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ABSTRACT

In this project, the researcher studied ways in which graduate students in research methods classes combined concepts into meaningful structures called conceptual ecologies (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). Conceptual ecology theory suggests that concepts "adapt to an intellectual environment [prior learning] much as organisms adapt to a biological environment" (Strike & Posner, 1976, p. 111). This is often referred to as "accommodation" (Piaget, 1970) or "restructuring" (Rummelhart & Norman, 1978). This study considered the development of a method for characterizing changes in relationships between concepts, in an attempt to gain insight into each participant's structured knowledge.

The participants of this study developed diagrams and repertory grid matrices that assessed their perceptions of the relationships between concepts related to "research". The diagrams and matrices suggested a level of development consistent with each participant's level of expertise. The diagrams and matrices also suggested changes to the participants' conceptual ecologies that could best be characterized in terms of structure and shared understanding. However, further research is necessary to answering questions concerning those factors that, on the surface, appear to make the diagrams reflective of unique conceptual ecologies.

ASSESSING CONCEPTUAL ECOLOGIES

"Psychology's hardest problems often involve the simplest things because they engage mental processes that are so efficient we are unaware of them." -- Marvin Minsky

Chapter 1
Introduction

"A central purpose of education is to improve students' reasoning abilities" (Lawson, 1985, p. 569). Instruction in the process of scientific inquiry (research and research methods) is one way reasoning abilities are taught during higher education. Learning to apply the concepts and principles of scientific inquiry (i.e., formulating hypotheses, designing experiments, and analyzing data) has been correlated with the development of formal operational thinking abilities (Padilla, Okey & Dillashaw, 1983). Learning the process skills of scientific inquiry requires more than the recitation and memorization of additional information; it requires the student to learn new concepts and the ways in which they influence each other.

In this study, I will use the concept "research" as a vehicle to explore the ways in which people combine concepts into meaningful structures. I propose to examine the knowledge structures of students receiving instruction on research methods. Of particular interest in this study are the ways in which students link ideas together to change their conception of "research." This type of conceptual change is often referred to as "accommodation" (Piaget, 1970) or "restructuring" (Rummelhart & Norman, 1978).

Based on earlier work by Miller and Johnson-Laird (1976) Medin and Smith (1984) distinguished between two aspects of conceptual knowledge, the core and the identification procedure (Medin & Smith, 1984). The core contains those properties that reveal relationships with other concepts while the identification procedure contains those properties that support categorization (Medin & Smith, 1984, p. 120). Most research on concepts and concept learning concerned the latter of these two properties (Medin & Smith, 1984). These research efforts typically trained subjects on classification rules and then studied the effectiveness with which the subjects assimilated learning to new examples (e.g., Haygood & Bourne, 1965; Homa, Sterling & Trepel, 1981; Medin, Dewey & Murphy, 1983; Medin & Schaffer, 1978; Medin & Schwanenflugel, 1981; Omohundro, 1981; Rosch & Mervis, 1975; Tennyson, Chao & Younger, 1981; Tennyson & Park, 1980; Tennyson & Rothen, 1977; Tennyson, Steve & Boutwell, 1975; Tennyson, Woolley & Merrill, 1972; Wallton & Budescu, 1981). These experiments addressed aspects of conceptual identification procedures (categorization), but not the relationships and ideas that form the conceptual core. Driver and Easley (1978) noted that these types of studies contributed to the growing body of nomothetic knowledge (group-derived knowledge that seeks to formulate universal statements or scientific laws) but neglected the need for idiographic knowledge (individually-derived knowledge that seeks to identify and describe concrete changes to a person's concepts and analyzes the concepts on participant's own terms). Finally, the requirements for rigor in these nomothetic methods often controlled for the interaction effects of prior learning that are relevant to actual classroom situations, reducing applicability (a key component to trustworthiness in qualitative research; Guba, 1980). However, the effects of prior learning are a problem inherent to studying the conceptual core.

The role of prior learning is important to advanced uses of concepts, uses that go beyond the identification of examples and non-examples. Medin and Smith (1984, p. 114) identified four functions served by concepts: (a) simple categorization (e.g., identifying "boy"), (b) complex categorization (e.g., identifying "rich boy"), (c) linguistic meaning (e.g., understanding that "boy" is the same thing as "lad"), and (d) components of cognitive states (e.g., linking several concepts to support the belief that "rich boys are spoiled"). Medin and Smith (1984) posited that approaches to concept learning that support the functions of simple and complex categorization may be insufficient to support structural or "linking" functions of concepts (Medin & Smith, 1984; Searle & Gunstone, 1990). Learning these increasingly complex functions of concepts requires significantly greater levels of interaction with prior learning. Studies have shown that the interaction of prior learning and personal theories affects concept learning by influencing the contexts and meanings associated with concept use (e.g., Barsalou, 1982; Gelman & Markman, 1986; Medin & Schoben, 1988; Rosch, 1975).

Medin (1989) suggested that an element of individual interpretation (personal theories), provides the conceptual links from the superficial properties of concepts to deeper, more fundamental properties, and make the concepts intelligible. These personal theories, or elements of individual interpretation, Medin suggested were responsible for the "psychological essentialism" that forms the basis for what we hold to be fundamental or essential truths concerning an object or circumstance. Given this view, personal theories help determine the significance of a concept's attributes. Indeed, Chi, Feltovich, and Glaser (1981) noted that even though experts and novices perceived the same attributes, and held roughly equivalent declarative knowledge, each group classified examples of physics problems differently. Novices classified problems according to surface features while experts classified problems according to fundamental laws. The difference, according to Chi, Feltovich, and Glaser, originated in the increased complexity of the experts' knowledge structures and the influence of those structures on their personal theories of what was the essential nature of each problem type.

A theory proposed by Posner, Strike, Hewson, and Gertzog (1982) suggests how a constructivist or generative view of concept learning may be helpful in exploring these deeper, essential truths (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). This theory, entitled Conceptual Ecology, suggests that concepts "adapt to an intellectual environment [prior learning] much as organisms adapt to a biological environment" (Strike & Posner, 1976, p. 111). Conceptual Ecology theory seeks to describe the relationships of concepts within the core and the conditions necessary for accommodation. This theory recognizes Medin's (1989) personal theories, or essential truths, and refers to them as epistemological commitments. Conceptual ecology theory offers one avenue to examine changes in knowledge structures, but it requires methodologies that assess changes in the ecologies. Such a methodology should allow inquiry into the ways individual students alter their knowledge structures and their understanding of a concept; in this study, the concept of "research."

Champagne, Klopfer, DeSena, and Squires (1978) approached this problem by assessing personal conceptual change through changes in complexity of conceptual relationships described by students. Their ConSAT technique provided a means of assessing relationships within the conceptual core by diagramming relationships between concepts. However, it is unclear exactly what this type of diagram assesses (as noted earlier by Shavelson, 1972 and Strike & Posner, 1976).

In this study, I will address the literature on concept learning and suggest why conceptual ecology theory may offer useful insights into conceptual change. I will also suggest a methodology for studying conceptual ecologies and conceptual change.

Statement of the Problem

The problem is how to assess conceptual change within conceptual ecologies. This requires a means of characterizing both the ecology and changes within it. Since conceptual ecologies (as described by Posner, Strike, Hewson & Gertzog, 1982) are unique to the individual, characterizations should depict the unique ecologies of individuals. Strike and Posner (1976) suggested focusing on those concepts that were fundamental to the domain in question. The concepts should be so fundamental that they influence the learner's ability to function within the domain. Descriptions of the perceived relationships among these fundamental concepts are an expression of what an individual considers to be acceptable or unacceptable, in terms of their conceptual ecology. For example, a conceptual ecology that describes the relationship between birds and ducks as subordinate or hierarchical (i.e., ducks are a sub-set of the category "bird") is distinctly different from conceptual ecologies that describe the relationship as indeterminate (ducks are somehow related to birds) or equivalent (ducks are birds and birds are ducks). The expression of an hierarchical relationship implies a greater complexity within the conceptual ecology surrounding ducks and birds than either the indeterminate or equivalent relationships.

Characterizations of the ecology should also be sensitive to change between the beginning and end states, at a minimum, to simplify comparison and determination of change. However, since individual ecologies may resist change, the value of a test-treatment-test paradigm is questionable unless confidence in the characterization process is established. In other words, how is one to know whether change did not occur or the method simply failed to recognize change? Conversely, if change is detected, is the ecology changing or is the instrumentation unreliable?

Significance of the Study

The significance of this study is in the development of a tool or tools to support the exploration of conceptual ecologies. If new concepts must "compete for their ecological niche" with current knowledge, then instructors may need an ecologically-based means of assessing concept learning.

Questions

This study will seek to answer the following questions:

1. 1. Do the characterizations suggest unique conceptual ecologies?
2. Does the methodology provide consistent characterization of the subject's conceptual ecology, given a test-retest application?
3. How trustworthy are the characterizations of the ecological structures?
4. Is the methodology sensitive to changes in the conceptual ecology? That is, given a pre-post assessment, is there a perceptible change in the conceptual ecology, and if so does it more closely resemble the instructor's?

Predictions

Is conceptual change only the refinement of categorization processes or is it also a function of linking additional knowledge to the concept and thereby changing the structure? If the ecology supports concepts, then conceptual change resulting from instruction will have effects on the ecology. Specifically, as a result of participation in a research methods class, ecologies surrounding the concept of "research" should evidence the introduction of additional concepts. To the extent that characterizations of ecologies are stable prior to instruction (i.e., that test-retest reliability is demonstrable) comparisons of descriptions before and after instruction should reveal whether changes in the ecology of "research" occurred.

Definition of Terms

Conceptual Ecology

For the purposes of this project, a "conceptual ecology" is the set of relationships between concepts relative to a target or focal concept as described by a participant. Conceptual ecologies, as envisioned by Posner, et al. (1982) possess the features of epistemological commitments and metaphysical beliefs, anomalies, misconceptions, analogies and metaphors, and other knowledge.

Depending upon its component concepts, the ecology will support certain views of what is acceptable and what is not (epistemological commitments). Consider a devoutly religious person whose "creation" ecology supports epistemological commitments that reject the concept of "evolution." But, what if that same person accepts the concepts of "cave men" and "dinosaurs?" The resolution of this anomaly requires conceptual change.

Criteria for Conceptual Change

Given this description of conceptual ecologies, "conceptual change" is an observable shift or alteration in one or more of the features of the conceptual ecology. Posner, et al. (1982) suggested that change will occur when a set of conditions is present. These conditions are: (a) dissonance or dissatisfaction, (b) intelligibility, (c) plausibility, and (d) fruitfulness (Posner, Strike, Hewson & Gertzog, 1982, p. 214; Strike & Posner, 1992, p. 149). Dissatisfaction (or dissonance) is brought about by the failure to fit new information into the ecology. Posner et al. noted that people tend to cling to their existing concepts, assimilating as long as possible, until anomalies make the concept dysfunctional (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). The less dissatisfied (or aware) one is with anomalies, the less dissatisfied one is with their current concepts, then the less likely one is to change concepts (Pintrich, Marx & Boyle, 1993). Once dissatisfaction is acknowledged, then the three other criteria (i.e., intelligibility, plausibility, and fruitfulness) must be met for accommodation to take place.

Conceptual ecology theory maintains that the new concept must be intelligible (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). By this, they meant that the learner must be able to represent the concept internally. The learner must also perceive how the new concept might change their experience sufficiently so as to offer a potential solution to the dissatisfaction (Posner, Strike, Hewson & Gertzog, 1982). Next, the new concept must be plausible. It should suggest potential to "solve or dissolve outstanding problems with current conceptions and consistency with other well-established beliefs" (p. 149). If the new concept is not seen as plausible, then it may be seen as "too inconsistent with current understandings to merit further consideration" (Pintrich, Marx & Boyle, 1993, p. 172). Finally, the new concept should have explanatory power (Pintrich, Marx & Boyle, 1993, 172). It should build upon the potential to solve problems by suggesting both new perspectives and utility as a "tool of thought" (p. 149). Conceptual ecology theory calls this trait "fruitfulness" (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992).

Trustworthiness

Verifying that the ecological descriptions are sensitive to conceptual change and that they support meaningful comparisons is potentially subjective. The issue of trustworthiness (not to be confused with the moral trait of honesty) must ensure that a sense of objectivity is maintained. Guba and Lincoln (as cited in Guba, 1980, p. 139) noted that in naturalistic inquiries, "trustworthiness" must be determined through the criteria of (a) truth value, (b) applicability, and (c) consistency.

Truth-value, analogous to internal validity, concerns credibility and interpretation, and is best verified through "testing the data with members of the relevant data source groups" (Guba, 1980, p. 140). Applicability, analogous to generalizability or "fittingness" or "the extent to which conditions in the context to which transfer is to be made 'fit' the conditions of the context in which the inquiry took place" (p. 140). Considering contextualized data and avoiding inappropriate generalizations that misapply findings to different contexts enhances applicability. Consistency, analogous to reliability, is not invariant but demonstrates that "changes that occur must be meaningful, not random, and their meaningfulness must be able to be established" (p. 140). Guba recommended overlapping methods, as a form of triangulation, to establish trustworthiness.

Summary

In this study I will try to develop a method that offers a means of characterizing changes to individual conceptual ecologies. Much of what is currently known about concept learning and conceptual change is based on studies of categorization behavior. Conceptual ecology theory offers one possible way of exploring conceptual change. I believe, however, that one reason so little research has been conducted using conceptual ecology theory as a base has been the lack of appropriate methodologies with which to describe and characterize the relationships within each ecology. If successful, this effort will provide a necessary tool to other researchers.

Chapter 2
Review of Literature

Concept Learning

Concepts are important elements of human thought and behavior. People fight wars over concepts. Governments rise and fall with the acceptance or rejection of the concepts espoused by political leaders. Religions support or argue dogmatically against concepts. Even if people agree that a concept exists (and that it is important), they dispute its meaning and the essential truths associated with it. Follow the religious example further. Within Christendom, for the most part, experts would agree that there was only one Christ and that the New Testament records his teachings (espoused concepts). However, select any particular concept within these teachings and there is likely to be broad disagreement about what it means and what it requires one to do. This is not a problem unique to European civilization. Sunni and Shiite have argued for centuries over the concept of *hadith* (i.e., scriptural authenticity and authority), although both sects proclaim the same Mohammed as Allah's prophet. The religious example is even more fascinating when you consider that exposure to the one side's concepts does little to change the concepts of the other. Similarly, within an academic community (i.e., educational technology academicians) consider the long-running debate on whether media make a difference in learning or not. The concepts of "media" and "learning" convey different meanings within each faction. Although each side has its concepts, neither side is disposed to change its mind. After all, if one changes their concept of "learning" that might require an ecological change affecting other concepts, such as "knowledge."

Concept learning requires categorization and symbolic representation of real-world things. But, concept learning also involves constructing abstractions by linking and coordinating knowledge as we interact with our physical and cognitive surroundings. At the heart of concept development is the structure of knowledge and the interrelationship of concepts and ideas (Jonassen, 1990, p. 3). The role of prior learning as a precursor to learning new concepts is a common element in both issues. Concept learning literature has recognized links between conceptual change and categorization skills. But, do changes in categorization skills lead to changes in conceptual ecologies?

Phenomenological Aspects of Concept Learning

Concepts offer a means of understanding and anticipating the surrounding world. Much of the study of concept learning is based on the requirements to categorize phenomena.

Concepts Defined

Many definitions of "concept" are premised on the role concepts play in categorization behavior. Fine distinctions exist within these definitions concerning whether concepts are actually categories or classifying rules. Travers defined a concept as ". . . a category within which objects or events are treated as equivalent." (1982, p. 279). Tennyson, on the other hand, defined a concept as ". . . a set of specific objects, symbols, or events which share common characteristics (critical attributes) and can be referenced by a particular name or symbol." (Tennyson & Park, 1980, p. 56). Merrill defined a concept as ". . . a set of common characteristics (attributes) referenced by a particular name or label, that can be applied to a set of referents (instances of that concept)." (Merrill, 1983, p. 297). Gagné, Briggs, and Wager (1992) considered concepts an intellectual skill that provides an individual with the ability to use symbols to respond to their environment. Wilson and Tessmer (1990) and Tessmer, Wilson and Driscoll (1990) suggested that in many ways "concepts are essentially categories that people use to organize their worlds and give order and meaning to their experiences." (1990, p. 690). Contrary to this view, Medin stated that concepts and categories are different; that a category is a partitioning class to which assertions can be applied, while a concept is an idea that includes "all that is characteristically associated with it" (Medin, 1989, p. 1469). Anderson (1990) considered concepts to be classifying rules, essentially a collection of facts related by the probability of their occurrence within a propositional network (Anderson, 1990). Even with the diversity of views concerning what concepts are, studies of categorization have revealed certain aspects of conceptual knowledge. To teach concepts one needs to have definitions, examples, and nonexamples. Concepts categorize examples into groups of members and nonmembers through processes of discrimination and generalization. Concepts also serve to structure memories into useful units that can aid in recall and inference. Acceptance of something as an example of a category member is based on perceptions of the item and a person's experience.

Role of Categorization Skills in Learning Concepts

Much of the concept learning research has been focused on categorization (Medin & Smith, 1984). Categorization and concept learning have been closely linked since Brunner, Goodnow, and Austin (1956) suggested that concept formation was an act of categorization. Medin (1989) and Gagné (1993) noted the importance of classification to support problem solving, in that it is the initial classification of the problem that allows one to bring relevant knowledge to bear. Categorizing supports discrimination between exemplars and nonexemplars of particular concepts.

Role of Definitions in Learning Concepts

Many studies of concept learning have considered the roles of definitions, examples and nonexamples, and characterizing attributes in developing categorization skills and concept acquisition. Tennyson and Park (1980) noted that if the definition uses appropriate language or terminology it could establish the necessary foundation for efficient concept learning. A good definition should identify and describe the critical attributes that are relevant to the concept and also convey the proper values and relationships of those attributes (Tennyson & Park, 1980, p. 57; Tessmer & Driscoll, 1986, p. 195). Just memorizing the definition, however, amounts to nothing more than verbal recall. Tennyson and Park (1980) and Gagne´ (as cited by Twitchell, 1990) pointed out that a definition is not enough by itself. The learner must use the definition to generate discriminations and generalizations. Gagne´ noted, "I think it is a mistake to say you can remember a concept, meaning by that state it, or remember a rule, meaning by that state it." (Twitchell, 1990, p. 39).

Definitions play an important role in concept learning because they support the basic categorization with concepts and allow for inclusion (generalization) or exclusion (discrimination) as concept learning occurs. Definitions may even have to "stand-in" for concrete examples that are not available.

<u>Role of Examples, Nonexamples, and Attributes in Learning Concepts.</u>

Besides definitions, categorization and concept learning need examples and nonexamples. Examples or instances (and their corresponding noninstances) join with facts associated with the concept. Anderson (1990) noted that the frequency with which learners encounter facts seems to determine how firmly linked they are to the concept. He provided the following observations:

1. If a fact about a concept is frequently encountered, it will be stored with that concept even if it could be inferred from a more distant . . . concept.
2. The more frequently the learner encounters a fact about a concept, the more strongly he or she will associate that fact with the concept. And the

more strongly associated with concepts facts are, the more rapidly they are verified.

3. Verifying facts that are not directly stored with a concept but that must be inferred takes a relatively long time. (Anderson, 1990, p. 133).

Features and attributes.

These "facts" comprise the attributes that many theorists posit are the "rules" by which concepts are described (Tennyson & Park, 1980; Dempsey, 1990). Attributes are necessary, not only because they form the basis of definitions, but because they provide a point from which to generalize and discriminate as the categorization process of concept learning takes place. Critical attributes are instrumental in discrimination between exemplars and nonexemplars (Tennyson & Park, 1980, p. 58). The variable attributes are important when learning to generalize the concept to new exemplars (Tennyson & Park, 1980, p. 58).

Most theories of concept learning and development support some form of feature analysis (either deductive or inductive) as a basis of categorization (Murphy & Medin, 1985; Tennyson & Park, 1980; Keil, 1987). Medin and Smith (1984) grouped concept learning theories into three schools of thought. They referred to these as classicalist, probabilistic, and exemplar. The basis for this classification system is the importance each school gives to attributes in concept formation. Classicalist theories, according to Medin and Smith, depend upon sets of attributes to create categories. Add a new attribute to the set, and you create a new category. Likewise, identification of an example depends on the presence or absence of the attributes. Probabilistic and exemplar theories, however, place no such restriction on concept formation. These two theory types allow that people identify examples of concepts based on combinations of attributes, and that all the attributes need not be present in every instance. In all of these approaches, the categorization is based to some extent on the identification of attributes and the recognition that things with like attributes can be referred to through a common symbol or referent.

Examples and nonexamples that highlight differences in attributes.

Haygood and Bourne (1965) noted that subjects acquired concepts best when instruction clearly pointed out the concept's relevant attributes. They decided this by having subjects do classifying tasks, sorting stimuli into groups of exemplars and nonexemplars. They found that if the classification rule remained the same, attribute changes had little or no effect on the classifying procedure. Markle and Tiemann (1965) suggested that improperly employed classification strategies would result in three types of classification errors, overgeneralization, undergeneralization, or misconception (misclassification). Over generalization, or failure to discriminate between different things, occurs when the user classifies nonexamples as examples (e.g., geese classified as big ducks). Undergeneralization, or failure to generalize, occurs when the user does not recognize new instances of the concept (e.g., a brown duck is not recognized as a duck). Misconceptions occur when the user bases category membership on an irrelevant attribute (e.g., ducks are white things in barnyards). In these cases, misconception is usually evident in the increased number of nonexamples judged to be examples (e.g., there were so many things called "duck" that the subject must not recognize the critical attributes of duck).

In their study, Tennyson, Woolley, and Merrill (1972) created situations that would cause students to misclassify, overgeneralize, and undergeneralize as the students attempted to classify examples of trochaic meter. Tennyson, Woolley, and Merrill manipulated the divergency of examples (on difference of irrelevant attributes), the probability of encountering examples and nonexamples (based on correct classification of examples), and matched examples with nonexamples (so that irrelevant attributes were similar). By manipulating these variables, they influenced classification errors, overgeneralization, and undergeneralization. They found that if subjects were presented with examples of concepts that differed widely in terms of irrelevant attributes, generalization skills (within classes) were promoted. Likewise, presenting examples and nonexamples with similar irrelevant attributes supported development of the ability to discriminate between classes.

This runs contrary to the earlier findings of Smoke (1933) and Morriset and Hovland (1959) who maintained that nonexamples had little value in teaching concepts. Tennyson noted, however, that Smoke did not establish a logical relationship between the examples and nonexamples shown students (Tennyson, 1973). Similarly, Tennyson noted that Morriset and Hovland did not operationally define the relationship between examples and nonexamples in terms of irrelevant attributes (Tennyson, 1973). Tennyson noted that both negative instances and irrelevant attributes should be presented to learners, otherwise "the subject might conceive an irrelevant attribute as a critical attribute" (p. 248). To further extend the results of Tennyson, Woolley, and Merrill (1972), Tennyson conducted experiments requiring subjects to identify adverbs in sentences and to identify examples of poetry (Tennyson, 1973). Tennyson noted that subjects who did not have examples and nonexamples were unable to reliably distinguish between critical and irrelevant attributes.

