gruber and Voneche (1977) and Kamii (1984) both observe that the stage concept is a minor aspect of Piaget's theory. The emphasis is placed instead on the construction of knowledge and on the nature of knowledge. In Piaget's view, and in the one presented here, logical knowledge is different from physical knowledge, social knowledge, and procedural knowledge.

A second issue is whether logical development is abrupt, indicating a reorganization of thought at a higher level. Gelman (1985) and Carey (1985) argue that children's logical structures are fundamentally the same as those of adults. What changes, they argue, is the flexibility and generalizability of these structures due to changes in children's theories of the world and metaconceptual knowledge. In support of her argument, Gelman refers to the "early competence" literature which shows that when tasks are specially designed for young children, they excel. What is compelling, nevertheless, is the dramatic consistency with which children's performance changes. Fischer (1983) describes the commonality among transitional shifts observed by a number of different researchers, each with their own theory. It seems unlikely that these shifts can be explained by positing that children's theories about many domains go through dramatic, qualitative change at about the same time. Logical knowledge seems to have a developmental trajectory of its own, but it is influenced by other kinds of knowledge more than previously assumed.

Another reason why logical knowledge is controversial is Piaget's assertion that "no sort of learning or physical knowledge is possible without logico-mathematical frameworks" (Piaget, 1971). While Piaget astutely recognized that knowing was constructive, he placed that function solely in the formulation of logical knowledge. While it is clear that knowing is constructive, it appears that some structures of conceptual knowledge serve a constructive function as well, at least to the extent that they provide a basis for inference (e.g., Anderson, Spiro, & Montague, 1977; Bransford, 1979; Glass, Holyoak & Santa, 1979; Nelson, 1978; Shank & Ableson, 1977). It must be pointed out, however, that constructive knowing is more than a veridical reading of information into a framework and then the use of inferences and defaults to fill in the empty slots. Rather, the information is assimilated to structures and the structures accommodate. So, it does not appear useful to maintain that logical-mathematical knowledge is the sole interpretive filter for all incoming stimuli.

A third reason why logical knowledge is controversial is because the higher order logics outlined by Piaget, such as class inclusion or propositional reasoning, appear to define a competence that may not be the norm in everyday functioning. For example, knowledge of classes and hierarchies of classes are only one possible form of conceptual organization. Organization based on spatiotemporal relations is also effective (Gelman & Baillargeon, 1983). The literature on prototypes (Rosch, 1978) and collections (Markman, 1978, 1979, 1981, 1983) suggests other powerful ways of organizing information that seem to have psychological validity. Chidren even appear to develop story schemas to help them organize stories (Mandler, 1982; Stein & Trabasso, 1982). Further, Ennis (1975) argues that propositional and combinatorial logics are defective logics for characterizing children's thinking.

To summarize, both the characteristics ascribed to logical structures and the hypothesized role of logic in knowledge acquisition have changed substantially since Flavell (1971). Criteria for stages have been relaxed and logical development appears to depend more on physical experience and socially acquired knowledge than previously assumed. Yet, while persons may have an innate capacity to reason logically, the systematic changes that occur as children become fluent with logic cannot be denied. The phenomena represented by logical structures will continue to be important in cognitive development, however, they must be understood in relation to other aspects of knowing.

Logical vs. Conceptual Knowledge

Many scholars appear to treat logical knowledge as an instance of conceptual knowledge. As noted in the introductory paragraphs, logical and conceptual knowledge share a number of important features. Both show qualitative change and both structure, or organize, knowledge. The major differences are that logical structures show stage-like changes in reasoning that are common to all domains, whereas conceptual knowledge remains domain specific.

The conceptual structures organize facts and beliefs into theories of the world. While the number of connections among elements in conceptual structures varies, at least one connection is required for new information to be learned and retained. The connections can also vary in meaningfulness.

The conceptual knowledge structures may contain relationships that are logical, but these do not constitute logical structures. They simply are other content specific facts that a person either knows or not. Formulations of conceptual knowledge do not assume a developing logic nor the logical implications that are inherent in the relationship. The functional rather than logical and theoretical aspects are stressed (Beilin, 1983).

Scholnick (1983b, 1983c) clarifies the distinction between logical classes and concepts. She argues that classification involves the ability to abstract a set of features or properties which are common to members of a set and which distinguish it from other sets. It also involves the identification of all elements which belong to the class. Class inclusion is specifically concerned with the coordination of the intension (the critical attributes that define a member) and extension (the range of members that meet the criteria) of a set to determine relationships among sets and subsets.