Not only is it important for nonexamples to be presented, but examples and nonexamples need to vary (diverge) in terms of irrelevant attributes. Example-nonexample pairs (and example-example pairs) that diverge in terms of irrelevant attributes focus the learner's attention on the critical attributes. For example, when teaching someone the difference between venomous and nonvenomous snakes, the initial example might present students with pictures of two different colored snakes and draw students' attention to the different head shapes as critical attributes are the bases for the determining conceptual categories. These findings support a notion that focusing on critical attributes during learning enhances concept learning.

Sequence of examples during lessons.

Based on the assumption that the sequence in which examples are presented to students affects concept learning, Tennyson, Steve, and Boutwell (1975) examined the role of instance sequencing and analytic explanations in helping learners to focus on the critical attributes during lessons. In two experiments, they required students to recognize concept examples (trochaic meter and drawings of crystalline molecules). Tennyson, Steve, and Boutwell found that presentation sequences (ordered in terms of divergence among critical attributes) were superior to random presentation sequences. In such instances, sequencing allows greater divergence between pairs of examples and nonexamples presented to learners (i.e., greater divergence in terms of irrelevant attributes). They also found that when analytic explanations accompanied the examples or nonexamples, students were better able to focus on the critical attributes.

Tennyson and Rothen (1977) noted the importance of providing definitions (defining rules) in terms of critical attributes. They also noted the importance of examples (that diverged from the definition to varying degrees) and nonexamples when presenting new concepts to learners. They maintained that their concept learning research supported four concept presentation strategies. These strategies suggested (a) presenting definitions in terms of critical attributes, (b) using examples that show the divergence of variable attributes, (c) presenting examples with nonexamples, and (d) presenting examples of varying degrees of difficulty

(Tennyson & Rothen, 1977). Tennyson noted that people seldom encounter concepts individually (i.e., concepts usually exist in sets of related, or coordinate, concepts). Citing earlier work by Tennyson and Merrill (Tennyson and Merrill, 1977 as cited by Tennyson, Tennyson & Rothen, 1980), Tennyson suggested that teaching concepts might be more effective if lesson design activities considered these coordinate relationships. This would require presenting coordinate concepts together, in sets, instead of sequentially.

Tennyson recommended the use of matched sets of exemplars and nonexemplars as the *optimal means* of learning concepts (Tennyson, 1980; Tennyson, Tennyson & Rothen, 1980). These matched pairs comprise rational sets. Each set pairs an example of a concept with a nonexample of that concept. It is interesting, that often the nonexample can be another concept that is similar to the first one (Tennyson & Rothen, 1980). At first the nonexemplars are very easy to discriminate from because they do not exhibit any of the critical attributes. Students then learn finer discriminations as lessons include one of the attributes, then another, and so on. As to the number of examples required to learn a concept, Tennyson bases that determination on individual learner differences (Tennyson & Rothen, 1977).

Tennyson, Tennyson, and Rothen (1980) compared three means of presenting concepts, (a) presenting them grouped in clusters, (b) presenting them grouped in sets, and (c) presenting them grouped in rational sets. They found that grouping was superior to linear orderings, and that rational sets of examples were superior to the other two presentation strategies.

Concept Learning as a Series of Stages

Tennyson, Chao, and Younger (1981) investigated the role of two instructional techniques on concept learning. Tennyson, Chao, and Younger noted that most concept acquisition research paradigms have little to do with learning concepts, rather they focus on instruction (1981, p. 326). These paradigms require subjects to sort and classify stimuli according to a simple rule (i.e., given what the subject knows about the attributes, the subject then identifies the next example presented him or her). Influenced by Rosch and her prototype theory of concept learning, Tennyson, Chao, and Younger suggested that children learn from clear-cut examples (best examples) and then start generalizing. If so, then this suggests that attribute identification and rule formation are secondary processes (p. 326); that concept learning might be a two-stage process with the first stage being acquisition and the second stage being classification. Put another way, this means that one must first spend time learning (being shown) the concept and then spend time (interrogatory time) practicing identification and classification. Based on earlier work by Miller and Johnson-Laird (1976) Medin and Smith (1984) also distinguished between two very similar aspects of conceptual knowledge, the core and the identification procedure (Medin & Smith, 1984). The core contains those properties that reveal relationships with other concepts while the identification procedure contains those properties that support categorization (Medin & Smith, 1984, p. 120).

Tennyson, Chao, and Younger (1981) compared each of these two strategies (expository and interrogatory) with a combination of these strategies (expository-interrogatory). Based on their results, they concluded that the combination (expository-interrogatory) was the most effective strategy.

Tennyson and Park (1984) investigated the expository-interrogatory approach further. They considered the question of when should the transition between strategies occur (i.e., when should the instruction stop showing examples to the subject and start requiring the student to identify new examples)? Tennyson and Park posited that the time required to learn a concept is a key measure of the efficiency with which learning takes place and of the cognitive effort involved (p. 453). Tennyson and Park found that by varying the exposure times (times that subjects spent forming prototypes) they were able to influence the time required to learn the concept. They argued that this finding supported their theory of a two-stage process of concept learning.

Tennyson's Theory of Concept Learning

As a result of his extensive research into concept learning, Tennyson developed a detailed theory for teaching concepts (Tennyson & Cocchiarella, 1986). This theory posits that concept acquisition is a two-step process. First the conceptual knowledge forms, then procedural knowledge develops. Two phases of application accommodate these steps. In phase one, the concept is established in memory. In phase two, the formation of conceptual knowledge is improved and elaborated upon. In the final phase, procedural knowledge is developed.

Tennyson's theory of concept learning is predicated on the mix of expository and interrogatory examples encountered by the learner. Tennyson's theory supports the formation of a "prototype" concept within the learner's mind. The learner does not remember sets of rules, but remembers an abstraction or prototype of the concept. This abstract representation or prototype is a basis of comparison as the user categorizes stimuli into exemplars and nonexemplars (Tennyson & Cocchiarella, 1986). Medin classified such views as exemplar-based, because the concept is represented by "... individual exemplars rather than some unitary description of the class as a whole." (Murphy & Medin, 1985, p. 294). The concepts within a domain are considered either successive or coordinate. Successive relationships limit learning to generalization within a class or category, while the coordinate relationships require both generalization among examples and discrimination between concepts. The coordinate relationships will become the basis for the development of procedural knowledge (Tennyson & Cocchiarella, 1986, p. 42).

In this model, (Table 1, below) strategy one concepts (successive-constant) require minimal instruction because the critical attributes are easily distinguishable from each other. Strategy two concepts (coordinate-constant) are more difficult to master and require simultaneous presentation of examples and nonexamples. Strategy three concepts (successive-variable) require the addition of context during instruction, while strategy four (coordinate-variable) concepts require the most effort in terms of simultaneous presentations and additional context.

Table 1. Tennyson's model for selecting instructional strategies (Tennyson & Cocchiarella, 1986).

Attribute Characteristics	**Relational Structure**	
	Successive	**Coordinate**
	Strategy 1	**Strategy 2**
Constant Dimensions	Label and definition Best example Expository examples (successive presentation) Embedded refreshment	Labels and definitions Best examples Expository examples (successive presentation) Embedded refreshment
	Strategy 3	**Strategy 4**
Variable Dimensions	Label and definition Context (problem domain) Expository examples Interrogatory examples Strategy information Embedded refreshment	Labels and definitions Context (problem domain) Expository examples Interrogatory examples Strategy information Embedded refreshment

The individual strategies used in each instance support the encoding and retrieval of the concept, and the use of the concept in categorization and inference. Expository examples embed information in memory meaningfully by activating related concepts while interrogatory examples aid in the proceduralization or recall process. Again, coordinate concepts are presented in rational sets.

Tennyson maintained that concepts are more than groupings of declarative knowledge. Conceptual knowledge refers to understanding of the concept, while declarative knowledge concerns verbal recall (Tennyson & Cocchiarella, 1986, p. 44). Tennyson argued that conceptual knowledge is more related to schema-based knowledge structures that not only store the information, but summarize it as well. He noted that learners do not seem to store lists of attributes in memory. Instead, learners seem to maintain an abstraction of some sort that they refine by generalizing and discriminating "elaborating on the meaning of the prototype" (Tennyson & Cocchiarella, 1986, p.51).

This theory holds that learners develop procedural knowledge by using (not by subsuming) conceptual knowledge to solve domain specific problems. According to this theory, conceptual knowledge is the storage and integration of information while procedural knowledge is a retrieval function for problem solving (Tennyson & Cocchiarella, 1986, p. 41). Tennyson's theory selects instructional strategies for concept lessons based on how the learner may store the concept in memory.

Klausmeier's Concept Learning and Development (CLD) Model of Concept Learning

To reiterate, Tennyson, Chao, and Younger (1981, p. 326) argued that many concept learning research paradigms rely on the teach-the-concept, test-the-concept approach and focus on classification behaviors (also noted by Medin & Smith, 1984). This research typically trained subjects on classification rules and then studied the efficiency with which the subjects assimilate the rules and apply them effectively to identify and categorize new examples. That may be quite appropriate, according to Klausmeier & Feldman (1975). They said that most concept learning is limited to the classificatory level whether it takes place in kindergarten or college (Klausmeier & Feldman, 1975, p. 174).

Developmental theories (such as those of Brunner, Piaget, or Klausmeier) stress general thinking skill development as the basis of concept development (Lawson, McElrath, Burton, James, Doyle, Woodward, Kellerman & Snyder, 1991; Klausmeier, 1976) in addition to prior (domain specific) learning with which to build the concept. Klausmeier's Concept Learning and Development (CLD) model of concept learning also distinguishes between prototyping and classification, but Klausmeier describes a four-stage process. In the concrete stage the subject consistently recognizes the prototype example. In the identification stage the subject recognizes the prototype example in various spatial representations (e.g., "A" in the upper right-hand corner of the black board is the same as “A” in the center of the black board). In the classificatory stage, subjects start identifying different examples of the concept. In the formal stage subjects discriminate between the concept's defining attributes.

Klausmeier assessed the extent of conceptual development (with four different concepts) in children from kindergarten through high school (Klausmeier, Bernard, Katzenmeyer & Sipple, 1973; Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973a; Klausmeier, Ingison, Sipple & Katzenmeyer, 1973b; Klausmeier, Marliave, Katzenmeyer & Sipple, 1974, as cited in Klausmeier, 1976). Klausmeier used a battery of tests to assess the level of development of the concepts “equilateral triangle”, “noun”, “tree”, and “cutting tool”. He predicted that by the end of the study (four years later) student results would show a pattern of successive concept acquisition. That is, as a group the subjects would progress from concrete levels of concept acquisition, to identification levels, to classificatory levels, and some would even attain the formal level. In accomplishing this, Klausmeier predicted that students would demonstrate this acquisition successively in an invariant sequence. In other words, if subjects passed tests at the identification level and not at the higher classificatory level, they would also pass at the lower concrete level, and fail at the higher formal level. Based on the findings, Klausmeier identified what he called five principles of conceptual development:

1. Concepts are attained at four successively higher levels in an invariant sequence.
2. The attainment level of any given concept varies among children of the same age.
3. Various concepts are attained by the same children at different rates.
4. Concepts learned at successively higher levels are used more effectively in understanding supraordinate-subordinate relationships, in understanding principles, and in solving problems.
5. Having the names of the concept and its attributes facilitates attainment of the concept at various levels and also the three uses of the concept. (Klausmeier, 1976, pp 15-22).

Klausmeier and Feldman (1975) investigated the relationship between definitions and examples. They noted that instructional materials usually *manipulated four variables:*

1. Examples and nonexamples clarify the prototype.
2. Definitions serve to notify learners of critical attributes (or at least they should, according to Tennyson, Woolley & Merrill, 1972, as cited by Klausmeier & Feldman, 1975).
3. Emphasizers facilitate discrimination between the examples and nonexamples, based on the attributes.

4. Feedback guides the learner as he or she categorizes examples and nonexamples.

Klausmeier and Feldman (1975) attempted to learn the effectiveness of definitions combined with rational sets (of examples and nonexamples) in classifying examples of equilateral triangles. They suspected that a combination of rational sets and definitions would be superior to using either variable alone, but the results of their study were less than decisive. Klausmeier and Feldman still argued that their study validated to a small degree the superiority of the combined approach (1975, p. 175).

Epistemological Aspects of Concept Learning

In the definitions of concepts discussed earlier, concepts categorize, provide a common reference, and share characteristics with other members of a group. Concepts allow us to categorize examples into groups of members and non-members (discrimination and generalization). In this sense, concepts allow us to provide structure to the surrounding world. Other aspects of concept learning, however, address the nature of conceptual knowledge. Concepts also serve to structure memories into useful units that can aid in recall and inference. But acceptance of something as an example of a category member is based, in part, on a person's experience.

The Perception of Similarities and the Probability of Attribute Occurence

Many views of conceptual formation recognize the role that the subject's perception of similarities (between instances) plays in categorizing. Medin and Smith noted, "Another new direction [in research] challenges the idea that categorization is based solely on similarity; instead, newer work focuses on the role of probability and intuitive theories in making categorical decisions" (1984, p. 135). While similarities seem to be important, determining which similarities are relevant is somewhat idiosyncratic. Murphy and Medin provided the example of a zebra and a barber pole (1985, p. 292). Although both are similar in that they have stripes, they are seldom considered in the same category. Murphy and Medin argued that for a concept to be useful, it must be based (at least in part) on a person's theories of the world around them (p. 299). These theories are entirely subjective and may not be entirely accurate. What seems to be more important is the likelihood, or probability of an attribute's occurrence with a particular instance.

Attribute Typicality on Categorization

Rosch (Rosch & Mervis, 1975; Rosch, 1975; Rosch & Lloyd, 1978) brought the issue of attribute typicality to the forefront of concept learning research. While people may describe concepts by their (the concept's) observable attributes, not all attributes are created equal. Rosch looked at typicality effects and assessed how frequently stimuli were classified as examples of concepts. She found that often, correlations of attributes made up an exemplar. Rosch and Mervis (1975) had subjects list the properties of exemplars of various concepts such as bird, fruit, and tool. They found that many of the properties were listed very frequently in some concepts but not in others. They concluded that attributes (and their relation to concepts) could be classified in terms of typicality. That is, a person considers certain attributes to be more typically associated with a concept than others. For example, one might consider hair a typical trait of mammals, while bills would be untypical (although the platypus has a bill).

Relative Significance of Attributes and Features in Categorization

Wallston and Budescu (1981) also noted this correlational process. They used conjoint and functional measurements analysis (techniques used in decision making theory) to assess categorization tasks. They asked clinical psychologists and graduate students to compare MMPI profiles. Their results suggested that novices categorized in an "additive" manner while experts tended to categorize along "correlated" dimensions.

Chi, Feltovich, and Glaser (1981) also found differences in the categorization behaviors of experts and novices. They asked groups of experts and groups of novices to categorize physics problems. The authors noted that the kinds of categories imposed on the stimuli were fundamentally different in each group. While novices tended to categorize the problems by their surface features (e.g., problems involving pulleys) experts tended to organize problems in terms of underlying principles of physics. Chi, Feltovich, and Glaser referred to this difference as surface and deep structure. In this case, two bases of similarity were used by subjects to establish coherence within categories, one by novices and the other by experts.

Using a "Best Example" for Categorizing

However, not all categories can be established along "neat and clean" boundaries. Asch and Zuckier (1984) noted a tendency for subjects to organize attributes around a central trait. Presenting subjects with descriptions of people that seemed to be contradictory (e.g., kind and vindictive) they found that subjects resolved the contradiction by making one trait more central than the other.

Medin and Smith (1984) suggested that theories of concept formation and acquisition generally fall into one of three categories, classical, probabilistic, and exemplar. The first of these, classical, holds that concepts share their defining attributes, implying that differences in concepts are distinct. They noted that this was not always the case, and that often the differences between concepts were "fuzzy." Medin and Smith (1984) suggested that there needed to be a distinction between prototype views based on exemplars and "probabilistic" views. Medin and Smith noted that in many concepts, attributes display the property of range rather than central tendency. For example, while most people initially describe birds as small and able to sing, they would still recognize an ostrich as a bird (Medin & Smith, 1984, p. 117). Medin and Smith noted that one problem with explaining categorization as a correlational process (only), is that how the categories are selected is not explained (p. 126). More specifically, do people categorize in a holistic fashion, or by making several discrete comparisons? Their view, the exemplar view, maintains that instead of abstracting these attributes, people develop an actual "best example" of a concept and determine class membership based on perceived similarity to the exemplar. They also noted that within this view of concept acquisition, there is a marked lack of constraint about what properties are associated with concepts and even on what constitutes a concept.

Medin and Schaffer (1978) suggested that similarity to known exemplars determined learning and transfer, not the proximity of attributes to a central tendency. They controlled for the proximity of transfer items to the central tendencies of two categories and manipulated the similarity of transfer items to known exemplars. In a similar experiment, Rips and Handte (1984, as cited by Medin and Smith, 1984) asked subjects if a circular object five inches in diameter was more likely to be a pizza or a coin. Their subjects generally thought that it was more likely to be a pizza, which Rips and Handte suggested indicated probabilities were more influential than similarities. Medin and Smith noted, "Presumably they did this because pizzas are more variable in size, and though the probability of a five inch pizza is very low, it is still larger than that of a five inch coin" (1984, p. 134).

Medin and Schwanenflugel (1981) conducted a series of experiments to find out whether concepts that were linearly separable would be easier to learn than those that were not. Linear separability refers to the overlap between concepts in terms of attributes. Medin and Schwanenflugel suggested that both prototype and classicalist theories suggest linear separability between concepts makes them easier to learn. However, Medin and Schwanenflugel noted no difference in ease of learning attributable to linear separability.

Homa, Sterling, and Trepel (1981) tested subjects for their ability to classify geometric patterns into one of three categories. In this case, they tested the subjects immediately after learning the categories and again one week later. Homa, Sterling, and Trepel found that as the number of instances increased, dependence on the central tendency of attributes also increased. They found that exemplars were most useful when numbers of instances were low, and that as the number of instances increased central tendency of attributes becomes more important. In a similar experiment, Omohundro (1981) used three distinctly different distorted polygons. In her experiment, the amount of distortion (relative to the prototype) equated to "distance." Instances with more distance were assumed more difficult to classify. Omohundro determined that with increased numbers of exemplars during learning transfer and retention increased. This was presumably due to more information with which to determine central tendency. However, Medin and Smith (1984) argued that geometric shapes, such as those used by Homa, Sterling, and Trepel (1981) or Omohundro (1981) were rather artificial, and that in every day life people seldom encountered such clean-cut instances (linear separability).

Role of Other Knowledge in Organizing Concepts

Wattenmaker, Dewey, Murphy, and Medin (1986) demonstrated the role of context or "organizing themes" in concept acquisition. They provided subjects with a list of properties and asked them what the properties had in common. For example, given the properties made of rubber, irregular surface, small size, and hard to grasp, could the subject evaluate their typicality? On the other hand, given the same properties and the organizing theme "substitutes for a hammer" could the subject evaluate the typicality of the properties? Wattenmaker, Dewey, Murphy, and Medin noted that with an organizing theme subjects were able to form conceptual prototypes and evaluate the typicality of the properties. In Medin's view, this supports the conclusion that the naturalness of categorization "cannot be predicted in terms of abstract category structures based on distribution of features, but rather requires an understanding of the knowledge brought to bear on them" (Medin, 1989, p. 1477). Stated in other terms, one interprets new examples and their attributes in terms of what is and is not acceptable. In this case, that a five inch object is more likely to be a pizza than a coin is more acceptable than the opposing view.

Gelman and Markman (1986) also noted the role of student knowledge for concept learning. They taught young children that different novel properties were true of two examples, and then asked which property was most likely true of a new example. For example, a flamingo was pictured feeding its young with mashed-up food, while a bat was shown feeding milk to its young. When shown a picture of an owl and asked how it fed its young, the subjects generally responded that it fed its young with mashed-up food. This in spite of the similarity in appearance of the owl and the bat (versus the dissimilarity of the flamingo and the owl). Gelman and Markman concluded that the category "bird" was evident in the subjects' theories of what owls fed their young.

Barsalou (1982) noted that not all of the information of a concept is activated when the concept is mentioned (or encountered). He suggested that a context of use is required to instantiate some of the core knowledge of a concept. Barsalou presented subjects with sentences in which the noun was underlined. Subjects were then presented with features (i.e., attributes) of the noun to determine if they recognized it. For example, a subject might be presented with the sentence, "The man sat in the chair." Then, subjects might be presented with features of a chair, such as "legs" or "seat" or "weapon." Those features that were contextually-related to the sentence ("legs" or "seat") would be more readily recognized as features of "chair" than would be a contextually-unrelated feature such as "weapon." Based on the speed with which contextually related features were recognized, Barsalou found that context was a crucial factor in concept activation. Barsalou determined that attributes were either contextually-independent or contextually-dependent.

Barsalou (1982) noted that studies such as Tennyson & Rothen (1977), Tennyson (1980), Tennyson, C., Tennyson, R. & Rothen (1980), Tennyson & Park (1980), Driscoll & Tessmer (1985), Murphy & Medin (1985), Tennyson & Cocchiarella (1986), and Park & Tennyson (1986) deal primarily with the context-independent properties of concepts (i.e., those properties readily linked by word association to the concept) and their influence upon concept learning. These properties form the core meaning of the concept (Barsalou, 1982, p. 82).

Barsalou (1982) found that concepts also have context-dependent properties. These properties are linked contextually to the concept instead of verbally, and are a source of "semantic encoding variability" (p. 82). This conception is similar in many respects to Wilson and Tessmer's (1990) view of conceptual connotations. These factors determine, in part, the appropriateness of actions taken with regards to the concept. Wilson, Tessmer, and Driscoll (1990) noted that the use of concepts depends in large part on the context in which they are used, suggesting "that learners acquire declarative and procedural knowledge for the specific settings in which they use a given concept." (p. 47).

Roth and Shoben (1983) also noted the role of contextual clues in concept acquisition. They measured the time needed to establish an anaphoric reference between the exemplar and the superordinate concept. For example, given the sentence, "The bird walked across the barnyard" Roth and Shoben determined that a set of core-connections is invoked that make "chicken" a more typical response than "robin." Medin and Shoben (1988) found that the terms white hair and gray hair were judged to be more similar than gray hair and black hair. Similarly, gray clouds and white clouds were judged less similar than gray clouds and black clouds. They theorized that theories of aging connected one set of instances while theories of weather connected the other. Where Barsalou looked to context to provide coherence to conceptual categories, Medin suggested that personal theories were a likely source. Medin maintained that this is evidence of "psychological essentialism." That is, "[p]eople act as if things (e.g., objects) have essences or underlying natures that make them the thing they are" (Medin, 1989, p. 1476).

Keil (1987) indicated that research supports a probabilistic approach to concept formation, but that this probabilistic approach has some flaws for many of the same reasons that Murphy and Medin (1985) provided. Keil referred to the characteristic-to-defining shifts that occur as children develop or construct their concepts internally. As one's experience and domain relevant knowledge base develops, the concept becomes more dependent upon those defining characteristics (critical attributes) and less so on those attributes that are characteristic of the example (but variable).

Keil (1987) studied the development of concepts among children. Children with lower levels of experience and domain knowledge tended to perceive little difference between those characteristics which defined the concept and those which were characteristic of it (variable attributes).

However, as domain knowledge of the concept increased, such as social knowledge concerning its use, then the concept took on new meanings. "Knowing the social context . . . is a crucial aspect of knowing what an artifact is . . . With increasing knowledge people come to reject mere collections of the most typical features as being adequate to specify a concept." (Keil, 1987, p. 23, 28). This shift is also characteristic of changes in coordinate concepts as well. By developing a better meaning for the concept, insight is gained concerning those concepts that are related.

Keil (1987) noted how the social context affects concept learning.

> "If we look at objects themselves, and only the objects, our understanding of their meaning is incomplete and must rely on the information in their characteristic features. If however, we are privy to information about who built them and why, our understanding may change considerably. Knowing the social context, in particular the intentions of the builder, is a crucial aspect of knowing what an artifact is." (Keil, 1987, p23).

In this sense, concept learning is influenced by the expectations (based in part on related knowledge) attached to the concept.

These findings lead to the conclusion that neither attributes nor instances are created equal (in the mind of the perceiver). Instead, some attributes and some instances are more typical than others. Influenced by context (Barsalou, 1982) by knowledge (Keil, 1987), and similar factors, learners develop abstract conceptual qualifiers based on the perceived significance and typicality of attributes. The difference in deep and surface structure noted by Chi, Feltovich, and Glaser (1981) appears similar to Medin's idea of personal theories (Murphy & Medin, 1985; Medin, 1989) in that they both describe a learner's belief in some underlying or essential quality of the problem that supports discrimination and generalization.

Structural Aspects of Concept Learning

A remaining question concerning the development of concepts, is the development of new highly abstract concepts that lack objective or concrete examples. Tessmer, Wilson, and Driscoll (1990, p. 48) refer to this in terms of making inferences about relationships between other concepts that are not coordinate to the target concept. These "defined" concepts exist in their subjective definitions only, not as objective realities. Tessmer and Driscoll (1986) argued that this class of concepts exists within a set of propositions containing procedural directives for their use. An example of such a concept would be the concepts concerning the processes of fusion, evaporation, and solidification. These concepts do not possess apparent "prototypes." They cannot be seen without great difficulty; therefore teaching these concepts usually points to their initial and end states. Lacking a "prototype" a propositional network of definitions that allows the user to classify the results supports categorization. This network is a type of conceptual or cognitive structure.

Defining Cognitive Structure

Shavelson (1972) and Shavelson and Stanton (1975) defined cognitive structure as a hypothetical construct referring to the organization (relationship) of concepts in memory (p. 226). Kelly described cognitive structure as a geometric space. This space is partitioned by planes that provide dichotomous referents for classifying real world examples of concepts (Kelly, 1970). The real world elements on one side of the partition are like each other with respect to a perceived property and are unlike the real world elements on the other side of the partition. Within this space there are several different partitions, each one representing some distinction between the elements that inhabit the space, and each plane intersecting the others. In this sense, the cognitive space is not defined by relations between concepts, but by a finite number of "slots" into which elements may fit.

Gagné and White (1978) used the term memory structure to refer to, "...the organized contents of long-term memory that are (1) learned, (2) cognitive in character, and (3) accessible as mediators of human performance in situations designed to assess retention and transfer of learning" (p. 188). Goldsmith, Johnson, and Acton (1991) noted that knowledge of an area or domain requires an understanding of the relationships among its concepts. Gagné and White (1978) listed four types of structures, (1) networks and propositions, (2) intellectual skills, (3) images, and (4) episodes. They noted that these four types usually exist in combinations to one degree or another and recommended that when learning outcomes are related to multiple types of structures, the integration between the structures should be studied. Citing Anderson and Bower (1973), they suggested that the basic elements of memory are concepts and relations (or symbols and symbol-structures or concepts and rules). "The term intellectual skills has been used to designate the learned memory structures that underlie the identification of concepts and the application of rules" (Gagné & White, 1978, p. 193).

Techniques Used to Assess Cognitive Structure

A common way of assessing cognitive structure is through associative meaning, or free-association responses to the concept. Deese (1962) noted that words with similar associated meanings should appear first in the same verbal environment. Deese further explained that this appearance should take one of two forms, either as substitutions for each other, or as part of each other's environment. Naveh-Benjamin, McKeachie, and Lin, (1986) noted, however, that reliance upon memory interjects a retrieval process that potentially obscures cognitive structure (Naveh-Benjamin, McKeachie & Lin, 1986). In other words, if the person does not retrieve the concept at the proper moment, does it indicate that the concept is not part of the subject's cognitive structure? Several authors (Naveh-Benjamin, McKeachie & Lin, 1986; Shavelson, 1972; Shavelson &

Stanton, 1975; Stewart, 1980) noted that there are generally three alternatives for assessing cognitive structure, (1) word association, (2) card sorting, and (3) graph building. Goldsmith, Johnson, and Acton (1991) recognized the use of these methodologies and also suggested using direct numerical rating of the degree of relatedness. Numerical methods, such as multidimensional scaling (MDS), cluster analysis, and additive trees offer this capability. However, Goldsmith, Johnson, and Acton (1991; citing Shvanevelt, Durso & Dearholt, 1985) suggested that while numerical techniques (such as MDS) capture global information, network diagrams get at local relationships.

Kelly's repertory grid matrix (Kelly, 1955) assesses conceptual structure by comparing 1) the terms used to describe concepts, and 2) the distinctions made between concepts. In clinical psychology, this method has been used extensively (Shaw and Gaines, 1992). This method yields numerical indices in several dimensions that allow for assessment of the local relationships that Goldsmith, Johnson, and Acton (1991) were concerned about.

All structured approaches generally involve three steps, (1) eliciting knowledge, (2) representing knowledge, and (3) evaluating the representation (Goldsmith, Johnson & Acton, 1991). The third step, evaluation of the knowledge representation may be either a qualitative characterization or a quantitative comparison with another representation. In such cases, the second representation (either a representation of the domain or of a subject matter expert's knowledge) becomes the de facto standard for evaluating congruence.

Outcomes of Assessing Cognitive Structure

Many of the methods discussed for assessing cognitive structure rely on the premise of cognitive distance, that is how closely associated one concept is with another. Strike and Posner (1976, p. 129) avoided these techniques, preferring interview techniques. They noted that while many of these methods are "ingenious measures of cognitive structure" it is not entirely clear what it is that is being measured, and why one would want to measure whatever it is that is being measured. They noted (Strike & Posner, 1976) that an "adequate" view of cognitive structure should:

1. Account for the relationship between subject matter structure and cognitive structure. Strike and Posner argued that discipline (subject matter) structure is "logical" where as cognitive structure is "associative." As such, cognitive structure is the embodiment of the conceptual features of the subject matter.

2. Explain the role of what is already known about learning. By this they meant, it should somehow illuminate the theory base of learning theory, in order to be useful.

3. Account for the "intellectual capacity" of those who have learned the subject matter. That is, an adequate view of cognitive structure should

describe the structure in "cognitive" terms (as opposed to behavioral terms). (129)

Naveh-Benjamin, McKeachie, and Lin (1986) also noted several problems with assessments of cognitive structure. These include missing potentially important characteristics of cognitive structure through the use of averaging techniques, dependence on recall, passivity (they fail to take into account the dynamic aspects of cognitive structure), and reliance upon relatively small amounts of information (e.g., one to two chapters in a text over a short instructional period). However, they maintained that unless cognitive distance is measured, the method will not yield adequate quantitative data (p. 131).

Naveh-Benjamin, McKeachie, Lin, (1986) assessed the state of measurements of cognitive structure by stating, "There is clearly a need for other techniques that not only measure distance from a standard but can also make comparisons in terms of other dimensions, such as amount of organization." (Naveh-Benjamin, McKeachie & Lin, 1986, p. 131).

Influence of Instruction on Cognitive Structure

Using the techniques discussed above, researchers have attempted to determine the influence of instruction on cognitive structure. Johnson (1964) used a free-association response test to assess the taxonomic relationships of physics concepts. Johnson noted that while words mentioned in class might be recalled, the taxonomic relationships between concepts might not match those discussed in class. For example, while subjects could recall that the concepts of "force", "mass", and "acceleration" were part of physics instruction, the relationships between them might not be recalled, or would be recalled incorrectly.

Shavelson (1972) studied the effects of instructional content structure to conceptual structure in memory. For a five day period, Shavelson had students read passages concerning Newtonian physics and assessed their cognitive structure using word association tests. These tests assessed taxonomic relationships which Shavelson suggested were indicative of cognitive structure. Shavelson found that students' cognitive structure, as measured by word associations, changed daily during instruction. At the end of the testing period Shavelson noted that students' word associations more closely resembled those of the content materials.

Shavelson and Stanton (1975) conducted two studies of cognitive structure. In the first, the authors developed their own means of eliciting and representing the cognitive structure of a particular mathematics curriculum. The curriculum's developers (the subjects) were then asked to use this method to build a representation of the curriculum's cognitive structure. In the second study, the subjects were two graduate interns, but the tasks remained the same. Requiring subjects to associate concepts with one of two groups, Shavelson and Stanton noted that the subjects generally placed similar concepts in the same groups.

They suggested that this demonstrated the congruence of cognitive structure and subject matter structure.

Naveh-Benjamin, McKeachie, and Lin, (1986) used an ordered tree technique (a diagramming method) to assess the relationship of instruction to cognitive structure among high school students in science classes. They found that over the course of a semester the diagrams indicated increased complexity and depth of structure. However, achievement test scores did not correlate highly with diagram results. The authors attributed this to the fact that the tests were primarily measures of recall and did not account for cognitive structure.

Based on Shavelson's work, Champagne, Klopfer, DeSena, and Squires (1978) postulated that during instruction student knowledge structures and the general discipline content structure become more congruent. Knowledge structures, as described by Champagne, Klopfer, DeSena, and Squires are "networks of concepts and relations between concepts in memory" (1978, p. 2). They noted that when scientists classify or categorize objects, the classification reflects beliefs that are influenced by the prevailing theories of the discipline. These "beliefs" are what Medin referred to as personal theories (even if they are shared by others). The "beliefs" are epistemological elements that determine what can and cannot be true within the domain. Champagne, Klopfer, DeSena, and Squires studied the knowledge structures of thirty children receiving instruction in geology. They used a concept diagramming task (ConSAT) especially developed to assess changes in the complexity of knowledge structures. Pre- and post-instruction measures of knowledge structure revealed that students' knowledge structures had changed and that congruency between these structures and the domain structure increased. Simply put, they found that students' knowledge structures had grown more complex and that this increased complexity resembled the complexity of the instruction presented in class. It is worth noting, however, that these subjects were selected for their lack of previous geology instruction. Given a more realistic situation, in which students come "prepared" with their own knowledge of the subject-matter characterizing conceptual change is likely to be more problematic.

Accommodating Conceptual Change Within Cognitive Structures

Posner, Strike, Hewson, and Gertzog (1982) conducted interviews with college students participating in an introductory physics course to study how students transitioned from Newtonian concepts to Einsteinian. Presenting students with problems concerning the relativity of time, the authors asked the subjects to solve the problems out loud. They noted that accommodation of the new concept was usually avoided, as students attempted to fit relativity into a Newtonian paradigm.

> "[P]eople who accept Einstein's two postulates may understand them in a rather non-Einsteinian fashion... Typically, students will attempt various strategies to escape the full implication of the two postulates or to reconcile them with Newtonian assumptions" (Posner, Strike, Hewson & Gertzog, 1982, p. 223).

The authors determined that two factors were significant in influencing conceptual change, (a) anomalies, and (b) fundamental assumptions concerning science. The anomalies occurred when information could not be effectively assimilated into existing knowledge structures (evidenced by students' inabilities to reconcile the solutions to the problems with their preconceptions of physics).

DeJong and Gunstone (1988) noted that the role of students' knowledge was significant, and often an impediment to science instruction. These preconconceptions (Ausubel, 1968) or autonomous frameworks (Driver & Easley, 1978) were resistant to change, regardless of instruction. DeJong and Gunstone conducted a two-phased five-year longitudinal study of seventh through twelfth grade students' knowledge of physics and the impact of instruction on their existing concepts of physics. During the first phase of instruction DeJong and Gunstone identified the students' concepts of physics. They accomplished this through questionnaires, interviews, and observations. The authors noticed a lack of conceptual change among the students, in that regardless of science instruction, students adhered to their pre-instructional concepts of physics. Following the introduction of a new physics curriculum, the authors began the second phase of their study. They looked for evidence of conceptual change in their students, and (when it was identified) conducted interviews to ascertain why the change occurred. DeJong and Gunstone found that "conventional instruction seems to have little effect in moving student's conceptions towards comprehensive science conceptions" (DeJong & Gunstone, 1988, p. 25). They also found that teaching strategies that "acknowledge" the implications of students' concepts were somewhat more effective in changing those concepts. They noted that, "Students' existing conceptions are an important element of this context, but not an absolutely determining one. It is not yet possible to confidently predict how an individual will reconstruct meaning after particular experiences, even when great detail of that individual's existing conceptions is known" (1988, p. 25).

Searle and Gunstone (1990) also noted that supporting long-term conceptual change was a very difficult process. They studied conceptual change brought about in physics students while using a "constructivist-based" instructional strategy (POE, or Predict-Observe-Explain). Specifically, they set out to determine three things: (a) the effectiveness of the instructional strategy in facilitating conceptual change, (b) what strategies the students used in trying to understand physics, and (c) the robustness of the new concepts that resulted from instruction. Searle and Gunstone employed interviews, observations, and semester examinations (finals) of students undergoing physics instruction. Searle and Gunstone found that students most frequently relied upon their own prior experiences to solve physics problems, although analogies, and formal principles were occasionally evident. While students commented that the instruction was relevant and interesting, little (if any) conceptual change occurred with regards to the subject matter. Searle and Gunstone noted that metacognitive factors, not present in their study, would probably have facilitated more conceptual change. The prior experiences of students were of limited use in conceptualizing physical phenomena. Teacher-generated analogies were less successful than student-generated analogies. Searle and Gunstone argued that student experience determined how effective teacher analogies were. They suggested that this was at least in part due to students' inability to see any value in the teacher's analogies. On the other hand, analogies that were representative of the student's experience, were generally more helpful to the student. This may also be due to a lack of readiness on the part of the students, in that they lacked the requisite concepts to interpret and apply the analogy (Ausubel, 1959).

Concepts as Both Categories and Meaning-based Representations

Concept acquisition and change involves categorization skills (in the form of generalization and discrimination) and coordinating knowledge. Generalizing and discriminating requires categorization skills that group things based on attributes, real or imagined. The same rules that facilitate generalization and discrimination, also serve to link concepts together in coordinate relationships based on context, circumstance, or theories. Medin and Smith (1984) noted that much of concept learning research has concerned the content of concepts and their use to categorize or classify stimuli. Gagné, Briggs & Wager (1992) noted that categorization is a key component of intellectual skills. E. Gagné (1993) regarded categories as an efficient means of abstracting information for retention in memory. She noted that this categorization allows for efficient packaging of knowledge. By placing bird in a hierarchy, for example, the attributes of the preceding items allow for efficient inferencing instead of redundantly storing common information with each item (i.e., if all birds have feathers, then ducks must have feathers).

Although some concepts seem to be based upon "obvious" or "natural" attributes (as noted by Rosch, Mervis, Gray, Johnson & Boyes-Barem, 1976), such as "animal", "vegetable", and "mineral", humans do not always agree as to the "naturalness" of the distinction (e.g., the ghost in the machine or the spirit in the rock). Even though we can perhaps distinguish between rocks and ancestors, the concepts may overlap considerably, and the categories may have different significance. Pines noted that concepts seldom have discrete meanings (i.e., meanings differ from context to context) and should not be viewed as categories, however tempting it may be to do so (1985, p. 109). Medin, also noted that concepts and categories are different. He argued that a category is a partitioning class to which assertions can be applied, but that a concept is an idea that includes "all that is characteristically associated with it" (Medin, 1989, p. 1469).

In this sense, concepts are meaning based representations of knowledge based in part on the experiences of the user (a view supported by Murphy & Medin, 1985). Concepts have also been viewed as schematic networks in and of themselves (Tessmer, Wilson & Driscoll, 1990). This view maintains that in addition to categorization, concepts should facilitate the recall of pertinent information and facilitate inference. "Students who can define, describe, give examples, and relate the concept to other knowledge are demonstrating their learning ." (Tessmer, Wilson & Driscoll, 1990, p. 48).

Relating Concepts to Other Knowledge

Gagne´, Briggs, and Wager (1992) described the role of intellectual skills (which includes concepts) as providing an individual with the ability to "respond to their environment through symbols" (p. 53). This skill starts with the development of an ability to discriminate between items (stimuli, examples, etc...) and culminates in the development of problem solving behaviors. These problem solving behaviors (or higher-order rules) enable individuals to "learn something that can be generalized to other problems having similar formal characteristics" (p. 64).

Medin and Smith (1984, p. 114) identified four roles of concepts: (a) simple categorization (e.g., identifying "boy"), (b) complex categorization (e.g., identifying "rich boy"), (c) linguistic meaning (e.g., understanding that "boy" is the same thing as "lad"), and (d) components of cognitive states (e.g., linking several concepts to support the belief that "rich boys are spoiled"). Klausmeier (Klausmeier & Feldman, 1975; Klausmeier, 1976) described four levels of conceptual development, similar in some respects to both of these, which culminate in a formal level in which hypotheses are generated and evaluated against definitive attributes.

In these examples, concepts play a variety of roles by organizing and linking knowledge. At a basic level, categorization skills (the foundation of concept learning) support consistent identification of like items. At the advanced level, concept learning requires knowledge to be linked with other knowledge. Both theories suggest that concept learning starts with recognition, proceeds to consistent categorization, and then develops into an ability (or skill) to generalize to other problems " having similar formal characteristics" (Gagne´, Briggs, and Wager, 1992, p. 64).

However, these two theories differ in that Medin's suggests that conceptual organization is not based solely on ontological experience, but that "naive" or "personal" theories also play a significant role in forming groups of concepts into meaningful units. This key difference illustrates what Strike and Posner (1985) consider to be a key difference between empiricist and conceptual change views of concept learning.

The Paradox of Adding New Concepts to Existing Structures

In the following table (Table 2-2, following page), Strike and Posner (1985, p. 214-215) compared what they suggested was the predominant empiricist epistemology (essential truths) of learning with their conceptual change epistemology of learning. Strike and Posner argued that the existing empiricist view of learning was inadequate to explain accommodation. They suggested that concepts form the basis of evaluating experience and developing new concepts.

Following this line of reasoning, the absolute origins of concepts (original concept) is irrelevant in everyday training and educational settings. Rather than view a student as a "tabula rasa", Strike and Posner argue that, pragmatically

Table 2. Empiricist and conceptual change epistemologies compared (Strike & Posner, 1985).

Empiricist Epistemology	**Conceptual Change Epistemology**
Knowledge originates in experience.	Conceptions are a precondition of experience (we do not see what we do not conceive).
Knowledge is additive from the bottom up.	Problems are originated by current conceptions.
Experience is the sole evidence for our beliefs.	Solutions to the problems are judged by means of current conceptions.
Experience is given to us in atoms, sometimes referred to as sensations or sense data.	Current conceptions are a product of a history of conceptual development.

speaking, learning takes place in the presence of developed concepts, naive or otherwise. For example, instead of portraying concepts as things that are experienced and then stored (additively), they suggested that one's concepts interact with and filter experience. This, in turn, creates problems that the learner must confront using current concepts. To solve the problem, the learner must first adopt the new concepts. Here lies the paradox; the new concepts are interpreted using the old concepts.

So, according to Strike and Posner, while several people may share a common physical experience, such as classroom instruction, their understanding of the experience is largely dependent on their conceptions. To the extent that these conceptions are similar, their views of the experience will be similar. However, to the extent that their conceptions differ, their interpretations of the same experience will differ. This paradox poses questions concerning whether people discover or impose structure on the real world (Medin, 1989), and the extent to which knowledge is considered to be "generative" (Wittrock, 1974) or constructive in nature. Thomas Schwandt noted that, "We invent concepts, models, and schemes to make sense of experience and, further, we continually test and modify these constructions in the light of new experience" (1994, pp. 125-126). However, how closely do concepts actually correspond to a "reality" as opposed to an "interpretation"? Is knowledge based solely on sensory impressions, as the empiricists would claim, or is knowledge created and recreated in the mind (Driver & Easley, 1978)?

Coherence Among the Concepts of a Structure

Murphy and Medin (1985) suggested that the categories supported by concepts are based in the theories of individuals; the theories by which individuals attempt to explain, or provide meaning to, the "real world." Driver and Easley (1978, p. 62) noted that the distinction between "misconceptions" which imply incorrect representations and "alternative frameworks" which suggest a difference in perspective are fine indeed. These theories provide individual (and potentially idiosyncratic) coherence or meaning to the categories. For example, a category of things that weigh more than thirteen tons and things that weigh less than thirteen tons appears very arbitrary and meaningless to some people; however, if you are loading vehicles onto aircraft (C-130s in particular) that becomes a very meaningful and coherent category. Murphy and Medin (1985) noted that the more salient a domain is to a person or group the more elaborate are the knowledge structures in the domain. Citing Bulman (1967), Murphy and Medin provide an example of a New Guinean culture that does not recognize the cassowary as a bird. Rather than classify the cassowary on the basis of physical attributes, this culture employs their theories of forest life and cultivation to classify the cassowary as a "forest creature." Murphy and Medin (1985) use this example to demonstrate how concepts are influenced by cultural knowledge. The cultural knowledge lends "coherence" to the conceptual structure.

Without this coherence, or meaning, the learner has no way to answer the question of the "ghost in the machine" posed by Ryle (1949). In this instance the question would go something like this, "Mother, I've seen the categories go by, but when will I see the concept?" Put another way, while standing on a train track, one may have the categorization skills to identify the make and model of an oncoming train; but without relating the concept "train" to the concept of "flatten" and other knowledge, it probably doesn't make much difference.

Ecological Groupings of Concepts

A new area of research is concerned with the idea of relating concepts to other knowledge is conceptual ecology. The metaphor of "conceptual ecology" is generally attributed to Toulmin (1972) and his use of the idea in a sociological frame of reference. He described a social and mental environment in which concepts compete for survival and influence. Toulmin held that,

> "...this model is a species of evolutionary theory. Just as changes in the environment and in the development of organisms alter the conditions of competition and thereby bring about changes in organisms and populations of organisms, similarly, changes in intellectual environments alter the conditions under which concepts develop. Concepts adapt to an intellectual environment much as organisms adapt to a biological environment." (Strike & Posner, 1976, p. 111)

While this pseudo-Darwinist metaphor has its limits (as noted by Hewson, 1985 and Pintrich, Marx & Boyle, 1993), it serves well for a starting place to consider the dynamics of conceptual structures. Posner, Strike, Hewson and Gertzog pursued this idea in developing their theory of conceptual change (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992).

Two processes, assimilation and accommodation generally describe the manner in which concepts change. Assimilation is the integration of information into existing concepts, and accommodation is the replacement, construction, or reorganization of concepts (Posner, Strike, Hewson & Gertzog, 1982, p. 212). Conceptual ecology theory (as stated by Posner et al., 1982) does not encompass all forms of concept learning, but focuses on accommodation. This theory was "meant to apply to concepts that play a generative or organizational role in thought" (Strike & Posner, 1992, p. 148). Posner and Strike (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992) maintained that cognitive dissonance (or dissatisfaction) with a concept is not adequate by itself to induce conceptual change (i.e., the adoption of a new concept or the radical modification of an existing concept).