For example, the conceptual knowledge used to classify shapes would include the attributes of the objects such as the color or the number of sides, the names of shapes, some knowledge of which potential groups are superordinate, the number of items in each group, etc. To classify plants, on the other hand, the conceptual knowledge would include the plant type, the shape of the leaf, the shape of the plant, the flower, fruit, etc. The same logical reasoning would act on the conceptual knowledge of shapes and on that of plants to guide the placement of items into categories and allow reasoning about the relationships between the subordinate and superordinate groups.

Class inclusion, then, not only involves the conceptual knowledge of which objects belong with which label, but more importantly, it involves the coordination of the intension and extension of the defining attributes. This "flexibility in composing and recomposing sets and examining arrays from multiple perspectives is implied by logical reversibility, which is a formal aspect of the organization of concrete operations" (Scholnick, 1983a). (See Voyat, 1982 or Scholnick, 1983a, 1983b for further discussion.)

This is not to say that the inferences and reasoning of children do not involve conceptual knowledge. For example, Markman has identified a reasoning ability based on a "logic" of collections that is similar in many respects to the logic of class inclusion. The critical difference is that reasoning about collections is dependent on the content or relations that define the collection, whereas reasoning about class inclusion depends on the abstract relations that exist among sets and subsets. Logical structures allow reasoning from logic rather than solely from data, and as such are characterized by logical necessity. Thus a primary distinction is that logical structures are patterns of reasoning where logical relations in conceptual knowledge are treated as data bound facts.

Logical structures, then, cannot simply be subsumed under conceptual knowledge by determining the existence of logical relations in conceptual structures. Conceptual structures do not share the properties of wholeness, laws of transformation and self-regulation that characterize Piaget's logical structures. Rather, they are simply an organized aggregate of nodes and relationships, where nodes can vary in the level of detail from attributes of a concept to a complete schema. Unlike logical structures, these are generally data driven and environmentall contingent (Beilin, 1983). Mandler (1983), for example, argues that event and space schemata in semantic memory become organized "on the basis of personal experience through daily contact with spatial and temporal co-occurances in the environment."

Finally, while the child's seeming competence with a logical structure varies with the context, the logical relation itself and the attending reversibility remains a significant achievement (Scholnick, 1983a). The focus on logical knowing is not to deny the content specificity of operations, but rather to consider how the child comes to understand that aspect which transcends content.

Logical vs. Procedural Knowledge

Although the terms schemes and operations used to characterize logical knowledge are referred to as actions, they are not to be confused with procedures. Procedural knowledge involves the use of content specific skills, rules, strategies, actions and sequences of actions to perform tasks. It mediates what is known conceptually and logically and the task demands. Procedures are selected or compiled as a result of executive planning functions such as means-ends analysis which operate on both conceptual and logical knowledge and the task demands to produce a plan of action.

A critical distinction between logical and procedural knowing is that logical knowing is constructive and procedural knowing is not (Pascual-Leone, 1980). The argument that logical knowing can be reduced to skill development ignores this distinction (Siegler, 1979; Siegler & Klahr, 1982). As Strauss and Levy (1979) point out, rules are chosen or invented only if the task is assimilated to logical structures. Operational structures provide the necessary interpretative framework to infer the boundaries of the concepts a child uses in a goal-directed activity (Karmiloff-Smith & Inhelder, 1974). Procedural knowledge consists of actions or algorithms which are employed to implement the solution plan.

Procedures also are not considered to be cognitive structures. Siegler (1983, 1986) observes that for procedures to work efficiently and effectively, they typically do not have multiple access routes nor many interconnections among the steps; instead, they tend to be linear sequences of steps. These characteristics minimize the connections with conceptual and logical knowledge and, consequently, procedures are more central to succeeding at a task than to understanding it. In fact, a procedure need not be understood at all to be used successfully. Rather, the degree of understanding depends upon the extent of relevant conceptual and logical knowledge. The verbalization of a rule can be one facet of that conceptual knowledge. Ideally, conceptual and logical knowledge need to be connected with procedures so that each is available when the need arises but the connections do not encumber the procedures.

Rules and skills appear to be the most useful form for psychological analysis. Rules have been defined as a way to operationalize concepts (Fowler, 1980). They are often represented as if-then statements that list the conditions under which certain conclusions are to be reached or actions are to be taken. Although rules can be adapted to computer simulations by using production system representations (Siegler & Klahr, 1982; Siegler, 1983, 1986; Chi & Rees, 1983), they usually are a broader psychological statement. Production systems do not always correspond to the psychological processes of individuals

(Van Lehn, 1983; Keil, 1984). Siegler's (1979) rule-assessment methods are a precise, and meaningful characterization of the development of procedural knowledge as a progression of more complex rules.