Conditions Supportive of Ecological Change

For conceptual change to take place, four conditions must be present. These are (a) dissatisfaction with the existing concept, and the availability of a new concept that is (b) intelligible, (c) plausible, and (d) appears to suggest fruitful avenues of investigation (Posner, Strike, Hewson & Gertzog, 1982, p. 214; Strike & Posner, 1992, p. 149).

Dissatisfaction.

Dissatisfaction (or dissonance) is still the beginning point of conceptual change in this theory. Dissatisfaction is essentially synonymous with the disequilibrium brought about by failure to fit new information into the "slot" of a schema (Piaget, 1970; Rummelhart & Norman, 1978). Posner et al. noted, however, that people tend to cling to their existing concepts, assimilating as long as possible, until anomalies make the concept dysfunctional (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). For example, DeJong and Gunstone (1988) noted the impact of existing concepts on learning. They observed that students with concepts of heavier objects falling faster than lighter objects maintain these beliefs even in the presence of evidence to the contrary. "When presented with the science generalization that acceleration in a gravity field is independent of weight, some of these students may conclude that heavy and light objects have the same weight" (p. 5).

The presence of anomalies in the conceptual ecology are to be expected; indeed, they are one of the prominent features of a conceptual ecology. The less dissatisfied (or aware) one is with anomalies, the less dissatisfied one is with their current concepts, then the less likely one is to change concepts (Pintrich, Marx & Boyle, 1993). Once dissatisfaction is acknowledged, then three other criteria (i.e., intelligibility, plausibility, and fruitfulness) must be met for accommodation to take place.

Intelligibility.

First, conceptual ecology theory maintains that the new concept must be intelligible (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). By this, they meant that the new concept must make sense to the learner. "One of the difficulties to overcome in bringing off a dramatic conceptual change is that a new conception is often not only counterintuitive, but incomprehensible" (Strike & Posner, 1992, p. 149). Tennyson's theory of concept learning suggests that intelligibility is best facilitated by examples that are capable of linking to existing concepts.

Plausibility.

Next, the new concept must be seen as plausible; not necessarily true, but possibly true. It should suggest potential to "solve or dissolve outstanding problems with current conceptions and consistency with other well-established beliefs" (p. 149). If the new concept is not considered plausible, then it may be seen as "too inconsistent with current understandings to merit further consideration" (Pintrich, Marx & Boyle, 1993, p. 172).

Fruitfulness.

Finally, the new concept should have explanatory power (Pintrich, Marx & Boyle, 1993, 172). It should build upon the potential to solve problems by suggesting both new perspectives and utility as a "tool of thought" (p. 149). Conceptual ecology theory calls this trait "fruitfulness" (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992).

Conceptual Ecologies, Schemata, and Mental Models

The reference to assimilation and accommodation suggests a similarity between conceptual ecology theory and schema theory. Both theories hold that concepts reside in networks which influence perception and lend meaning to the whole (Gagné, 1987; Neisser, 1976; Rummelhart & Norman, 1978; Rummelhart & Ortony, 1977; Piaget, 1970; Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). To this extent, conceptual ecologies and schemata appear quite similar.

That is not to say conceptual ecology and schema theory are synonymous; that has not been determined. But, they both addresses similar issues of conceptual change. When knowledge is accommodated into the schema, a new (or highly modified) schema is created (Piaget, 1970; Rummelhart & Norman, 1978). The schematic explanation for accommodation is the inability of the schema to assimilate, or place into a slot, new information. Conceptual ecology theory seeks to explain the preconditions to accommodation (dissatisfaction, intelligibility, plausibility, and fruitfulness). Posner's theory equates accommodation to a "paradigm shift" (Kuhn, 1970). Furthermore it seeks to describe the characteristics and qualities that exist in groups of concepts (anomalies, analogies and metaphors, epistemological commitments, metaphysical beliefs, and other knowledge).

If there is a potential difference, it may be in the subtle implications of ecological anomalies and the uniqueness of each ecology resulting from the instantiation of the ecology with specific data. In this regard, conceptual ecologies are similar to mental models in that they both tend to be idiosyncratic and subjective (Hong, 1992; Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992).

Pintrich, Marx, and Boyle (1993) noted that this theory of conceptual change assumes that change within the individual is analogous to change in scientific paradigms. They state that this theory (as well as other conceptual change theories) assumes learners will behave as scientists who have become dissatisfied with an idea and will conduct a logical search for a replacement (p. 172). They also noted the paradoxical situation with regards to theories of conceptual change, "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" (p.170). That is, the features of the conceptual ecology (e.g., epistemological commitments, metaphysical beliefs, and anomalies) determine what new concepts are intelligible, plausible, and fruitful.

Phenomenological Aspects of Conceptual Ecologies

The views of concept learning expressed most often within the instructional technology field are generally tied to information processing models (e.g., Gagné, Briggs & Wager, 1992; E. Gagné, 1993; Tennyson & Cocchiarella, 1986; Tennyson & Park, 1980) and suggest that concept instruction stress comparing examples and classification behavior based on the concept's prototype. As noted by E. Gagné,(1993) this is superior to providing just definitions since it reduces cognitive load and supports the development of elaboration by way of inference. These examples support links to existing concepts, and incrementally make the new concept more "intelligible."

Jonassen, Beissner, and Yacci (1993, p.4) noted that "procedural knowledge is dependent on complex interconnections between ideas" which requires knowledge of what (declarative knowledge), how (procedural knowledge), and why (structural knowledge). It is the structural knowledge that allows the learner to link the concepts together in a manner that allows schemas, scripts, and procedures to function (Jonassen, Beissner & Yacci, 1993, p. 4).

In such instances, concept learning must account for how the learner relates (structures) the new concept to his or her current ideas (Strike & Posner, 1985). In this respect learning requires the student to understand the concept. Posner, Strike, Hewson, and Gertzog (1982) stated that this requires the student to "grasp how experience can be structured by a new concept sufficiently to explore the possibilities inherent in it" (p. 214). Next, students must evaluate the concept, relate it to his or her existing knowledge, and perceive some benefit to changing his or her existing concepts (Strike & Posner, 1985, p. 212). Imagine the difficulty that a child of the not too distant past (circa 1930) would have with the concept of what a doctor (physician) might do during her visit to a sick person. While the child might have a vivid script or procedure for what doctors do, the notion that the doctor is a "her" might not conform to the ecological requirements of the concept. Indeed, my own daughter's ecological requirements reject the notion of "her" as an acceptable pronoun when referring to "airplane pilot" or "boss."

Conceptual Ecology and a Concept of God

Consider the following example a concept of "God," as an example of a conceptual ecology at work. When I was about four years old, I believed that God looked like Col. Sanders. How I arrived at this conclusion is, I think, a good example of a conceptual ecology at work. I was watching a television show, produced by a local church, on the subject of Noah and the Ark. The show featured various members of the congregation as actors in the key roles of Noah, Mrs. Noah, and the entire Noah family. They all wore biblical costumes to include robes, wigs, and beards (for the men, that is). I fully understood that this was not the real Noah; these were actors. I also understood that actors dress up to resemble the persons they are portraying. Whenever God addressed Noah, an actor portraying God would walk on stage and converse with Noah. This actor wore a distinguished silver mustache and goatee, had silver hair to match, and dark-rimmed glasses (i.e., he looked like Col. Sanders). Just as I understood that an actor portrayed Noah, I also understood that another actor portrayed God. Since actors made themselves up to resemble the person they portrayed, obviously this person was made up to resemble God. Therefore, God must look like Col. Sanders.

Besides being a humorous anecdote, it is interesting that in this situation I did not ascribe attributes to a concept of "God" based on a set of theological or religious beliefs. Nor did the concept result from an "experience" in which I was informed, "Hey kids! Did you know that God looks like Colonel Sanders?" This concept developed on the basis of another completely different concept (actors), related only by the context of the moment (i.e., a television show). Referring back to the Conceptual Change Epistemology, the conception was a product of a history of conceptual development.

This also provides a simple example of several of the features used to describe conceptual ecologies. As described by Posner et al., a conceptual ecology has the following features: (a) anomalies, (b) analogies and metaphors, (c) epistemological commitments, (d) metaphysical beliefs and concepts, and (e) other knowledge.

Pintrich, Marx and Boyle noted that in such a model, conceptual change in one area may create anomalies in other areas (1993, p. 171). The implications of an "ecology" are that effects in one area should ripple throughout the system. First, there is the anomaly of how an invisible God can be portrayed by a visible actor. Second, there are analogies and metaphors between actors portraying mortals and actors portraying deity. There are epistemological commitments that assert if it is on the TV it must be true. There are also metaphysical beliefs and concepts that did not directly refute the notion of God looking like Col. Sanders. Finally, there was "other knowledge" of food containers bearing the likeness of "God" which were often seen at church picnics.

How that ecology was later changed, is not exactly clear. To some extent, I was exposed to religious instruction that caused me to confront the concept, and conflicts between concepts within the same ecology were resolved (e.g., if no one can see God, then how do we know He looks like Col. Sanders?). At some point it either became unproductive to presume that God looked like Col. Sanders, or perhaps it became "fruitful" to modify the concept.

Epistemological Aspects of Conceptual Ecology

Strike and Posner stated that theirs is an epistemological theory more than a purely psychological one (Strike & Posner, 1992). Kitchener stated that traditionally, epistemology is at odds with psychology because of its philosophical origins (Kitchener, 1992). While psychology is thought to concern itself with "describing and explaining the purely factual realm of the mind and behavior" epistemology concerns "evaluating the adequacy of these beliefs" (p. 119). Kitchener noted, however, that epistemology should be viewed as a branch of science and that "an essential part of epistemology is empirical science" (p.120). As such, epistemology is scientific and should be applied to scientific inquiry by determining the adequacy of theory to explain, predict, and describe.

Epistemological commitments are a key feature of conceptual ecology theory. As described by Posner et al. (Posner, Strike, Gertzog & Hewson, 1982; Strike & Posner, 1985) epistemological commitments are explanatory ideals and general views about the character of knowledge. Medin's idea of personal theories (Medin, 1989) and Champagne, Klopfer, DeSenna, and Squires' "beliefs" (Champagne, Klopfer, DeSenna & Squires, 1978) are expressions of epistemological commitments.

Posner, Strike, Hewson, and Gertzog (1982) studied physics students learning special relativity theory at the introductory level. They presented the students with two physics problems, one concerning a light clock and its implications on concepts of time, the second concerning simultaneity and synchronizing distant clocks. Students were asked to solve the problems aloud. The first exercise required students to consider how a light clock worked. The second exercise required students to read two descriptions of a problem (concerning simultaneity and synchronization of distant clocks) and repeat them back. Posner et al. found that if the new theory was unintelligible (i.e., students could not represent the problem internally, so they could not explore the potential of the concept to solve problems). These students recited the answer but demonstrated no processing of the information. The authors also found that students who understood the material must next decide if the explanations were plausible. If the explanations were evaluated as implausible, epistemological commitments prevented assimilation.

Strike and Posner (1992) examined the relationship between epistemological commitments and learning high school physics. Using a questionnaire to survey 236 high school students enrolled in physics classes, the authors collected data on epistemological commitments towards physics, student attitude towards physics, and student ability to answer physics problems. This data was collected at the beginning and end of the school year. Although direct correlations between the individual items failed to yield findings of any significance, an assessment of direction of change using factor analysis did yield interesting results. Low correlations (.220) were revealed between increases in epistemological commitments and gains in ability to solve physics problems. The authors interpreted this result to as consistent with their model of conceptual change in that as epistemological commitments increasingly suggested a view of the universe as a "rational" or "predictable" place, students' abilities to perform physics problems improved. In other words, changes in epistemological commitments appeared to coincide with changes in ability.

Ryan (1984) studied the reading comprehension strategies of 91 undergraduates in terms of their epistemological beliefs. He noted that during higher education experiences, students typically moved from "primitive conceptions of knowledge as an unorganized set of discrete and absolute truths to a more mature conception of knowledge as an array of interpreted and integrated positions" (Ryan, 1984, p. 248). Ryan determined that students who held "primitive" conceptions of knowledge scored significantly lower on tests of reading comprehension than those who held more advanced epistemological beliefs. He attributed this to lower scoring students relying more on memory as a comprehension monitoring strategy as opposed to relying on application and integration with existing knowledge. He noted, "The data suggests that one's epistemological beliefs may dictate one's choice of comprehension standards, and that these epistemological standards, in turn may control the effectiveness of one's text processing efforts" (Ryan, 1984, p. 248).

Schommer, Crouse, and Rhodes (1992) looked at the relationship between students' epistemological beliefs in simple knowledge and mathematical text comprehension. They determined that the more prevalent a subject's belief that knowledge was structured in isolated bits and pieces the less they comprehended in statistical texts. The authors noted that subjects' epistemological beliefs influenced the strategies subjects selected to study and monitor text comprehension.

Schommer (1993) investigated the development of epistemological beliefs among 1,000 high school students. She found that after controlling for intelligence, students' grade point averages correlated with their scores on epistemological ratings. She also determined that epistemological beliefs among the subjects changed as they progressed through school. Younger, more inexperienced students tended to believe that the ability to learn was fixed, that knowledge is structured as small unrelated increments, that learning occured quickly (or not at all), and that knowledge never changed.

Schommer and Walker (1995) assessed the similarity of epistemological beliefs across domains. They assessed students' beliefs in learning in two domains (mathematics and social sciences) and compared them to test scores from those domains. The epistemological factors of mathematical and social science assessments revealed a correlation and epistemological beliefs in both areas predicted text comprehension in both subject areas. The authors stated that this indicated epistemological beliefs were generally constant across domains (i.e., if students believe in simple knowledge or that learning is quick and easy in one domain, they will tend to believe so in all domains).

The implications of epistemological beliefs (or commitments) to concept learning are intriguing. Epistemological commitments validate explanations and determine what can or cannot be true (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). Klausmeier's CLD theory suggests that each stage of development (concrete, identification, classification, and formal) represents a potential for epistemological commitments to change and develop. Likewise, changes from overgeneralization, undergeneralization, and misconception to reliable categorization may require changes in epistemological commitments. In each case, changes in the relationships among the core concepts; concepts which are significant structural features of the discipline, would change the capability of the user to employ them, if altered (Strike & Posner, 1976).

Learning the Concepts of Scientific Inquiry

As stated in chapter one, this project concerns the conceptual ecology of "research." According to Strike and Posner (1976) researchers should consider two constraints when characterizing the structural features of a discipline, such as scientific inquiry. The features should concern concepts which are essential to (1) the conceptual organization of the discipline and (2) performing intellectual tasks in the discipline. "[T]here should be some prima facie evidence that learning the particular structure will increase the learner's intellectual power" (Strike & Posner, 1976, p. 125).

Much of the empirical work concerning issues related to instruction in research methods concerned effective instruction and course design (e.g., Jaus, 1987; Mitman, Mergendoller, Marchman & Packer, 1987; Riley, 1979; Ross, 1988; Ross & Maynes, 1983; Staver & Bay, 1987; Strawitz & Malone, 1987; Tobin, Espinet, Byrd & Adams, 1988; Wolf, 1979; Yager, 1986; Zeitler, 1981). According to these authors effective instruction in the discipline of scientific inquiry should focus on the intellectual tasks of identifying, isolating, and controlling variables.

This focus meets Strike and Posner's criteria; acquiring this ability should enable the learner to solve problems within the discipline (Strike & Posner, 1976). Piaget considered this scientific inquiry to be a fundamental indicator of the formal operations stage of cognitive maturation (Inhelder & Piaget, 1958).

Mastery of scientific inquiry techniques was found to correlate strongly with the acquisition of formal operations (Allen, 1973; Baird & Borich, 1987; Boyer & Linn, 1978; Linn & Thier, 1975; Padilla, Okey & Dillashaw, 1983; Webber & Renner, 1972).

What is not clear, is the role of ecologies in learning the concepts of scientific inquiry. DeJong and Gunstone (1988) observed that students with concepts of heavier objects falling faster than lighter objects maintained those beliefs even in the presence of evidence to the contrary. "When presented with the science generalization that acceleration in a gravity field is independent of weight, some of these students may conclude that heavy and light objects have the same weight" (p. 5). Although DeJong and Gunstone were conducting instruction in basic physics, not scientific inquiry techniques, similar phenomena (concerning the structure of the discipline and the conceptual ecologies of the students) are evident.

In this case, the essential truths of an existing paradigm are contrary to the conceptual structure of the discipline (physics) and limit the intellectual ability of students to solve problems within the domain. Hypothetically, the concepts of mass, acceleration, and gravity are characterized by the dependence of acceleration on dependent variable of mass and gravity. There is possibly even a failure to discriminate between the concepts of acceleration and energy (i.e., going faster and impacting harder may be viewed as the same thing). These beliefs give way to statements that greater mass must cause greater acceleration, if gravity is constant. Clearly, an alteration of these ecologies would have a fundamental effect on the students' intellectual abilities to solve the same problems.

Methods for Evaluating Conceptual Structure

The concept of "research" should be evaluated in terms of the essential structural features of the conceptual organization of the discipline, and the ability of the subjects to perform intellectual tasks within the discipline. A characterization of the conceptual ecology surrounding "research" could focus on conceptual relationships that significantly improve or degrade students' abilities to solve problems within the discipline.

For example, consider the relationship(s) between the concepts "validity", "hypothesis", and "observation." Within the generally accepted concept of "research" these three concepts are coordinate (i.e., they influence each other, but none of them are subordinate to any other). However, depending upon the ecology that characterizes the relationship between these three concepts students may perceive them to be hierarchically or sequentially related (or even unrelated). This would also offer insight into the subject's ability to generalize and discriminate between the concepts (e.g., the expression of an hierarchical relationship would imply failure to discriminate and generalize). But the question remains, what methodologies might lend themselves to a characterization of conceptual ecologies?

Much of the research on concepts and concept learning has concentrated on discrimination, generalization, categorization (Medin & Smith, 1984) and on the congruence of student's concepts to "accepted" definitions and descriptions (Driver & Easley, 1978). Driver and Easley (1978) noted that these research efforts typically ask the following questions:

> 1. At what age can an idea be effectively taught?
>
> 2. In what order should conceptually oriented material be presented and is the logical order the same as the psychological order?
>
> 3. In what way is conceptual learning related to Piagetian stages?
>
> 4. What are common "misconceptions" which occur during the learning process? (p. 63)

The instructional prescriptions associated with these research efforts typically trained subjects on classification rules and then studied the effectiveness with which the subjects assimilated learning to new examples (e.g., Haygood & Bourne, 1965; Homa, Sterling & Trepel, 1981; Medin & Schaffer, 1978; Medin & Schwanenflugel, 1981; Omohundro, 1981; Rosch & Mervis, 1975; Tennyson, Chao & Younger, 1981; Tennyson & Park, 1980; Tennyson & Rothen, 1977; Tennyson, Steve & Boutwell, 1975; Tennyson, Woolley & Merrill, 1972; Wallston & Budescu, 1981). These experiments addressed aspects of conceptual identification procedures (categorization), but not the relationships and ideas that form the conceptual core. Their methods tended to reduce their data to a point that obscures individual differences in conceptual cores. Driver and Easley (1978) noted that these types of studies contributed to the growing body of nomothetic knowledge but neglect the need for idiographic knowledge; knowledge based on exploring and analyzing a person's concepts on their own terms. Finally, the requirement for rigor in these experiments causes them to limit the interaction effects of prior learning that are relevant to actual classroom situations. However, since the effects of prior learning are a problem inherent to studying the conceptual core, these methods reduce applicability, a key component to trustworthiness (Guba, 1980).

The Use of Interviews to Evaluate Conceptual Structure

In their own work, Posner, Strike, Hewson, and Gertzog (1982) relied upon clinical interviews to explore and analyze individual conceptual ecologies. Stewart (1980) noted that the clinical interview is probably one of the oldest and most often tried techniques for such investigations. The purpose of the interview is to "probe" the subject's cognitive structure within a "narrowly circumscribed area" (Stewart, 1980).

Clinical interviews can provide a descriptive assessment of learning (Posner & Gertzog, 1982, p. 199). This technique is a blend of information gathering and diagnostic techniques. It is best if the interview is based on concrete phenomena (Posner & Gertzog, 1982; Stewart, 1980). Structuring the interview around a concrete phenomenon brings the interviewer to grips with the problem in that it gathers useful information without "falsifying" the natural inclination of the subject (Posner & Gertzog, 1982). Interview techniques, however, tend to have problems with replication, and problems with articulation of answers by subjects (Head & Sutton, 1989). To remedy this, Head and Sutton (1989) suggested that sentence completion tests might elicit full and frank responses, allow respondents to answer in their own words, and require less time than complex interviews. The clinical interview allows the subject to speak freely yet allows the researcher to probe and explore; something not allowed by paper and pencil instruments.

Piaget's categories of interview responses.

Piaget (as cited in Posner & Gertzog, 1982) classified five types of response to interviews. These are:

1. Answers at random (e.g., providing the first answer which comes to mind, indicating the subject is uninterested).

2. Romancing (e.g., spontaneous answers given for the sake of amusement, but lacking conviction).

3. Suggested conviction (e.g., a response provided to please the interviewer, but one in which the subject does not actually believe; this may also be brought about by leading questions or poorly worded questions).

4. Liberated conviction (i.e., a response neither spontaneous nor suggested, but based upon reasoning at that point in time).

5. Spontaneous conviction (i.e., a response based upon previous reflection; more spontaneous in that the subject has already thought about the answer).

The objective of the clinical interview is to not be "taken in" by the first three types of responses (answers at random, romancing, and suggested convictions) and to elicit either liberated or spontaneous convictions.

Problems noted with the use of interviews.

There are problems noted with clinical interviews, however. Posner and Gertzog (1982) noted that:

1. The interviewer must make a decision to categorize overall performance (e.g., categorizing a participant as ecology type A, based on the sum of all questions) or specific question performance (e.g., reduction by each element of information). This goes to the heart of resolution (i.e., how many pixels will compose the picture of each participant). In studying conceptual ecologies, categorizing overall performance was not recommended since it "obscures concern and capability for describing the substantive qualities and interrelationships of the concepts being learned." (Posner & Gertzog, 1982, p. 201). This will require individual interpretations of each question, posing the difficulty of data-inundation. To avoid this complication each interview session will need to be carefully guided, and may need to incorporate sentence completion tasks.

This will allow for the reduction of data while avoiding over-generalization.

2. The interviewer must guard against taking portions of the interview out of context (but still not rate the entire interview).

3. Too much input by the interviewer may lead to suggested convictions (leading). *To remedy this, the interviewer should focus on listening,* and provide only minimal input and stimuli to get to the end of the interview (which Posner and Gertzog suggest should not exceed 30 minutes).

4. The rating scheme, used to evaluate the interviews, should reflect the dimensions under consideration. Posner & Gertzog (1982) suggest that these dimensions be assessed: epistemological commitment and metaphysical beliefs, extraneous ideologies or purposes (such as conflicts with existing beliefs, or conflicts between the purposes of instruction and the purposes for which they are attending the class), assimilative strategies (how does the learner try to bend the information to fit within their existing "interpretive framework," and misconceptions (concepts that lack veridicality within context).

5. The process of developing transcript ratings must be objective at all times. To maintaining objectivity of transcript ratings, multiple raters should be used.

The Use of Diagramming to Evaluate Conceptual Structure

Diagramming is also a commonly used method to graphically depict and compare the information contained in a subject's cognitive structure (Stewart, 1980). The most common of these techniques, concept mapping, has been used in a wide variety of settings to visually represent the relationships in knowledge structures. West, Farmer, and Wolff (1991) identified nine types of relationships that concept maps most often depict. These are:

1. Classificatory (Is an example of, is a kind of)
2. Property (Is a feature of, is an attribute of)
3. Equivalence (Is the same as, is identical to)
4. Similarity (Is similar to, is like)
5. Un-similarity (Is not similar to, is unlike, is different)
6. Quantity (Is greater than, is less than)
7. Sequence (Occurs before, occurs after)
8. Causal (causes, produces, or because of)
9. Enabling (enables, allows, is allowed by)

Typically, these relationships represent curricular distinctions, recognized by a body of experts or authors, and not actual cognitive relationships. Furthermore, the question remains as to whether changes in these relationships, as noted by a concept mapping technique are indicative of conceptual change.

Champagne, Klopfer, Desena, and Squires (1981), developed the Concept Structuring Analysis Technique (ConSAT) as a means of assessing changes in conceptual structures. Although a diagramming methodology, it also draws upon word associations to provide the basis for diagrams. Champagne, Klopfer, DeSena, and Squires (1981) developed this technique to evaluate the way students relate and order concepts into larger structures.

The ConSAT technique assumes that a "standard" knowledge structure exists in the instructional content (i.e., a goal of the instruction is to impart the socially or culturally accepted knowledge structure to the students). In their work, Champagne et al. analyzed texts and other curricular materials and then determined the complexity of the dimensions along which the knowledge was organized. Outside experts (university professors) were used to review, evaluate, and confirm the dimensions produced by this analysis. These dimensions formed the bases for evaluating student knowledge structures, as depicted in the students' diagrams.

In ConSAT, words pertaining to a concept are written on labels or cards, and the subject is told to place them on a piece of paper in a manner that illustrates their mutual relationships. Once the labels are in place, the student is then asked to describe the relationships between the words. As the subject describes these relationships, the interviewer marks the paper to reflect those relationships. Although the relationships are noted in terms used by the student, and are likely to be unique to the student, the relationships denoted by the marking system should be based upon the relationships expressed by the instructor. In this manner, the ConSAT technique incorporates many of the advantages of "Think-Aloud" protocols. Upon completion of the diagramming portion of the task, each subject's paper is analyzed to determine the extent of organizational complexity. This is accomplished by searching the student diagrams for evidence of the standard knowledge structure's dimensions and then determining to what extent these dimensions are demonstrated.

The dimensions originally identified by Champagne et al. (1978) are based upon scientific concepts of geology present in texts and curricular materials used in a particular elementary/middle school setting. Their analysis revealed three structural dimensions to the subject matter under consideration. These dimensions were definitional and taxonomic, hierarchical, and transformational. Using these dimensions, Champagne et al. developed a scale for detailed evaluation of student diagrams.

After evaluating student diagrams, the diagrams were then placed in one of the following categories as a means of overall classification of the structural complexity of student knowledge for the task. Stewart (1979) noted that assessments of cognitive structure should allow for comparisons over time. Champagne et al. noted that comparisons of pre- and post-treatment evaluations indicated the extent to which students' knowledge structures conformed to the structure of the instructional content. The ConSAT technique, used by Champagne et al. offers some potential advantages over other diagramming techniques.

Problems with the use of diagramming.

Stewart (1979) noted that often the diagrammed relationships of concepts, when based on semantic proximity, are purely temporal or syntactic, and often restrict inferences of propositional meaning. "The upshot should be obvious - if one is interested in the nature of meaning in cognitive structure, one must ensure that assessment devices assess the nature of that meaning" (Stewart, 1979, p. 400). Noting the same problem, Strike and Posner (1976) questioned the use of many diagramming techniques. "When we have mapped out this sort of concept hierarchy, what is it that we know about the concepts or the relations between concepts in the hierarchy?" (Strike & Posner, 1976, p. 125). In particular, both Strike and Posner (1976) and Stewart (1979) noted that these techniques do not rule out the effects of temporal contiguity. Stewart (1979) further suggested reliance upon syntactical mechanisms to infer ordinal measurements often produces data that is reduced 'beyond all recognition.'

In all fairness, it should be noted that these comments were directed primarily at Shavelson and others who were concerned with the relationships between content structure and cognitive structure. Shavelson (1972) used semantic proximity to compare the cognitive structure of students to the content structure of science instruction. Stewart suggested that what Shavelson actually assessed with semantic proximity was just that; semantic proximity (Stewart, 1976, p. 404). Goldsmith, Johnson, and Acton (1991) maintained that a degree of relatedness, such as Shavelson and others attempted to estimate, is best determined with a technique such as multidimensional scaling (MDS). These techniques capture global information, while network diagrams get at more localized relationships (Goldsmith, Johnson, and Acton, 1991).

The ConSAT technique used by Champagne et al. is less dependent upon semantic proximity than Shavelson's techniques. Rather than infer cognitive structure based upon individual statements, subjects explain their understanding of the content structure. Comparison of the subject's results with that of the content model yields a qualitative evaluation of the difference in terms of complexity. Although ConSAT assigns a numerical index to the levels of conceptual complexity these values are nominal and represent a "characterization" of the level of complexity as opposed to an actual measurement. A characterization may be a more appropriate means of assessing conceptual ecologies.

Identifying Changes Within the Conceptual Ecology

As noted previously, concepts are a type of knowledge structure, supporting the organization of knowledge in long term memory. This structure is composed of relationships between two properties, internal connectedness and integrative understanding (Jonassen, 1990, p. 3). Concepts do not exist in *isolation but in structured relationships with other concepts* (Tennyson, Tennyson & Rothen, 1980, p. 499). Concepts are most often categorized as subordinate, superordinate, successive, and coordinate.

For example, the concept "duck" might generally be considered superordinate to "mallard" and subordinate to "bird", while being coordinate with such diverse concepts as "chicken", "goose", "sparrow", and perhaps even "ostrich." Successive concepts differ from the categories of subordinate and superordinate in their relation with coordinate categories. Successive concepts are distinctly different from other concepts, having "clearly distinguishable critical and variable attributes." (Dempsey, 1990, p. 4). For example, the concepts "duck" and "egg" are clearly distinguishable from each other (although which one came first is another matter). This compares to coordinate categories which have "multiple, common, critical and variable attributes" (Dempsey, p.4) such as "duck" and "chicken."

Successive concepts have nothing in common with each other, while coordinate concepts have overlapping attributes (i.e., some of the critical or variable attributes of one concept overlap with those of another, making them much more difficult to distinguish). It is these relationships, particularly the coordinate relationships, that are often of the greatest instructional value since they are often part of pre-existing knowledge structures that are activated during learning (Tennyson & Park, 1980; Tennyson, Tennyson & Rothen, 1980). "In most theories of LTM [long term memory], the meaning of any concept is determined by the pattern of relationships to other concepts in the learners [sic] knowledge structure." (Jonassen, 1990, p. 3).

Extensional relationships.

These classifications, when viewed within a given domain or context, suggest two fundamental sets of conceptual relationships. The first type are the hierarchical superordinate – subordinate relationships. Hierarchies are extensional relationships based on the denotations that determine set membership, either inclusively or exclusively. For example, the extensional meaning of "duck" is the group comprising all existing types of ducks. So, mallards (a kind of duck) are extensionally related to "duck."

Subordinate and superordinate relationships concern the relationships between concepts in terms of categorization. This structuring suggests that concept learning has taken place at higher levels that support the understanding of principles and solving of problems (Jonassen, Beissner & Yacci, 1993; Klausmeier, 1976). In such instances, concept learning influences how the learner includes (or structures) the new concept to his or her current ideas (Strike & Posner, 1985). Recognition that multiple concepts are related to each other in the context of a larger (superordinate) concept implies an ecological state of relatedness and class membership; change to that superordinate or subordinate relationship suggests that the ecology has been altered.

Intensional relationships.

The second type of relationship is the coordinate – successive (or intensional) relationships. Intensional relationships are those based on conceptual properties. Intensional relationships bridge between concepts of differing hierarchical relationships based on the connotations (implications) of each concept. For example, several different hierarchies are invoked when someone is asked to name three things that are striped (e.g., barber poles, zebras, and highways). By definition, intension gives rise to an extension, in the case of these relationships, the extension is a set of concepts with a perceived relationship based on an overlapping attribute or property but not considered to be part of the same superordinate - subordinate relationship. Literature suggests that the coordinate – successive (intensional) relationships may be more relevant to daily learning activities.

Changes to intensional relationships.

Coordinate and successive relationships (as described above) emphasize the ability to recognize, and to discriminate between similar concepts. This is fundamental to concept learning (Gagné, Briggs & Wager, 1992; Klausmeier & Feldman, 1975; Klausmeier, 1976; Tennyson & Cocchiarella, 1986; Tennyson & Park, 1980; Tennyson, Tennyson & Rothen, 1980). These conceptual relationships influence what concepts are or are not acceptable within a given ecology and what concepts form the core of the ecology (Strike & Posner, 1976). Inclusion of a new concept in the set of concepts that comprise the ecology would suggest the possibility of a small change to the ecology that would support further concept learning (Klausmeier, 1976). Likewise, exclusion of a previously accepted concept would also suggest changes to the ecology. Inclusion or exclusion both address example recognition aspects of coordinate and successive relationships within a context of an ecology.

Changes in coordinate – successive relationships may suggest changes in conceptual ecologies. Successive, coordinate, superordinate, and subordinate conceptual relationships reveal the scope of concept structure and suggest ecological relationships. Alterations to these relationships suggest changes to concepts and to their attendant ecologies. In each case, the conceptual ecology includes core relationships that, if altered, would change the capability of the user to employ the knowledge of the domain (Strike & Posner, 1976).

Diagramming Changes In Conceptual Relationships

A diagramming protocol that could describe changes to intensional and extensional conceptual relationships (i.e., superordinate – subordinate and coordinate – successive) may provide insight into the state of conceptual relationships within the subject's conceptual ecology. Essentially, the technique of diagramming requires the participant to develop a spatial array of key concepts that somehow represents the participant's conceptual structure. By themselves, these arrangements are difficult to interpret and describe. However, the interviewer also provides the subject a standard method of diagramming the links between the concepts, hence the name diagramming. Typically the method involves drawing lines between the concepts, connecting them into meaningful clusters or hierarchies that provide a means of comparing one diagram with another and drawing conclusions concerning the subject's conceptual structure.

Given the criticism of diagramming methodologies that rely upon semantic proximity (Stewart, 1979; Strike & Posner, 1976) such a protocol should assess the nature of the conceptual relationships themselves and do so in a way that allows for comparison over time (Stewart, 1979). Coordinate - successive relationships do not rely on semantic proximity. By diagramming these relationships one may be able to make inferences concerning conceptual ecologies. In particular, by diagramming the intensional relationships one might be able to develop insight to the meaning of the coordinate structures of the conceptual ecology.

Repertory grid matrices offer one means of analyzing changes within coordinate – successive relationships. This technique provides an estimate of proximity between concepts, but this estimate is not semantically based. Repertory grid matrices estimate proximity on the similarity of the intensional distinctions participants make between the concepts. Changes in the polarity of these distinctions, or in the estimated proximity of, provide a descriptive measure of change to successive – coordinate relationships.

Concept mapping can also elicit participant's views of conceptual relationships. Concept mapping protocols generally recognize the following types of relationships (Armburster & Anderson, 1984; Huang, 1988; McAleese, 1985, 1986, 1988; and West, Farmer & Wolff, 1991).

1. Classificatory (Is an example of, is a kind of)
2. Property (Is a feature of, is an attribute of)
3. Equivalence (Is the same as, is identical to)
4. Similarity (Is similar to, is like)
5. Un-similarity (Is not similar to, is unlike, is different)
6. Quantity (Is greater than, is less than)
7. Sequence (Occurs before, occurs after)
8. Causal (causes, produces, or because of)
9. Enabling (enables, allows, is allowed by)

With the exception of the first, these relationships are fundamentally intensional in that they describe relationships in terms of properties. Changes to intensional relationships within the conceptual ecology may reflect changes to the properties of the concepts themselves and to the manner in which they are related.

Potential Difficulties with Diagramming

Posner, Strike, Hewson, and Gertzog (1982) based their characterizations of changes to conceptual ecologies on interviews. They and other authors (e.g., DeJong & Gunstone, 1988; Strike & Posner, 1976; Posner, Strike, Hewson & Gertzog, 1982) have noted that accommodation seldom occurs immediately after instruction. This is a potential problem for diagrams, in that no change in the diagram may signify no change in conceptual ecology (no accommodation) or insensitivity in the protocol. Whether the diagram protocol is sensitive enough to note changes in the conceptual ecology is a key question to this project. Part of the answer lies in the stability, or reliability, of the protocol to dependably characterize the subject's conceptual ecology. When faced with a similar problem, Chi, Feltovich, and Glaser (1981) employed a version of test-retest reliability. They noted that the first assessment and the second assessment yielded almost identical results for each subject, regardless of experience level. Champagne, Klopfer, DeSena, and Squires (1978) also noted that their ConSAT protocol was reliable in this regard.

However, neither Stewart (Stewart, 1976; Stewart, 1979) nor Strike and Posner (1976) in their criticism of diagramming techniques suggest that stability is an issue; they argue instead that the results yield uninterpretable and decontextualized measurements. Without falling into the trap of over-reducing the data to the point of unintelligibility (e.g., reducing data to a single numerical index), one must demonstrate that the changes noted in assessments over time are meaningful characterizations of conceptual change. This suggests that a parallel assessment is needed to: 1) determine whether the conceptual ecology changed, and 2) to characterize the change in a manner that facilitates a meaningful comparison between methods.

A concept mapping protocol supports highly structured interviews similar to those used by Posner, Strike, Hewson, and Gertzog (1982). While the maps themselves serve to illuminate student responses to the unique diagramming task, the interview data would provide one basis for confirmatory information on the student's conceptual ecologies. Another method for gathering confirmatory information was demonstrated by Chi, Feltovich, and Glaser (1981). During interviews, they presented their subjects with descriptions of physics problems. They noted that the manner in which subjects classified the problems characterized the subjects' underlying knowledge structure. This method also provides a comfortable fit with earlier concept learning research methods (e.g., Tennyson, Tennyson & Rothen, 1980; Tennyson, 1973; Tennyson, 1980; Tennyson, Chao & Younger, 1981) by allowing observation of subjects' ability to generalize and discriminate between examples and nonexamples.

One other method is the use of repertory grid matrices to provide an empirical assessment of changes to conceptual structures. Such models have been used successfully to elicit and compare conceptual structures (Sewell, Cromwell, Farrell-Higgins, Palmer, Ohlde & Patterson, 1996; Shaw, 1980; Shaw & Gaines, 1989). These techniques "elicit knowledge indirectly by prompting individuals for critical elements and relevant constructs in a coherent sub-domain" (Shaw & Gaines, 1995). The technique identifies areas where polarity of individual concepts change with regards to their intensional distinctions. For example, concepts that are initially rated as very similar (in terms of an intensional distinction) may be rated as very different on a subsequent assessment. This is referred to as a change in polarity. Changes in polarity indicate a change in the properties the subject attributes to the concept. The technique also identifies areas where, due to group changes in polarity, the proximity of entire sets of concepts increases or decreases. Interviews and the use of repertory grid matrices will provide the means to evaluate the effectiveness of a concept mapping approach to diagramming the conceptual ecology.

A methodology for studying conceptual ecologies must consider changes in other concepts as well as the larger concept of "research." Such a methodology should describe changes in the content of the ecology and relationships among the constituent concepts of the ecology. It should also explore how the participant applies conceptual knowledge to their surroundings. The nature of the relationships within the ecology should support characterizations of the ecology that allow for assessment of conceptual change or resistance to change. Four techniques, in particular, offer the overlapping capabilities needed: 1) interviews, 2) concept mapping, 3) classifying examples, and 4) repertory grid matrices.

Chapter 3
Research Method

Review of Research Questions

This study is idiographic in its design, as opposed to nomothetic, in that it does not seek to formulate universal statements or scientific laws. Instead, the intent of this study is to identify and describe concrete changes in individual conceptual structures. In this study, participants described the relationships between several concepts. It is intended that these descriptions should provide a mechanism for identifying and describing (i.e., characterizing) aspects of participants' conceptual structures. By characterizing aspects of these structures, this study does not seek to explain the phenomena of concept formation and change. Instead, this study seeks to understand concrete aspects of individual conceptual structures in terms of the participant's specified purpose or intent. This study approaches changes in conceptual structures in the sense of "verstehen" (i.e., the meaning of the phenomenon) as opposed to "erklaeren" (i.e., the explanation of the phenomenon) as addressed by Schwandt (1994).

Given the interpretive nature of this approach, the methodology should capture unique data and not artifacts or researcher bias. Instrumentation and procedures should conform to expectations of reliability and validity, yet the data collected does not provide conventional indices of the same. In light of these requirements, a review of the research questions is in order.

This study sought to answer the following questions:

1. Do the characterizations suggest idiographic conceptual ecologies?
2. Does the methodology provide consistent characterization of the subject's conceptual ecology, given a test-retest application?
3. How trustworthy are the characterizations of the ecological structures?
4. Is the methodology sensitive to changes in the conceptual ecology? That is, given a pre-post assessment, is there a perceptible change in the conceptual ecology, and if so does it more closely resemble the instructor's?

Characterizing Conceptual Ecologies

Do characterizations suggest unique conceptual ecologies surrounding the concept of "research?" In this study, methodologies will need to support an interpretation (characterization) of the relationships among concepts. Using a naturalistic approach, there is an underlying assumption that

> " . . . there are multiple realities, that inquiry will diverge rather than converge as more and more is known, and that all 'parts' of reality are interrelated so that the study of any one part necessarily influences all other parts" (Guba, 1980, p. 133).

This then produces concerns of reliability and validity with regards to whether the characterization represents some unique aspect of the participant's conceptual ecology.

Some evidence of this uniqueness has already been demonstrated. Using a modified ConSAT technique, three volunteers (participants A, B, and C) participated in diagramming and interviews. The volunteers were participating in an off-campus research methods course. Participant A had research experience at the undergraduate level, participant B had no previous research experience, and participant C had research experience within the context of military service. Each participant developed a unique diagram, which yielded unique characterizations. Additionally, the instructor was able to identify each participant by the unique ways each participant linked concepts within the diagram.

Schwandt recommended that in such instances researchers judge interpretation in terms of "thoroughness, coherence, comprehensiveness" and whether the interpretation is "useful" (Schwandt, 1994, p. 122). Guba (1980), noted that relevance was as important as rigor (p. 136) and suggested that researchers can best verify the truth value (analogous to internal validity) of interpretations by "testing the data with members of the relevant data source groups" (p. 140). In a similar manner, consistency (analogous to reliability) is not invariant but demonstrates that "changes that occur must be meaningful, not random, and their meaningfulness must be able to be established" (p. 140).

This suggests that an appropriate method would involve an assessment of the characterization by a 'member of the relevant data source group' as to the 'usefulness' of the characterization and the 'meaningfulness' of changes captured by the characterization. The participant's instructor is the single common-factor (human factor) of each data source group and as such is in a unique position to assess the utility and meaningfulness of participant data. Pilot data, when reviewed by the instructor, indicated that not only were the characterizations unique to each individual, but that they were indicative of specific individuals (i.e., the instructor was able to identify the participant based on a review of the diagram).

A "blind review" of participant data should reveal the extent to which idiographic conceptual ecologies surrounding the concept of "research" would be useful and meaningful in characterizing conceptual changes. This should be accomplished by providing instructors with diagrams (to include excerpts from interview data that amplify the diagram) of participants. If the data is useful and meaningful, the instructor should recognize which participant generated the data, by matching before and after diagrams. More than just random guessing, the instructor should be able to point out specific aspects of the student data that provide the "clues" to characterizing the participant.

Operationalizing the Characterizations

As a result of the research effort, participant data suggested two broad descriptors of conceptual change—structure and understanding. The relationship of structure and understanding represent two continuums. Structure appeared to be characterized by simple or elaborate.

A difficulty presented itself in applying the value-laden term "misconceptions" (Posner, Strike, Hewson, & Gertzog, 1982) to participant understandings of research concepts. The term carries with it connotations of "correct" and "incorrect" which became difficult to support in every instance. For example, the two instructors did not agree entirely in their understandings. What the data did suggest, however, was that student-participant understanding of many of the concepts was not shared by the larger community of educational researchers.

In this sense, understanding appeared to be characterized by whether it was unique to the participant or shared with the larger professional community (as represented by the instructor). Student-participants' data generally demonstrated simpler structure and more unique understandings in their initial diagrams and increased elaboration and more shared understandings in second diagrams. The structure-understanding relationship suggests one way in which conceptual ecologies and their changes may be characterized.

This project operationalizes "understanding" as the manner in which the participant uses the knowledge as compared to a larger social context (i.e., the profession of educational research). Understanding becomes increasingly shared (and less unique) when 1) the concept names resemble those used within the social setting (Klausmeir, 1976), 2) the concept is used in a context that is congruent with the larger social context (Keil, 1987), and 3) the participant brings relevant knowledge to bear when employing the concept (Medin, 1989).

The other dimension, "structure," is operationalized as the extent to which the participant organizes the diagrammed relationships, demonstrating a "connectedness" between the concepts of the ecology (Jonassen, 1990). The structure becomes increasingly elaborate as: 1) the participant employs more complex structures and networks (Champagne, Klopfer, DeSena, & Squires 1978), and 2) the organization becomes more purposeful in providing a self-description of the participant's ecology (Medin, 1989).

Consistency of Characterizations

Does the methodology provide consistent characterization of the subject's conceptual ecologies? This refers to consistency (analogous to reliability). Consistency is not invariant but demonstrates that "changes that occur must be meaningful, not random, and their meaningfulness must be able to be established" (Guba, 1980, p. 140). It is important to determine whether or not the characterization of a conceptual ecology is a consistent reflection of a conceptual structure or if it reflects other confounding influences that would yield the characterization unreliable.

This question is best addressed by a test-retest approach as employed by Chi, Feltovich, and Glaser (1981). Using this technique, the researcher intended to determine whether the diagrams should yield similar characterizations when employed after a short period of time, for example, two or three days. By comparing the first and second iteration data, the researcher intended to determine the extent to which participants consistently employed the same methods of depicting their conceptual ecologies. In such a comparison, the researcher evaluated evidence of significant change to the overall diagram structure (i.e., how similar were clusters of concepts and core concepts). Also, the researcher considered relationships and links between individual concepts and whether they remained relatively unchanged between tests. Most importantly, however, the researcher evaluated interview data to determine if it revealed significant changes in the meaning ascribed by the participants to the conceptual relationships.

Determining the Trustworthiness of Characterizations of Conceptual Ecologies

How trustworthy are these characterizations of ecological structures? Guba and Lincoln (as cited in Guba, 1980, p. 139) note that "trustworthiness" must be determined through the criteria of truth-value, applicability, and consistency. One of the most effective ways to assure this is by "testing the data with members of the relevant data source groups" (Guba, 1980, p. 140). In this instance, the relevant data source groups were the students and the instructors.