Procedures and logical structures contrast on a variety of dimensions (Inhelder & Piaget, 1980). First, while procedures are fundamentally temporal processes which operate only in regard to specific goals, structures extract connections to form atemporal systems. Structures are defined as atemporal operations that tend to become logically interrelated. The more complex they become, the more stable they become. Alternatively, procedures are goal-oriented linear sequences of aims and means. Procedures are integrated when a subprocedure becomes part of the completed procedure. The more complex the procedure becomes, however, the less stable it is, and the more opportunity for errors. "The richness of procedures depends on their variety and number, and the richness of structures depends on the coherence and complexity of the integrative links between them--not on their number."

Yet, Inhelder and Piaget (1980) maintain that procedures and structures are closely intertwined. Using or inventing structures implies the use of procedures. Further, the exercise of actions or procedures provides information for the elaboration of structures. The temporal dimension of procedures is lost as the logical patterns or structures are abstracted. These logical structures can then form an interpretative framework for the intelligent selection of additional procedures.

Finally, procedures are specific to particular tasks. For example, the procedural knowledge entailed in classifying shapes would include the physical and mental actions performed to compare the shapes and to place them in groups. These procedures would differ from those used to compare and group plants because the attributes on which the objects are compared differ.

Summary

Logical knowledge, then, must be retained as an aspect of knowing because of its unique characteristics. Logical structures provide an abstract form with lawful properties to organize content. Logical knowledge also shows qualitative changes that are similar in many domains. In contrast, while conceptual knowledge may show qualitative change, such as when novices become experts at chess (Chi, 1978), these changes do not appear to be associated with change in age and they appear to be content specific. A second way in which logical and conceptual knowledge differ is that logical structures are abstract patterns of reasoning that are common to many domains. Consequently, logical structures are useful for describing the commonalities among formally similar tasks (Beilin, 1983). Conceptual knowledge is domain specific. In other words, the conceptual knowledge differs whether shapes or plants are classified. Yet, the same part-whole logic is entailed when reasoning about either domain.

Logical and procedural knowledge differ in that logical knowledge is used to construct new knowledge but procedural knowledge is not. As Strauss and Levy (1979) point out, rules (procedures) are chosen or invented only after the task is assimilated to logical structures. Operational structures provide the necessary interpretative framework to infer the boundaries of the concepts a child uses in a goal-directed activity (Karmiloff-Smith & Inhelder, 1974). According to Inhelder and Piaget (1980), procedures and logical structures contrast on other dimensions as well. For example, procedures are content and time specific whereas logical structures are atemporal and common to many domains.

To summarize, procedural, conceptual and logical knowledge are distinct aspects of knowing, each with unique characteristics. It is essential when studying the acquisition of logical knowledge to respect the distinctions with conceptual and procedural knowledge.

Interrelating Conceptual, Procedural and Logical Knowledge

The remaining question is whether logical, procedural, and conceptual knowledge are independent, whether one is superordinate to the others, or whether they work interdependently during knowledge acquisition. Support for independence would come from Boden (1982) who argues that the artificial intelligence literature suggests that "knowledge may be modular, with limited opportunities for coordination between various models, and that potential contradictions can exist within a knowledge system without prejudicing its functioning." Thus, it may be that different subsystems in the knowledge structure do not communicate.

From the traditional Piagetian view, logical structures would be superordinate to the other two. Earlier discussion discounts the viability of this position. Nevertheless, this does not mean that logic grows out of, or is the same as, either procedural or conceptual knowledge. Procedural and conceptual knowledge, however, can provide a supportive context in which logical structures can be acquired. Consider the case of learning arithmetic. Experience with addition, such as found in playing children's games, is an effective way for children to learn the addition facts (Kamii, 1985). More importantly, it is also an effective way for children to construct the logic of number. Children learn to solve addition problems like 5 + 6 by remembering that 5 + 5 = 10, six is one more than 5 so the answer is 11. The conceptual knowledge that 5 + 5 = 10, is an important data base for the child. It supports the construction of logical structures through reflection on the numbers and the experience with addition.

In some cases it appears that conceptual and logical knowledge take the lead in knowledge acquisition. Anderson

(1982, 1983) suggests that in skill acquisition the subject begins by learning what to do as declarative knowledge and then interpreting it with general problem solving strategies to effect action. The interpreted procedures begin in very small steps that are gradually compiled and automatized as more efficient procedures.

On the other hand, it could be argued that procedures drive the acquisition of the others because they provide the raw data. It can be argued that procedures need to be mastered before persons can reflect on them to understand how they work. This appears to be the hidden assumption of most instruction in mathematics and science today. Yet, it is clear that simply learning procedures is an ineffective way to learn mathematics (Cauley, 1985; Hiebert, 1984). As children and adults try to make sense out of procedures they often construct incorrect models of the world (Gentner & Stevens, 1983) or assign incorrect meaning to their procedures (Cauley, 1985).

Karmiloff-Smith and Inhelder (1974) and Kuhn and Phelps (1982) suggest that conceptual and logical knowledge, or having a theory, is critical for making sense of feedback in problem solving situations. According to Karmiloff-Smith and Inhelder (1974), having a theory consolidated and generalized allows the subject to recognize counterexamples and incorporate them into the system. They also observe that "the very organization and reorganization of the actions themselves, the lengthening of their sequences, their repetition and generalized application to new situations give rise to discoveries that will regulate the theories, just as the theories have a regulatory effect on the action sequences." Kuhn and Phelps (1982) conclude that those subjects who successfully solved their task did so because they had a plan or a theory that could inform their inferences about the results of their procedures. At the same time, procedures were changed or were added in response to the data. These procedures, then, provided additional data that in turn influenced the theory. This too suggests that no one component drives the others, but that they each can play an energizing role. It seems most likely, then, that the three aspects of knowledge are interdependent, although one may have a more central role with certain tasks, or at certain times in learning about a content.

Procedures and structures seem to interact such that the results of an action can modify the procedure and the reflection on that action can construct the relationships that constitute structural knowledge. For example, as one repeatedly tries to balance a scale, procedures are elaborated to consider more than one variable, and the structure of how those variables interrelate--their compensatory and reciprocal relationships--is abstracted. Conceptual knowledge about weight as a force and weight as a property of objects can also influence the role of weight as a factor in structures and procedures.

In regard to the interrelationships between conceptual and procedural knowledge, Chi (1985) argues that the use of specific rules may be easier for children if their domain knowledge is organized such that the rules can be easily applied. She cites the case of children who cannot remember the girls' names from an arbitrary list of children's names. These same children, when asked about their classmates, are able to name the girls by "going around the room" and using their spatial organization of where everyone sits. Children's failure to use a rule (e.g., grouping names by males and females) then, may be due to a failure to have that knowledge organized appropriately.

Logical and conceptual knowledge also influence the acquisition of each other. For example, logical structures usually characterize a child's thought about familiar content before unfamiliar content. That is, one must know about the attributes of fish and mammals to classify certain animals properly. Discovering that a whale is a mammal and not a fish may lead to a reorganization of those categories. Mammals might then be subdivided into those which live in water and those which live on land. The individual may only now understand that not all things that swim in the sea are fish. Further, the inference that a party must have more children than boys is perhaps more obvious than that a bouquet must have more flowers than hyacinth, simply because the overlapping attributes are more familiar.

Logical knowledge can also influence the acquisition of conceptual knowledge. For example, imposing a categorical structure on a content may force one to become aware of the critical attributes.

In a study of the parallel between logical reasoning and explanations of electromagnitism and gravity, Krupa, Selman and Jacquette (1985) concluded that logical reasoning appeared to be a temporally prior acqusition when group data were considered. Some individuals, however, scored higher on some specific measures of scientific explanation. There appears to be an interplay between logical competence and content knowledge.

Similarly, in the conservation literature, Murray and Armstrong (1976) and Murray and Smith (1985), Ames and Murray (1982) have observed that some preoperational children feel that their nonconservation judgment is necessary. These same children are most likely to change to conserving positions, again with necessity, after being placed in a social interaction situation with another nonconserving child. Murray (in press) suggests that these children make valid deductive arguments but, because they have an incorrect premise about the effect of the transformation, they deduce a non-conservation response. The social interaction situation apparently provides a situation in which they can correct that premise.

So, overall, logical, conceptual, and procedural knowledge have the potential to influence each other in interesting ways.

It is unlikely that any of the three aspects knowledge can be studied in isolation. It is necessary to distinguish each of them for a complete explanation of cognitive development. It is particularly important to study children in the process of learning to determine how procedural, conceptual and logical knowledge change and how they influence each other.

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Table 1

Comparison of Logical, Conceptual, and Procedural Knowledge

	Logical	Conceptual	Procedural
1.	primarily qualitative change	quantitative and qualitative change/	quantitative change
2.	"weak" stages	no stages	no stages
3.	structures cross domains	domain specific structures	no structures/ domain specific actions
4.	construct knowledge	construct knowledge	not constructive