Trustworthiness was assessed in two ways. First, the researcher examined statements provided by participants during diagramming to establish their meaning. Evidence of trustworthiness lies first in the participant's assessment that the interpretation of the diagram is correct (e.g., Interviewer: "So, hypothesis and observation are not related?" Participant: "That is correct, they are not."). It was incumbent upon the interviewer to ascertain that truth-value of each statement to ensure subsequent evaluations were not based on faulty assessments of the participant's intent. Second, the researcher asked instructors to review the characterization of each student's conceptual ecology to ascertain if the conceptual changes noted were reflective of their assessment of the student's development through the semester. The level of consistency was revealed in an assessment of whether changes appear to be random or purposeful (i.e., changes were explainable within the context of the data).

Determining Sensitivity to Changes in Conceptual Ecologies

Is the method sensitive to changes within the ecology? Over the course of time, and given exposure to instruction, one would expect conceptual ecologies to demonstrate some change (Posner, Strike, Hewson & Gertzog, 1982). If the method does not reveal change, then one is left asking whether the method lacks sensitivity or the conceptual ecologies did not change. Interviews provided some insight to this. If, indeed, conceptual ecologies did not change, the study employed interviews to provide substantiation. On the other hand, if interviews revealed a change in conceptual ecologies, then the level of the method's sensitivity must also be demonstrated.

Another measure used to determine whether changes in conceptual ecologies occurred was provided by the use of an external assessments in the form of repertory grid matrices (Kelly, 1955). Rooted in personal construct psychology, the repertory grid matrix provided an empirical method of gauging conceptual structure and its changes. "Repertory grid techniques elicit knowledge indirectly by prompting individuals for critical elements and relevant constructs in a coherent sub-domain." (Shaw & Gaines, 1995, p. 1). Given a list of concepts (which were related in a specific context), participants compared and grouped concepts based on perceived similarities and differences. The similarities and differences were elicited through triadic comparisons made by the participants. For example, given three concepts (e.g., hypothesis, question, and validity) the participants selected the concept that was most different. The participants then provided a description of why the selected concept was different from the other two, and a description of what made the other two similar. Employing these descriptions, the participants evaluated the remaining concepts in the set.

The repertory grid matrix offered several benefits. First, it provided additional insight into each participant's frame of reference. Second, comparison of initial repertory grid matrix data with diagram and interview data allowed a fuller understanding of each conceptual ecology. Third, the repertory grid matrix provided a capability for numerical indices of conceptual relationships. The data yielded by this technique was analyzed in its native numerical matrix form and through principal components analysis. Changes in conceptual structures (or lack thereof) were determined by comparing each participant's pre and post treatment repertory grid matrices. They also provided a basis for assessing whether the diagramming technique was sensitive to the same changes.

In their work with diagramming, Champagne, Klopfer, DeSena, and Squires (1978 and 1981) found that student diagrams (and the implied cognitive structure) more closely resembled those of the curriculum and the teacher following instruction. In the same manner that participant diagrams (and repertory grid matrices) were compared over time, they were also compared with the instructor's diagram (or matrix) to determine if they were similar following instruction. This required an initial "benchmark" diagram (and matrix) from the instructor. Comparison with student participant diagrams early in the instructional period suggested key differences. The researcher intended to determine whether comparisons after the instructional period revealed how those differences were mediated, if at all.

Research Design

This study sought to answer the research questions by applying the methodology, in a qualitative approach, to a small group of graduate students (at both the doctoral and masters levels) studying research methods. The concept "research" is very relevant to graduate level education and to characterizations based on a conceptual ecology view. "Research" does not lend itself to simple attribute-based descriptions. There is (potentially) a "web" of intensional and extensional relationships (structural knowledge) associated with the concept.

At the root of these relationships are the types of conceptual relationships noted by earlier researchers (Armburster & Anderson, 1984; Huang, 1988; McAleese, 1985, 1986, 1988; and West, Farmer & Wolff, 1991):

1. Classificatory (Is an example of, is a kind of)
2. Property (Is a feature of, is an attribute of)
3. Equivalence (Is the same as, is identical to)
4. Similarity (Is similar to, is like)
5. Un-similarity (Is not similar to, is unlike, is different)
6. Quantity (Is greater than, is less than)
7. Sequence (Occurs before, occurs after)
8. Causal (causes, produces, or because of)
9. Enabling (enables, allows, is allowed by)

It is these relationships that support the conceptual ecologies and the subjects' fundamental understanding of "research." As the conceptual ecologies change, the relationships should also change.

Methodology Plan

This study employed a diagramming methodology. Diagramming exercises required the participants to describe the relationships between sets of concepts relevant to "research." Using the concepts contained in Table 3-1 (following page), test-retest pilot participants and instructors depicted and described the relationships between them with regards to the concept of "research." Additionally, instructors modified this set of concept labels by removing or adding concepts. The modified set of concepts was then employed with the instructors' respective students.

During diagramming sessions, the researcher described the methodology to the participants, ensuring that each understood what was expected. This explanation included signing release forms, as required by the Institutional Review Board. The participants were asked to answer a few questions concerning their perception of the concept "research." The researcher presented these questions from a prepared questionnaire.

Table 3. Generic concept labels provided for test-retest pilot and for instructor use.

Observations	Reliability	Ethics
Experiments	Qualitative	Alternative Hypothesis
External Validity	Variability	Samples
Instrumentation	Hypothesis	Internal Validity
Validity	Data	Causation
Theory	Questions	Accuracy
Quantitative	Literature Review	Generalizability
Conclusions	Variables	Null Hypothesis
Survey	Results	Empirical
Prediction	Correlation	Methodology
Interview	Statistics	

1. What is the meaning of research?
2. Define research.
3. List some words related to research.
4. What are the important activities related to research?
5. What are the features of research?
6. How and why are these particular features selected?
7. What is your purpose for taking the research methods class?
8. What do you expect to gain by taking this class?
9. How much experience do you have conducting research?
10. What settings have you conducted research in?
11. If one has a good grasp of the concept research what do you feel that one should be capable of doing?

The interviewer recorded the verbal responses in writing and on tape. The purpose of the questions was to gather initial data about the participant's experience with research practice and their beliefs about the purpose of research.

Next, participants were shown how to perform the diagramming task. Similar to other diagramming methodologies, participants placed gummed labels bearing the concepts names on a large sheet of paper, arranging them in a pattern or array that the participant determined represented the proper "structure." Participants were encouraged to discuss the task, and their placement of the labels, as they progressed. Participants then connected the concept labels with lines that designated relationships between the concepts. The interviewer asked the participant to describe the relationship between the two concepts, and then label the relationship (line) accordingly with one of the following designations:

1. Classificatory (Is an example of, is a kind of)
2. Property (Is a feature of, is an attribute of)
3. Equivalence (Is the same as, is identical to)
4. Similarity (Is similar to, is like)
5. Un-similarity (Is not similar to, is unlike, is different)
6. Quantity (Is greater than, is less than)
7. Sequence (Occurs before, occurs after)
8. Causal (causes, produces, or because of)
9. Enabling (enables, allows, is allowed by)

10.Other/uncertain.

As the participants performed the diagramming exercise, the researcher periodically questioned them concerning the relationships, their meaning, and examples of similar relationships.

Once elicited, these same concepts provided the basis for establishing the repertory grid matrix. Instructors evaluated triads of concepts drawn from their own set of concept labels. Triads were developed purposively by the researcher to elicit constructs that made distinctions between overlapping (coordinate-successive) concepts. Each participant evaluated each triad to determine, in their opinion, which of the three concepts was most different from the other two. For example, given "observation", "experiments", and "external validity" the participants determined which concept was most different from the other two. Next, the participants described (using a word or short phrase) what made the one concept different and (using another word or short phrase), what made the other two alike.

These two words represented opposite poles of a discrete continuum (or construct) known as an intensional distinction. Each distinction described a property of the conceptual ecology that its members most likely shared. Participants evaluated each concept of the ecology to determine whither it possessed this property and if so, to what extent. Participants evaluated each concept, determining which "pole" of the continuum best describeed it. By approximating the intensional distinction through its extensions (i.e., through its application to the other concepts) this technique "measured" the concepts. Arraying these concepts and their "measurements" in table form constituted a repertory grid matrix.

The repertory grid matrix allowed for comparisons of conceptual ecologies through comparisons of terms used to describe concepts and distinctions made among the concepts. Since the participants were provided a set of concepts, to facilitate diagramming, the terms used to describe them were unlikely to change. However, the distinctions made among the concepts allowed for comparisons over time and between participants. The repertory grid matrix supported the comparison of any two concepts across all distinctions. This facilitated the comparisons with the diagramming method. If changes in the intensional distinctions noted in the repertory grid matrix accompanied changes in the conceptual relationships noted by the diagramming task, then conceptual change would most likely be evident.

This assessment of conceptual change (or non-change, as the case may be) would provide one means of determining how trustworthy the diagramming technique was. Comparison of repertory grid matrix data with diagram and interview data would also provide additional insight into participants' conceptual ecologies. This method (diagramming, interview, and repertory grid matrix) would be performed at the beginning and end of the semester.

Additionally, during the semester, an interview (without diagramming) would be performed. This interview would seek to enrich the data collected to that point and clarify questions concerning conceptual ecologies. The interview sought to elicit the participants' views concerning an example of a research project. During the interview subjects were asked to describe what it was that made the project a good example of research. The purpose of these interviews was to gather information on how the participants applied their conceptual knowledge to "real world" examples. The researcher intended to assess whether their description provided additional information concerning their conceptual ecologies.

Sequence of Events

The study was organized into two tracks of two parts each. One track followed doctoral students participating in a research methods class, the second will followed masters students in a similar class.

Test-Retest Pilot

To ensure the diagrams yielded consistent (reliable) results, the technique was evaluated using two participants. Each participant performed the diagramming task twice, with a one-day interval between sessions.

First Instructor Diagrams and Interviews

This plan called for interviews with instructors and students (using diagramming, repertory grid matrix, and interview techniques) as a first step.

Diagramming began with the instructor immediately prior to or during the first week of the semester (Fall 1996). The instructor brought to class the official concept of "research" (e.g., what is research, what activities constitute research, what one must know to conduct research, how does one know if it is research, etc.). Champagne, Klopfer, Desenna, and Squires (1981) noted that during the process of instruction the ecological changes may result in a student diagram that more closely mirrors the dimensions of the instructor's. The introductory interviews (with the instructor) incorporated diagramming, interviews, and repertory grid matrices.

Using the concept list and triadic comparisons, instructors developed diagrams and repertory grid matrices. Analysis of these matrices (through principal components analysis) would yield concept sets that would be provided to student participants for their use in developing repertory grid matrices. This interview concentrated on characterizing the instructor's conceptual ecology of "research" and on determining critical instructional events that may occur.

First Student Diagrams and Interviews

During the first two weeks of the semester, participants were interviewed, performed the initial diagramming task, and develop their repertory grid matrices. These activities sought to establish an assessment of the students' initial knowledge base. Analyses of the diagrams and repertory grid matrices served (a) to provide additional questions for future interviews, and (b) as a means of characterizing the subjects' entry level knowledge. The interviews attempted to determine the instructional/learning goals of students and look for evidence ofconceptual ecologies relevant to the concept of "research."

Mid-Semester Student Interviews

A subsequent interview (without diagramming) occured midway through the semester. This interview sought to enrich the data collected to that point and clarify questions concerning conceptual ecologies. Doctoral students were asked to come to the interview prepared to provide one example of a "good" research project in an area of interest to them. During the interview subjects were asked to describe what it was that made the project a good example of research. Masters students were provided with an example of a research project in the form of a research article. Each student was be asked to describe what made the example “good” or “bad.”

Based on the previous data, interview questions sought to gather additional information about relationships expressed in the participants’ diagrams.

End of Semester Student Diagrams and Interviews

At the end of the semester, participants were then asked to repeat the diagramming technique and repertory grid matrix to identify changes in structural complexity. End of semester interviews were conducted as close to the end of the semester as possible, without interfering with finals schedules. This interview was conducted in essentially the same manner as the first interviews. The results of this interview were compared to earlier diagrams of the subject and the instructor.

Using the concept diagrams, pre- and post-instruction assessments were compared to evaluate changes in conceptual ecologies. Participant interviews were examined to identify what differing interpretations (if any) they have developed through the semester. Repertory grid matrices were compared to determine the extent and nature of conceptual change during the semester.

Follow-On Instructor Interviews

The intent of this project was to interview the instructors early in the Spring 1997 semester concerning their assessment of student data collected during the previous semester. Instructors would be presented with student pre- and post-instructional diagrams and the researcher's characterization of the diagrams. Instructors would not be presented with interview transcripts or any information that might embarrass the participants. The purpose of this interview would be to gather confirmatory data from the instructor concerning changes in the subject's conceptual ecologies identified by the methodology. Agreement between the instructor's assessment of the student's understanding of "research" (as evidenced during the previous semester) and the characterizations of student conceptual ecologies, would suggest that the methodology was trustworthy and stable (valid and reliable) in the eyes of the instructor.

Selection of the Sample

The sample consisted of graduate students participating in the Doctoral and Masters level research methods class. This sample selection was purposive, not representative, since this project was not intended to generalize findings to similar populations. Only three participants were desired per class. The logistics constraints associated with diagramming and interviewing participants would have made any larger than three per class, unwieldy within the time lines of one semester. Participants would then be interviewed as soon as possible in the beginning of the semester to minimize potential instructor influence on their conceptual ecologies. Three students per class would provide an adequate base for diverse interviews and guards against the potential of attrition during the semester.

Limitations of the Study

This study assumes, at least initially, that conceptual change is in many respects unique to individuals, although the changes may be influenced by shared understandings among groups. To this end, this study aims to describe the changes and the implication of these changes in the context of the subjects themselves. The trustworthiness of the methodology rests with the agreement of participants (instructors and students) that the data produced reflects an accurate portrait of the participant.

This study is intended to be a qualitative effort. It is essentially a grounded theory approach incorporating elements of comparative analysis. This is based primarily upon participant interviews that will seek to develop a shared understanding during the interaction between the researcher and the participant (Firestone & Dawson, 1982). This approach should allow the participants' interpretation of experience to be explored in terms of their existing knowledge structures.

Chapter 4
Research Findings

Overview of Procedures

As previously described, I employed a diagramming methodology to gain insight into participants' conceptual ecologies. I collected data in the form of interviews, diagrams, and repertory grid matrices.

After selecting participants from masters and doctoral research methods classes, I conducted a test-retest pilot to gauge the consistency of the diagramming technique. Then, the instructors of the two classes participated in a diagramming session. From this diagramming session I derived two concept sets; one for each instructor. Participants employed the concept set derived from their instructor during the conduct of their respective diagramming sessions.

During the first session, participants completed the diagramming exercise and a repertory grid matrix. This was followed with a mid-term interview in which participants described a research article. I provided masters participants with an article, doctoral participants selected an article. At the end of the semester, participants completed another diagramming session and repertory grid matrix. I recorded interviews and transcribed them afterwards. Repertory grids were analyzed using the University of Calgary's Web-Grid (http://tiger.cpsc.ucalgary.ca/WebGrid). This tool records the results of the repertory grid and provides analysis in the form of principal component analysis. Transcripts and repertory grids were compared with diagrams to develop characterizations of each participant's conceptual ecology. The characterizations were then compared over the course of the semester to assess changes in conceptual ecologies. This chapter will provide a participant-by-participant discussion of the results. As I discuss participant data I will compare it to instructor data and to other participant data when it serves to highlight unique features in each participant's conceptual ecology.

Preparatory Activities

Selecting Participants

Participants were drawn from graduate students participating in the Doctoral and Masters level educational research methods class at a southwestern university. Presentations concerning the research were made to each class with the consent of the instructors. Doctoral students were offered no incentive for participation, while Masters students were offered course credit for participation. Twelve students initially volunteered and signed consent forms (five doctoral

Table 4-1. Participants.

Participant Type	Participant ID
Pilot	P1 and P2
Masters	A and B
Doctoral	C and D

students and seven masters students). However, self-elimination and non-participation reduced this pool to two participants in each category and two participants for the test-retest pilot (Table 4-1).

Development of Initial Concept Set

The initial concept set was described in the previous chapter. This group of concepts provided a base of terms commonly associated with research methods instruction. The concept set consisted of the terms shown in Table 4-2 (below).

I used this concept set to provide a base for conducting the test-retest pilot and the instructor interviews. During the instructor interviews, each instructor modified this set to reflect concepts they used in their research methods classes.

Table 4-2. The *initial concept set* for use by test-retest pilot participants and instructors.

Observations	Experiments	Quantitative	Instrumentation
Validity	Theory	Interview	Conclusions
Survey	Prediction	Hypothesis	Reliability
Qualitative	Variability	Variables	Results
Questions	Literature review	Ethics	Data
Correlation	Statistics	Causation	Accuracy
Samples	Internal validity	Empirical	Methodology
Generalizability	Null hypothesis	Alternative hypothesis	Correlation
	External validity		

Test-Retest Pilot

To determine how consistent (reliable) the diagram technique was, the technique was evaluated using two participants. Each participant (participants P1 and P2) met with me at a time and place of their choosing. During the sessions each participant completed a brief introductory interview in which they answered questions concerning their experience in educational research methods and reasons for taking a research methods class. Before beginning the diagramming exercise. Upon completing the interview, each participant was provided with a set of concept labels and a sheet of backing material. After listening to the instructions, each participant performed the diagramming task twice, with an interval between performances of approximately 24 hours. Once again, the participants performed these exercises using the initial concept set, not instructor specific sets. Both participants understood at the time of the task that this was a "calibration" effort.

Participant P1

P1 was self-described as a researcher with some experience. In the opening interview, P1 described a background in survey research and qualitative interviews. This experience stemmed from previous work performed in school and for professional organizations. P1 described "a systematic approach" as an important activity and a primary feature of research. When asked what key words were related to research, P1 provided three that were among the list of concepts to be used in the diagramming exercise (i.e., *theory*, *observation*, and *hypothesis*). P1 is the only participant that provided a learning-goal for taking a research methods class (i.e., stated that the reason for taking the class was to develop skills and knowledge of research methods).

P1's first diagram (Figure 4-1, below) was highly structured. This took P1 approximately 30 minutes to produce. P1 expressed little doubt in the diagram's accurate reflection of the concept of research.

P1 developed the second diagram approximately 24 hours later. On the surface, P1's diagrams appear very similar. Both begin with the concepts of *literature review*, *theory*, *questions*, *hypothesis*, and *null hypothesis*. From this point they proceed in a more-or-less linear (but somewhat muddled) fashion to the concept of *alternative hypothesis*. It is interesting to note that in both instances, P1 diagrammed *null hypothesis* as a type of *hypothesis* while classifying *alternative hypothesis* as an outcome of the research process. At no time did P1

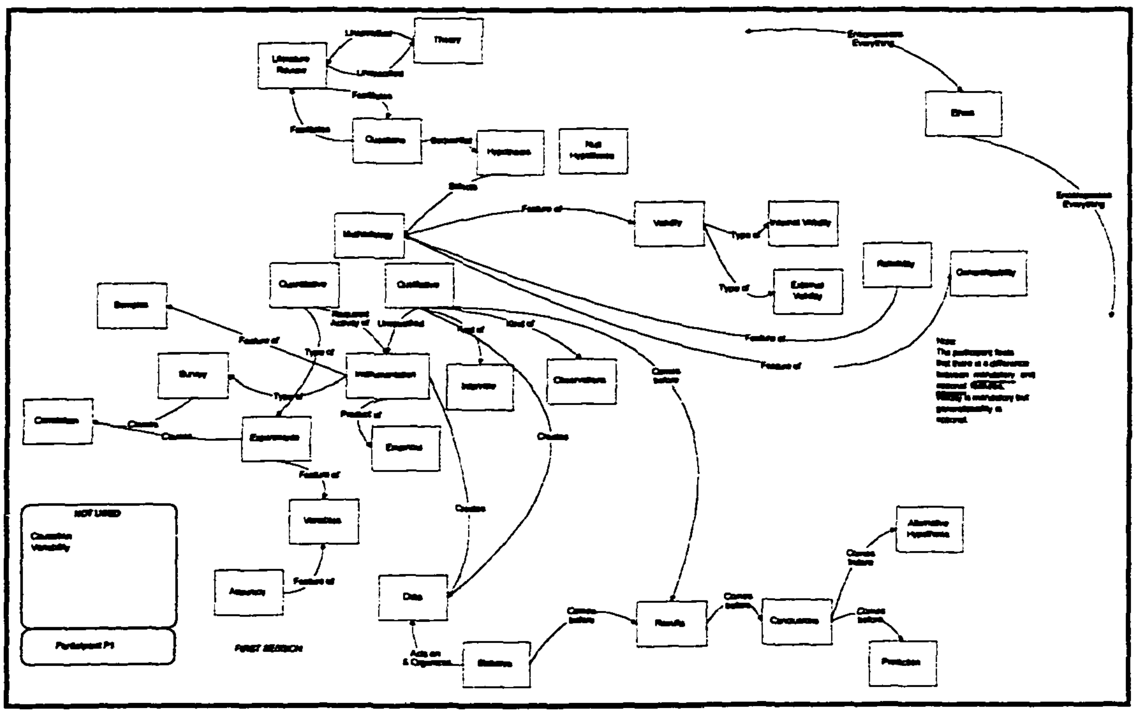


Figure 4- 1. Participant P1's initial diagram.

indicate that the concept of alternative hypothesis might be another type of *hypothesis* (i.e., P1 did not include the concept of *alternative hypothesis* in the larger hierarchy of *hypothesis*).

Methodology plays a central organizing role in P1's diagrams. In each diagram, P1 placed the concept of *methodology* in a prominent position—central to the diagrammed relationships. In both diagrams, P1 diagramed a hierarchical relationship between the concepts of *methodology*, *validity*, *internal validity*, *external validity*, *reliability*, and *generalizability*.

During both diagramming sessions, P1 divided the universe of methodologies into two types—*qualitative* and *quantitative*. P1 did not link the concepts of

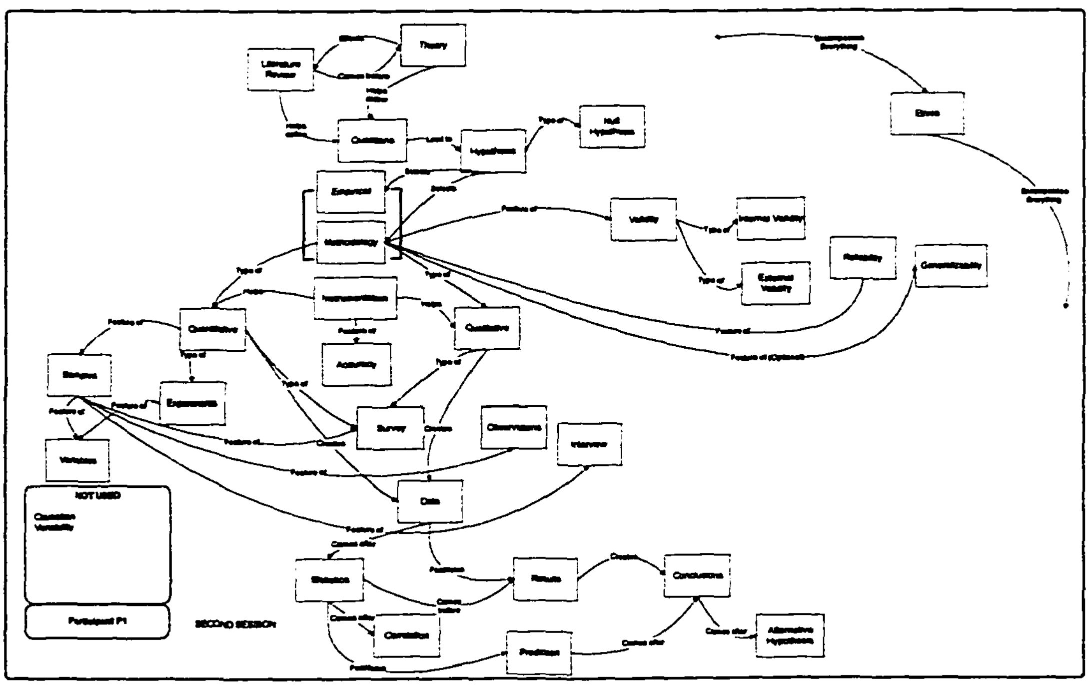


Figure 4- 2. Participant P1's second diagram.

qualitative and *quantitative* to *methodology* in the first diagram. However, their placement within the diagram, and the subsequent relationships demonstrates how P1 organized the diagram into *qualitative* and *quantitative* domains. In the second diagram, P1 actually drew links between the concepts of *methodology*, *qualitative*, and *quantitative*—P1 classified qualitative and quantitative as "types of" methodologies.

Following this *qualitative-quantitative* bifurcation, comparing the placement of concepts becomes somewhat fuzzy. While P1's diagrams still exhibit an ordered linearity, the placement of concepts differs between the diagrams. P1's placement of the concepts of *observations* and *interviews* highlights this fuzziness. Although both are placed in similar locations and sequences, the first diagram shows them placed on the qualitative side and linked to the concept *qualitative*. The second diagram shows them on the qualitative side, but linked to quantitative concepts.

Likewise, the concepts of *survey* and *correlation* changed position between diagrams one and two. In the first diagram, P1 placed the concepts of *survey* and *correlation* in the quantitative portion of the diagram, describing *surveys* as a type of *instrumentation* and *correlation* as an outcome of *experiments* and *surveys*. In the second diagram, however, P1 placed *survey* in the center, between *quantitative* and *qualitative*, and linked it to both of them. P1 placed the concept of *correlation* much later in the diagram, subordinate to *statistics*.

Changes between P1's first and second diagram become more apparent following an examination of the relationships used to link the concepts together. In both diagrams, P1 drew links between the concepts and described how the concepts were related. The following table depicts a summary of the links, by category, for both diagrams. Between the first and second diagrams, P1 used approximately the same number of links, and the same types of links. However, many of the links changed between the first and second diagrams. For example, P1 linked *results* and *conclusions* in both diagrams. In the first diagram, P1 described the relationship as, "Results come before conclusions." In the second diagram, P1 described the relationship as, "Results creates conclusions." While both relationships suggest a temporal relationship, the second description includes an element of causality. Another example of this change is the relationship between *qualitative* and *results*. In the first diagram, P1 linked them sequentially

Table 4- 3. *Comparison of diagrammed links for Participant P1.*

P1	**Relationships**									
Total Relationships	Example of / Kind of	Feature of	Identical to	Similar to	Dissimilar to	More / Less than	Occurs before / after	Causes / Caused by	Enables / Enabled by	Other / Uncertain
First Diagram	7	7	0	1	0	0	6	4	3	32
Second Diagram	7	9	0	0	0	0	6	3	7	30
Changes in Second	3	6	0	0	0	0	3	2	5	0

(i.e., *qualitative* comes before *results*). In the second diagram, P1 did not link them at all.

The physical placements of concepts in P1's diagrams (the diagram pattern) remained fundamentally the same between sessions. P1's diagram is characterized by an elaborated concept *methodology* which functions as the central organizer in the hierarchy (i.e., of thirty concepts, approximately 25% are linked directly to *methodology*). In this way, P1 brought relevant knowledge to bear as P1 described the concept of research. Viewed in the light of comments provided during the initial interview, this is not surprising. During this interview, P1 stated that an important aspect of research was a "systematic approach." The cluster of concepts linked to *methodology* remained virtually unchanged between diagrams.

Immediately following *methodology*, the diagrams both bifurcate along the lines of *qualitative* and *quantitative*. Both diagrams conclude with the production of data that leads to conclusions and a possible alternative hypothesis. The primary difference in the diagrams lies with the description of the relationships, which changed somewhat between sessions.

Participant P2

P2 was self-described as a novice at educational research. P2's experience stemmed from earlier academic efforts and historical research conducted some years earlier. It is important to note that P2 described the research process as an "experimental" process. P2 defined research as, "Having a question and finding an answer through a series of experiments." P2 used the concept *experiment* as a key word for research, an important feature of research, and an important activity of research. P2 suggested that this stemmed from high school chemistry and physics classes where one experiments (in a laboratory setting) to find answers. The initial interview suggested that the concept of *experiment* would play a significant role in P2's conceptual ecology.

P2 admitted that the primary reason for taking a research methods class was, "it is a course requirement." (In defense of P2 it should be noted that all participants, with the exception of P1, provided the same answer.) The first diagram took P2 approximately 60 minutes to produce, as did the second. P2 expressed some doubt in the first diagram's accurate reflection of the concept of research, but stated that the second diagram was "better." This suggests that P2 had reflected on the previous diagram and had perhaps brought more knowledge to bear (whether relevant or irrelevant) during the second session. A comparison of the two diagrams reveals that the placement pattern differed somewhat but some of the relationships remained similar.

In P2's initial diagram (Figure 4-3, following page) *ethics* and *empirical* are global concepts that affect the entire diagram. However, in the second diagram, P2 depicted very specific relationships for both. While *questions*, *hypothesis*, and *theory* are generally at the beginning of the diagram, their relationships differ.

The first diagram depicts sequential relationships between them, while the second depicts enabling relationships. Most pronounced in both diagrams is the central organizing role of *experiments*.

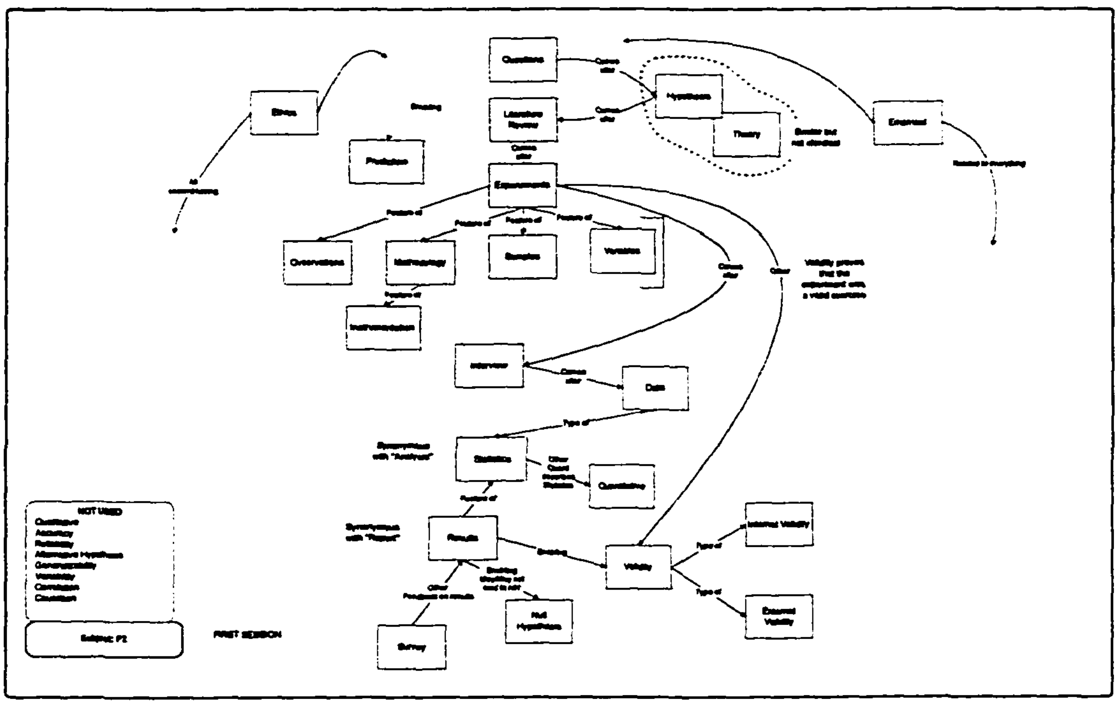


Figure 4- 3. Participant P2's initial diagram.

An examination of both diagrams reveals that *experiments* is the subject of the greatest elaboration. In both diagrams P2 linked *observations*, *methodology*, *samples*, *variables*, *interview*, and (indirectly) *instrumentation* to experiments. In the second diagram, *experiments* received additional links with *qualitative*, *quantitative*, *correlation*, and *causation*. In fact, the significance of this concept seems evident in the first diagram, where P2 drew elongated lines to ensure *validity* and *experiments* were connected. In both diagrams, P2 employed a structure of elaborated links to tie relevant concepts to the concept of *experiments*. Also, in both diagrams, the bifurcation of the diagram around *qualitative* and *quantitative* (as seen in P1's diagram) does not exist. P2, self-described as inexperienced in research, expressed insecurity in using the concepts qualitative and quantitative, because of a lack of understanding, with regards to the domain of research.

The differences between P2's diagrams become apparent with the following table. In the first diagram, P2 was more likely to arrange concepts sequentially and describe relationships in global terms. In the second diagram, P2 depicted a

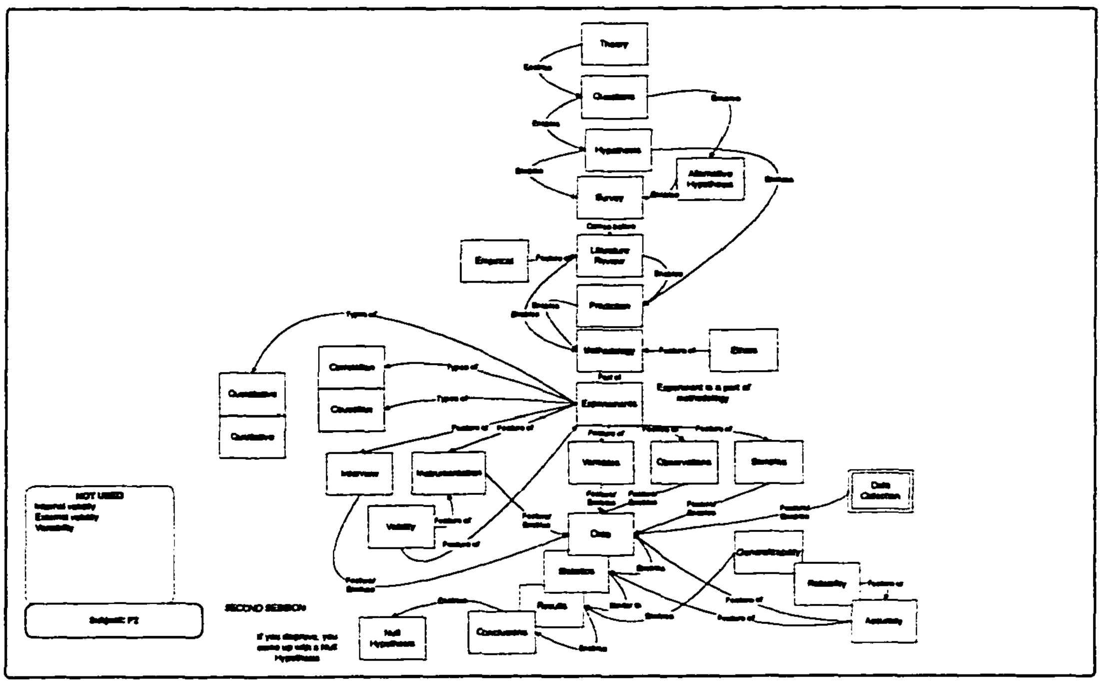


Figure 4-4. Participant P2's second diagram.

much more organized hierarchy of extensional relationship (i.e., "features of" relationships) surrounding the concept *experiments*. However, many of the concepts linked to *experiments* are the same in both diagrams. The physical placements of some concepts in P2's diagrams (the diagram pattern) changed somewhat between sessions. P2's diagram is characterized by an elaborated concept *experiment* that functions as a central organizer within the hierarchy. Viewed in the light of comments provided during P2's initial interview, this too is not surprising. During this interview, P2 described research as an experimental process. The cluster of concepts linked to *experiments* remained consistent between diagrams.

Table 4- 4. Comparison of diagrammed links for Participant P2.

P2	**Relationships**									
Total Relationships	Example of / Kind of	Feature of	Identical to	Similar to	Dissimilar to	More / Less than	Occurs before / after	Causes / Caused by	Enables / Enabled by	Other / Uncertain
First Diagram	3	5	0	1	0	0	5	0	3	67
Second Diagram	4	20	0	1	0	0	2	0	12	0
Changes in Second	4	17	0	1	0	0	2	0	11	67

Analysis Of Test-Retest Pilot

Analysis of the test-retest pilot results suggested that the diagrammed links were subject to changes between sessions. Since the sessions were so close together, it is unlikely that instruction played a significant role in changes to the participants' diagrams. The most likely explanation for these differences is reflection on the part of the participant—during the second session, Participant P2 commented that reflection following the first diagram had played a role in developing the second. The diagramming exercise elicited comments from most participants that it caused them to reflect upon the concepts of research in new ways. The novel experience of the diagram and the short time between sessions (less than 24 hours) may have allowed participants to reflect on their experience and elaborate on their answers (i.e., look for additional or different relationships).

Upon close examination, however, characteristic elements of each participant's diagrams remained in tact between sessions. Participant P1 continued to structure the diagram around the concept *methodology*. Participant P2 continued to structure the diagram around the concept *experiments*. In both instances, these concepts provided an integrating function for other concepts in the diagram—tying the other concepts together and allowing the participant to then bring that knowledge to bear on the whole diagram in an organized manner.

Participants organized the diagrammed relationships, demonstrating a "connectedness" (Jonassen, 1990) between the concepts of the ecology. Portions of the structures were somewhat elaborate suggesting the participants were employing more complex structures and networks (Champagne, Klopfer, DeSena, & Squires 1978) for the purpose of describing their conceptual ecologies. In their use of the concepts, P1 and P2 were not entirely congruent with the larger social context (for example, the evidence of a *qualitative-quantitative* bifurcation in both participants' diagrams). This suggests that the participants' understanding was somewhat limited (Keil, 1987). This appeared to influence the diagramming exercise as participants attempted to bring relevant knowledge to bear (Medin, 1989) when diagramming the concept research.

Initial Instructor Sessions

The purpose of the instructor interviews was to obtain a working concept set. While the initial concept set, used during the test-retest pilot, consisted of terms common to research methods instruction, further testing required the use of a concept set that was unique to each instructor.

Each instructor (I1 and I2) participated in an initial interview. Following the interview, Instructor I1 and Instructor I2 were provided a set of concept labels and backing material. Instructor I1 and Instructor I2 were read the instructions and then commenced to place the concept labels on the backing.

Instructor interviews took place at the time and place of the instructor's choosing. Instructor interviews took, by far, the longest time. Instructor I1 required two sessions of 1.5 hours each while Instructor I2 required a single session of 2.5 hours. It is interesting to note that neither instructor was absolutely convinced that they had provided the "right" answers (i.e., answers that were both technically and epistemologically correct). Both commented that there were several ways in which they could place concepts in the diagram and draw relationships. Both continued to change the placement of concepts on the diagram throughout the exercise. In fact, instructors expressed the least confidence in the absolute nature of their responses of all participants.

Instructor interviews differed from the test-retest pilot in one major point. During the instructor interviews, Instructor I1 and Instructor I2 also completed a repertory grid matrix. The purpose of the repertory grid was to gather additional information on Instructor I1's and Instructor I2's conceptual structure. Later, this data would be compared to student data in an effort to ascertain what similarities existed with student conceptual structures.

Instructor I1

Instructor I1 was self-described as an experienced researcher, with a background in educational research. As an instructor, I1 taught research methods classes to graduate students. During the initial interview, Instructor I1 defined research as a systematic process that gathers knowledge. According to Instructor I1, research may consist of either empirical processes (to gather new evidence) or processes aimed at reconceptualizing previously gathered data. Instructor I1 stated that both processes occur in a research context—the synthesis of research gathers and rearranges data in an attempt to create knowledge. Instructor I1 emphasized the role of *synthesis* within research, stating, "All research is a synthesis process." Instructor I1 also used the concepts *process*, *empirical*, *theory*, *evidence*, *instruments*, *ideas*, and *community* to describe research.

The concept of *community* was important to Instructor I1's overall concept of research. Instructor I1 stated that the purpose of research was to "share knowledge within a community of interested people." This is important to Instructor I1 because the knowledge must be shared to be useful. Thus, Instructor I1's concept of research includes a sharing mechanism, or *report*.

The concept of *community* and *sharing* was evident in Instructor I1's self-described instructional focus during research methods classes. Instructor I1's research methods class concentrates on developing the skills for participation in the educational research community through "critical reading" of research articles. Instructor I1 did not expect the students to develop the skills necessary

Table 4- 5. Instructor I1's concept set.

Observations	Experiments	External Validity
Instrumentation	Validity	Theory
Quantitative	Conclusions	Survey
Prediction	Interview	Reliability
Qualitative	Variability	Hypothesis
Alternative Hypothesis	Questions	Literature Review
Variables	Results	Correlation
Statistics	Ethics	Data
Samples	Internal Validity	Causation
Accuracy	Generalizability	Null Hypothesis
Empirical	Methodology	*Interpretation*
Alternative Explanation	*Report*	*Synthesis*

for executing research, however, the class should "move" them towards this goal. Instructor I1 developed the concept labels shown in Table 4-5 (following page).

Instructor I1 used more time than any other participant to conduct the diagramming exercise—requiring two sessions to complete the diagramming exercise. Throughout the exercise, Instructor I1 expressed uncertainty that the concept labels were placed correctly on the background. Instructor I1 produced the diagram shown in Figure 4-5 (following page).

An analysis of Instructor I1's diagram reveals several characteristic points. Instructor I1's diagram depicts states and processes in intricate and recursive relationships. The structure of Instructor I1's diagram is far more elaborate and integrated than the structure of either Participant P1 or Participant P2. Instructor I1 depicted the relationship of *ethics* as broad and over arching. Instructor I1 described the role of *ethics* as governing research at the "highest level." Instructor I1 then depicted a cluster of concepts (*synthesis, theory, research,* and *literature review*) that interact with each other. Instructor I1 commented several times about the role of *theory* to this cluster. Research, according to Instructor I1, is a theory-based process because the profession (i.e., educational psychology) is theory based. The objective of the cluster is to refine or develop *theory* to the point that *prediction* and *hypothesis* are available. Collectively this *theory*-object also interacts with other objects throughout the diagram—providing an illustration of *synthesis* at work in Instructor I1's concept of the research process.

Instructor I1 brought relevant knowledge to bear in several ways. The use of clusters (an action performed by Instructor I1 with no prompting from me) suggests that Instructor I1 used unnamed concepts to describe an interrelationship or integration among the concepts provided. Instructor I1 also added concepts to the diagram (those depicted with double lines). These additions do more than make the diagram's structure more elaborate; they also allowed Instructor I1 to bring relevant knowledge to bear (Medin, 1989).

Data collection, a concept that Instructor I1 added to the list, is by far the most elaborate concept of the diagram. An interesting point is that Instructor I1 ordered *data collection*'s elaboratory concepts in terms of their use in *qualitative*

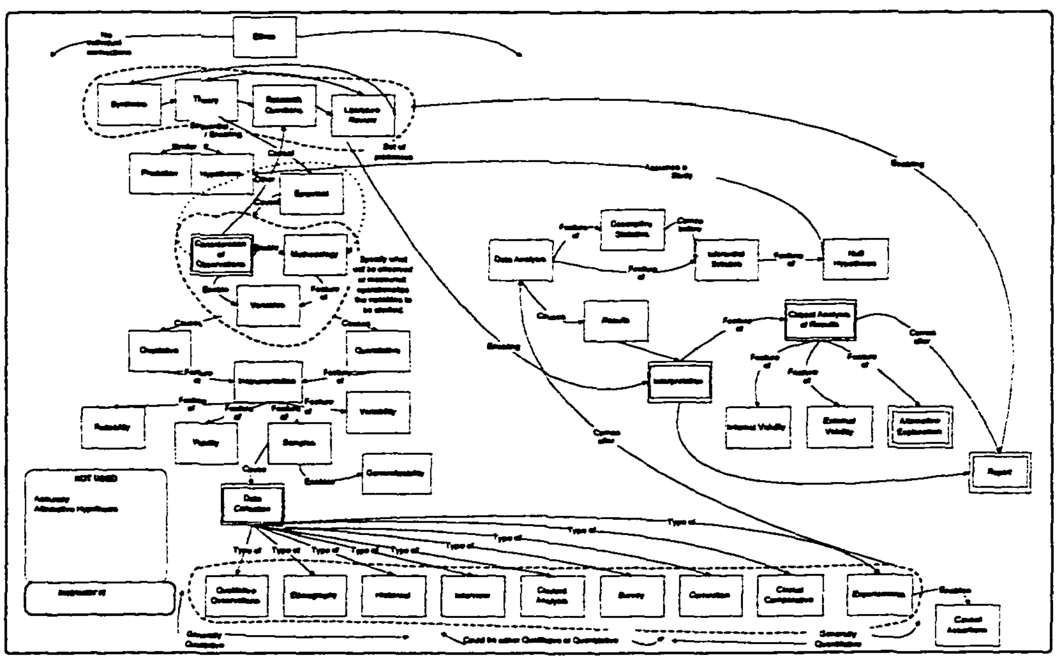


Figure 4-5. Instructor I1's diagram.

and *quantitative* methods. This is not, however, a bifurcation between *qualitative* and *quantitative* concepts. Instructor I1 described a unified group that arrays itself along a type of *qualitative-quantitative* continuum. In fact, Instructor I1 provided little evidence of *qualitative-quantitative* bifurcation in the diagram. The concepts of *qualitative* and *quantitative* did not divide Instructor I1's diagram—they ordered it.

The *qualitative-quantitative* bifurcation evident in Instructor I1's diagram appears to differ from those observed in Participants P1 and P2. The *qualitative-quantitative* bifurcation observed in P1 and P2 served in a dissociative way to divide the conceptual ecology. In the case of Instructor I1, however, the *qualitative-quantitative* bifurcation integrates concepts and supports the creation of a core concept.

Instructor I1 also completed a repertory grid matrix using the diagram's concepts. The repertory grid matrix assesses conceptual structure by comparing 1) the terms used to describe concepts, and 2) the distinctions made between concepts. Given a list of concepts (which related in a specific context), participants compare and group concepts based on perceived similarities and differences. The similarities and differences are elicited through triadic comparisons made by the participant. For example, given three concepts (e.g., *hypothesis*, *question*, and *validity*) the participant selects the concept that is most different. The participant then provides a description of why the selected concept is different from the other two, and a description of what makes the other two similar. Employing these descriptions, the participant evaluates the remaining concepts in the set. I1's repertory grid yielded seven constructs (Table 4-6).

Instructor I1 evaluated all 42 concepts in terms of seven constructs derived from the concept triads. Instructor I1 noted that the repertory grid matrix was very difficult to complete, again because Instructor I1 was unsure the answers were correct (i.e., whether or not the answers supported accepted epistemological conventions). A principal component analysis of the repertory grid matrix yielded the diagram shown on the following page (Figure 4-6).

Table 4- 6. Instructor I1's concept triads and resulting constructs.

Concept Triads			**Resulting Constructs**
Theory	Data Analysis	Methodology	1. Research Tools-New Tools
Prediction	Conclusion	Research Questions	2. Beginning-Not beginning
Causal Assertions	Correlation	Validity	3. Not Causal Relationships-Causal Relationships
Empirical	Quantitative	Inferential Statistics	4. Quantitative methods-any method
Qualitative	Interview	Report	5. Qualitative methods-any methods
Hypothesis	Experiment	Literature Review	6. Specific To Quantitative Methods-General Empirical Methods
Reliability	Generalizability	Null Hypothesis	7. Evaluation Of Results-Evaluation Precedes Results

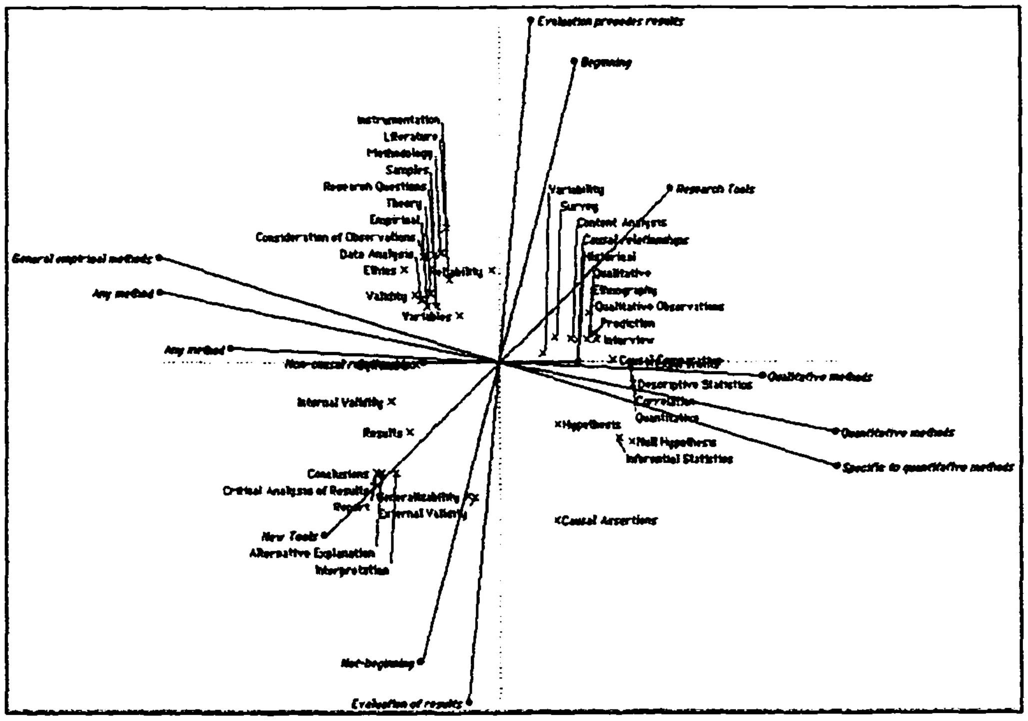


Figure 4-6. Instructor I1's principal component analysis diagram.

The principal component analysis suggests three primary factors among the concepts provided by I1. The first factor combines constructs 2 (Beginning-Not Beginning) and 3 (Not Causal Relationships-Causal Relationships) in terms of process, sequence, and results in a manner that resembles Instructor I1's description of *synthesis*. Construct 1 (Research Tools-New Tools) stands alone, with minimal influence on the body of concepts. Constructs 4, 5, 6, and 7 form an axis of sorts that orders concepts in terms of their specificity of data analysis methodology (i.e., are the concepts general or do they relate to a specific methodology, either quantitative or qualitative). The principal component analysis supports the diagram's characterization of Instructor I1's conceptual ecology—Instructor I1 did not divide the concepts into *qualitative* and *quantitative* domains (i.e., there was no evidence of *qualitative-quantitative* bifurcation).

Instructor I2

Instructor I2 was also self-described as a very experienced researcher with an extensive background in qualitative and quantitative educational research. Instructor I2 provided research methods instruction to graduate students—during the period of this study, Instructor I2 instructed doctoral candidates in dissertation research. Instructor I2 described research as the "gathering of information which provides help for decision making." Although Instructor I2's background in research stems from decades in academic settings, Instructor I2 insisted that research was not limited to the college or laboratory. According to Instructor I2, research has broad application and consists of many levels—academic research is one of those levels. While Instructor I2 described research as providing answers to scientific questions, Instructor I2 equated the term "science" to a "need to know" not to formality.

In academic settings, according to Instructor I2, the final result of research is the research article or publication. Instructor I2 was careful to differentiate between types of academic publications commonly viewed as research and what Instructor I2 viewed as true research. The key distinguishing mark of true research, in a publication, is the presence of data—research collects and reports data. This distinguishes research from publications that are actually more journalistic in nature (e.g., policy building or developing prescriptions). The purpose of the research publication is to enable other researchers to draw upon and extend the work.

Instructor I2 described the stages of research as progressing from synthetic to analytical. In the beginning of the process, researchers perform activities to "learn everything there is to know" about the topic. This process may involve several iterations of literature reviews, interviews, and knowledge sharing. Eventually the researcher shifts to an analytic effort to identify gaps and voids in the knowledge base. This analysis, also an iterative process, allows the researcher to develop insight and eventually identify a research problem.

Key to Instructor I2's concept of research is the researcher. Instructor I2 emphasized the qualities of the researcher, pointing out that the researchers require patience, balance, fairness, and analytical skills. Researchers, according to Instructor I2 must carefully define problems, attend to multiple data sources, and seek data driven conclusions. Regardless of the level at which research is performed, it is still an empirical, theory-driven process—not serendipitous. This description stemmed from Instructor I2's observation that anyone performing research would want to maximize the probability of pay off in any research effort.

Everyone, according to Instructor I2, engages in research at sometime. The purpose of research methods instruction is to develop sophistication in a researcher's skills. This sophistication involves what Instructor I2 described as the "critique-and-build dialectic." Researchers must understand the threats to internal validity while realizing that they can only minimize these threats, never eliminate them. Instructor I2 noted that researchers must realize that all research is flawed, but that all research has something to offer.

Among sophisticated researchers, Instructor I2 noted that there were generally two types. Some researchers specialize in one area, tool, design, or topic. Other researchers are generalists, with a broad base of skills and the ability to move from one perspective to another. Instructor I2 emphasized that breadth does not equate to a lack of depth. Rather it implies flexibility grounded in an extensive knowledge of the literature.

Instructor I2 used approximately 2.5 hours to complete the diagramming task. Instructor I2 began by arranging the concept labels into clusters. Instructor I2 began adding concept labels almost immediately, trying to balance concepts judged to be quantitative with others judged to be qualitative.

Instructor I2 encountered some difficulty placing certain concepts within the diagram—in much the same way as Instructor I1 encountered difficulty. Instructor I2, for example, had no difficulty with concepts such as *validity* but was perplexed by concepts such as *accuracy*. Even though I reminded Instructor I2 that it was permissible to exclude concepts, Instructor I2 persevered and eventually worked *accuracy* into the diagram. Compared to the test-retest pilot, and to the subsequent participants, the instructors encountered great difficulty with concepts that were ill defined with regards to the discipline of research. These concepts (e.g., *accuracy*), derived from other disciplines or general language, did not lend themselves to an understanding that the discipline of educational research shared. Participants who described themselves as novices had little difficulty with these concepts, selecting and placing them into the diagram based on "shallower" uses of the word instead of the "deeper" meaning of the concept (Chi, Feltovich & Glaser, 1981).

Employing the concept list, Instructor I2 developed a list of forty-seven concepts for diagramming (Table 4-7). Those concepts shown in italics were

Table 4- 7. The set of concept labels developed by I2.

Accuracy	Experiments	Results	*Naturalistic inquiry*
Alternative hypothesis	External validity	Samples	*Coding*
Methodology	Null hypothesis	Survey	*Single subject*
Causation	Generalizability	Statistics	*Field notes*
Observations	Prediction	Validity	*Causal-comparative*
Conclusions	Hypothesis	Variables	*Research problem*
Correlation	Interview	Variability	*Trustworthiness*
Data	Instrumentation		*Understanding*
Internal validity	Qualitative	*Legal issues*	*Quantitative data*
Empirical	Quantitative	*Qualitative data*	*Quasi-experimental*
Ethics	Reliability	*Inductive theory*	*Deductive theory*
Literature review	Theory	*Guiding questions*	*Ethnography*

added to the list by I2. The only concept not selected by Instructor I2 was *questions*.

As did Instructor I1, Instructor I2 expressed uncertainty that the concept labels were placed correctly on the background. An analysis of Instructor I2's diagram reinforces the emphasis Instructor I2 placed on the concept *data*. That Instructor I2 believes research is a "data driven process" is obvious from the manner in which Instructor I2 elaborated on the concept *data*. Of 47 concept labels, Instructor I2 used approximately one-third to describe data. Instructor I2 also elaborated upon the concept *methodology*. Again, Instructor I2 used approximately one-third of the concept labels to describe *methodology*. Whereas

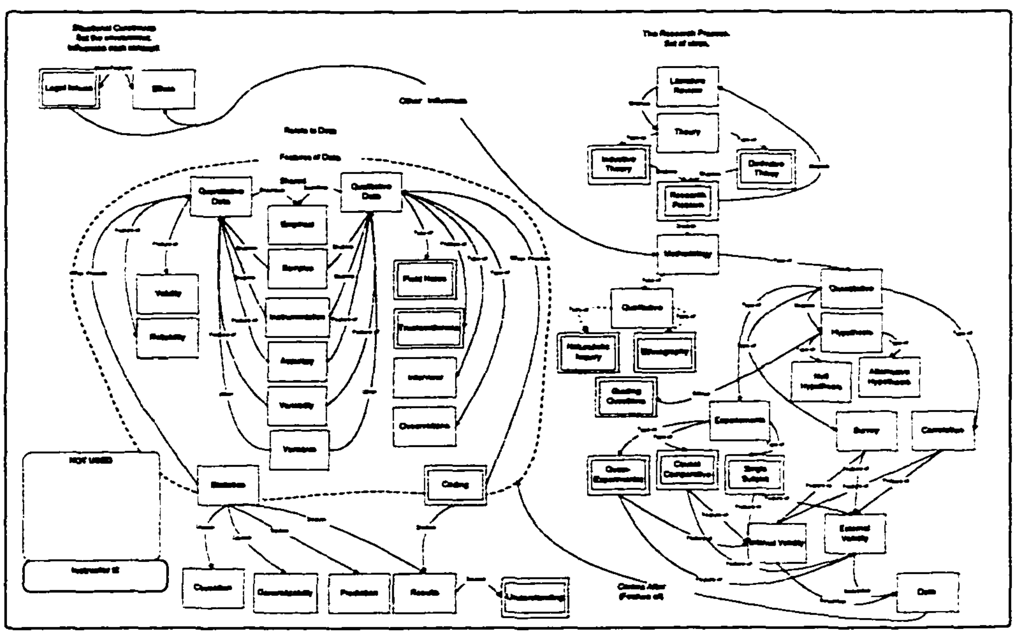


Figure 4-7. Instructor I2's diagram.

Instructor I1 described *ethics* as an umbrella, Instructor I2 described it as an influence upon *methodology*.

Instructor I2's diagram begins with the process of data collection and refinement that eventually creates a *methodology*. This is consistent with Instructor I2's description of the research process as synthetic in the beginning and analytic towards the end. The only recursion found in Instructor I2's diagram occurs here. Otherwise, Instructor I2's diagram is very linear and hierarchical.

Table 4- 8. Instructor I2's triads and resulting constructs.

Concept Triads			**Resulting Constructs**
Observation	Experiments	External validity	1. Generalizable-Non Generalizable
Validity	Instrumentation	Theory	2. Abstract-Concrete
Quantitative	Conclusions	Survey	3. Methods-Non Methods
Prediction	Interview	Reliability	4. Quantitative-Non quantitative
Qualitative	Variability	Hypothesis	5. Broadening-Narrowing
Alternative hypothesis	Questions	Literature review	6. Divergent-Convergent
Variables	Results	Correlation	7. Output-Input
Statistics	Ethics	Data	8. Means-End
Samples	Internal validity	Causation	9. Experimental Designs-Not Experimental Designs
Accuracy	Generalizability	Null hypothesis	10. Practitioner Concerns-Non Practitioner Concerns
Empirical	Methodology	Correlation	11. Design Issue-Data Issue

Instructor I2's diagram is also very symmetrical. Instructor I2 attempted to maintain a spatial balance throughout the diagramming task.

The *qualitative-quantitative* bifurcation found in P1 and P2 is subtly evident in Instructor I2's diagram. In the *methodology* cluster Instructor I2 developed two parallel hierarchies, one qualitative the other quantitative. This was very deliberate on the part of Instructor I2, who added concept labels to balance the hierarchy. The two hierarchies merge into the common features of *external validity* and *internal validity*. This merging continues into the concept *data* where concepts are somewhat divided between *qualitative data* and *quantitative data*. *Qualitative-quantitative* bifurcation is more pronounced in the *data* cluster than in Instructor I1's diagram, but the concepts overlap considerably, suggesting more of a continuum than a division. As with Instructor I1, Instructor I2's *qualitative-quantitative* bifurcation serves an integrating role as it supports and orders two core conceptual units—*methodology* and *data*.

Instructor I2's diagram concludes with *understanding*, a concept Instructor I2 added to the list. *Understanding*, in Instructor I2's view, applies to research in a personal and community sense. For Instructor I2, the goal of research is to develop and share understanding.

Instructor I2 also completed a repertory grid matrix, using the concepts from the diagram. The triads and resulting constructs developed for Instructor I2's repertory grid matrix are listed in Table 4-8 (previous page).

Instructor I2 stated that the repertory grid matrix was very difficult to complete, just as Instructor I1 reported. Instructor I2 also provided the same reason for this difficulty as did I1—uncertainty that the answers were correct. The principal component analysis of Instructor I2's repertory grid matrix suggests three primary components among the concepts provided by I2. The first component combines constructs 8 (Means-End) and 3 (Methods-Nonmethods) in terms of data manipulation, or Instructor I2's the "critique-and-build dialectic." This component arranges the concepts along a synthetic-analytic continuum. Key to this component is the juxtaposition of *theory* and *data*. In the diagram, Instructor I2 depicted the synthetic role of *theory* in the formative stages of

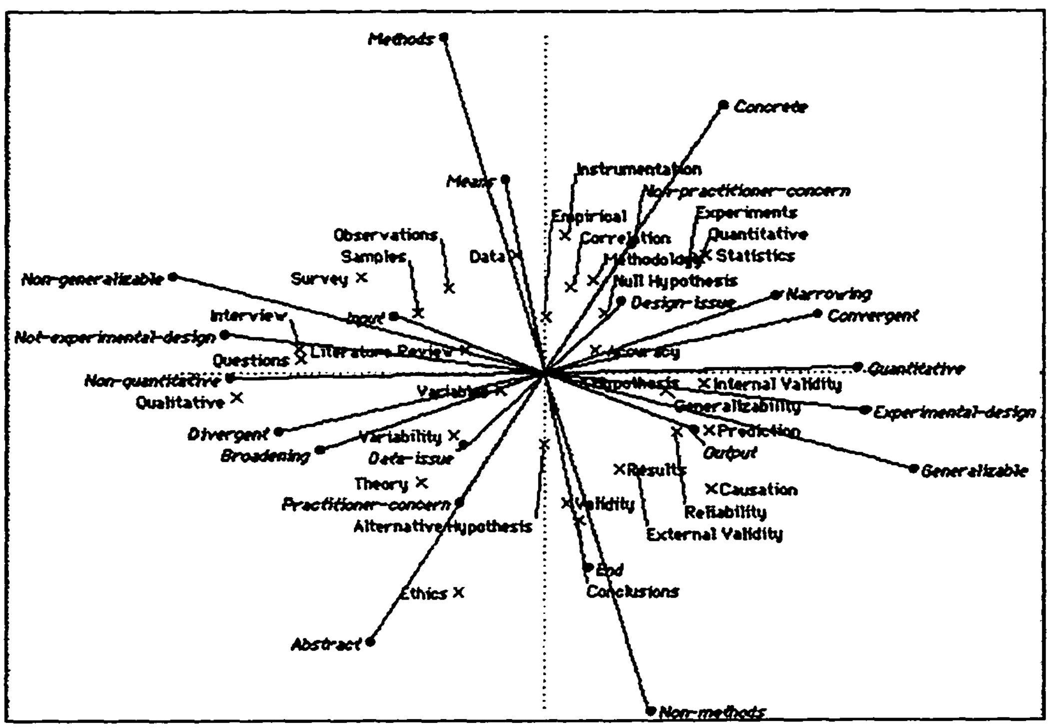


Figure 4-8. Instructor I2's principal component analysis diagram.

research. Instructor I2 also depicted *data* as an analytic outcome of the research process. At the same time, this component does not distinguish between *quantitative* and *qualitative*. In Instructor I2's the "critique-and-build dialectic," the concepts *quantitative* and *qualitative* are virtually neutral, since a researcher would be gathering information from all sources.

Constructs 1, 4, 5, 6, 7 and 9 are very similar in terms of data reduction. In this component, the concept *data* is evaluated neutrally. Further analysis suggests that this component arranges concepts in terms of their reductive effect on the research process. It is interesting to note the effects of *qualitative-quantitative* bifurcation within this component. Instructor I2 labeled construct 4 as Quantitative—Non-quantitative, and then evaluated *quantitative* and *qualitative* at opposite ends of the construct, implying a key difference between them in terms of data reduction. In this sense, Instructor I2 demonstrates slightly more *quantitative-qualitative* bifurcation than Instructor I1, as the diagram suggests. Constructs 2, 10, and 11 form a component that mediates the effects of the other components.

Summary of Instructor Sessions

Instructor interviews yielded diagrams with rich structure. When compared with Participants P1 and P2, Instructors I1 and I2 developed diagrams that exhibited an understanding of educational research that was shared by a larger academic community. Their diagrams also demonstrated elaborate structures that integrated the concept set into clusters or core concepts. While the linking was prompted (i.e., I asked both instructors to draw links between their concept labels) clustering was not. Yet, Instructor I1 and Instructor I2 both used this form of elaboration to depict their conceptual structures without prompting.

As with Participants P1 and P2, Instructor diagrams also evidenced *qualitative-quantitative* bifurcation. The *qualitative-quantitative* bifurcation of Participants P1 and P2 was dissociative in that it served to divide the domain of research. The *qualitative-quantitative* bifurcation of Instructor I1 and I2 tended to play an integrative role in that it served to support core concepts. In both instances the *qualitative-quantitative* bifurcation allows the participant to bring what they perceive to be relevant knowledge to bear (Medin, 1989). However, in the case of Participants P1 and P2 the knowledge brought to bear suggests a somewhat unique understanding of the concepts. The knowledge brought to bear by Instructors I1 and I2 suggests an understanding of the concepts (i.e., *qualitative* and *quantitative*) that is shared with the larger community of educational researchers.

It is also interesting to note that Instructors I1 and I2 took far longer than Participants P1 and P2 (subsequent sessions with other participants revealed that the instructors took far longer than anyone else). In addition to taking far more time, the instructors expressed less confidence in the results of their diagrams than anyone else. Even though Instructors I1 and I2 demonstrated an understanding of the concepts employed in the diagram, they expressed less certainty that they had depicted “absolute truth.” The issue of shared and unique understandings (of specific concepts) suggests that perhaps Instructors I1 and I2 (both highly experienced) employed a “deeper” understanding while Participants P1 and P2 (both novices) employed a “shallower” understanding (Chi, Feltovich & Glaser, 1981).

Generally, the data that was gathered through repertory grid matrices substantiated the data that was gathered through interviews and diagramming. This information served to form the basis for comparing students’ understanding of the concepts.

Instructor interviews also yielded unique concept sets. Instructor I1’s concept set was then employed during interviews with masters students, while Instructor I2’s concept set was employed with doctoral students. The concept sets were employed in two ways. First, the concept sets served as the basis for developing concept labels for the diagramming task. Secondly, the concept sets were organized into concept triads for use in the repertory grid matrices to be used by the student participants. Each triad consisted of three concepts. The researcher, to facilitate comparisons, purposively derived these triads.

Masters Student Sessions

The two masters-level participants (Participants A and B) performed the same tasks as the instructors. Each participant selected the time and place of the interview. The first interview covered the purpose of the exercise and the rules. Each participant answered questions and then proceeded to complete the diagramming exercise. Masters students used the concept labels listed in Table 11 (below).

At the conclusion of the diagramming exercise, each participant was given a repertory grid matrix to complete and a self-addressed, stamped envelope with which to mail it back.

Participant A

Table 4- 9. Concept labels provided to masters-level participants.

Alternative explanation	Empirical	Internal validity	Reliability
Causal assertions	Ethics	Interpretation	Report
Causal comparative	Ethnography	Interview	Research questions
Conclusions	Experiments	Literature	Results
Consideration of Observations	External Validity	Methodology	Samples
Content analysis	Generalizability	Null hypothesis	Survey
Correlation	Historical	Prediction	Synthesis
Critical Analysis of Results	Hypothesis	Qualitative	Theory
Data analysis	Inferential statistics	Qualitative observations	Validity
Descriptive statistics	Instrumentation	Quantitative	Variability
			Variables

During the first session, Participant A completed the diagramming exercise and a repertory grid matrix. This was followed with a mid-term interview in which Participant A described a research article that I had selected and provided. At the end of the semester, Participant A completed another diagramming session and repertory grid matrix. Throughout the semester, Participant A's diagrams and discussions suggested an understanding of educational research methods that somewhat unique becoming more shared with the instructors.

Initial session.

Participant A performed the initial interview during the second week of the masters' research methods course. Participant A was self-described as a novice at the research process. The purpose for taking the masters-level research methods class was primarily as a core requirement for future work in counseling. However, Participant A expressed a desire to gain a deeper understanding of the "qualities" of research. Participant A's background in research consisted of assisting professors with data collection and library tasks. Participant A stated that this background was inadequate in terms of planning and conceptualizing a research project—something Participant A described as critical to someone conducting research. Participant A hoped that this class would help address that need.

Participant A described a very quantitative concept of research. In Participant A's view, research is a controlled, methodical, and numerically focused. Several times in the initial interview, Participant A described the requirements for "control" in a research process. Participant A described research as a controlled process to look at "specific" things to see how they fit together. The end result of research, according to Participant A was to provide meaning to the data.

Participant A took approximately two hours to complete the diagramming exercise. Initially, Participant A laid the concept labels on the backing to view

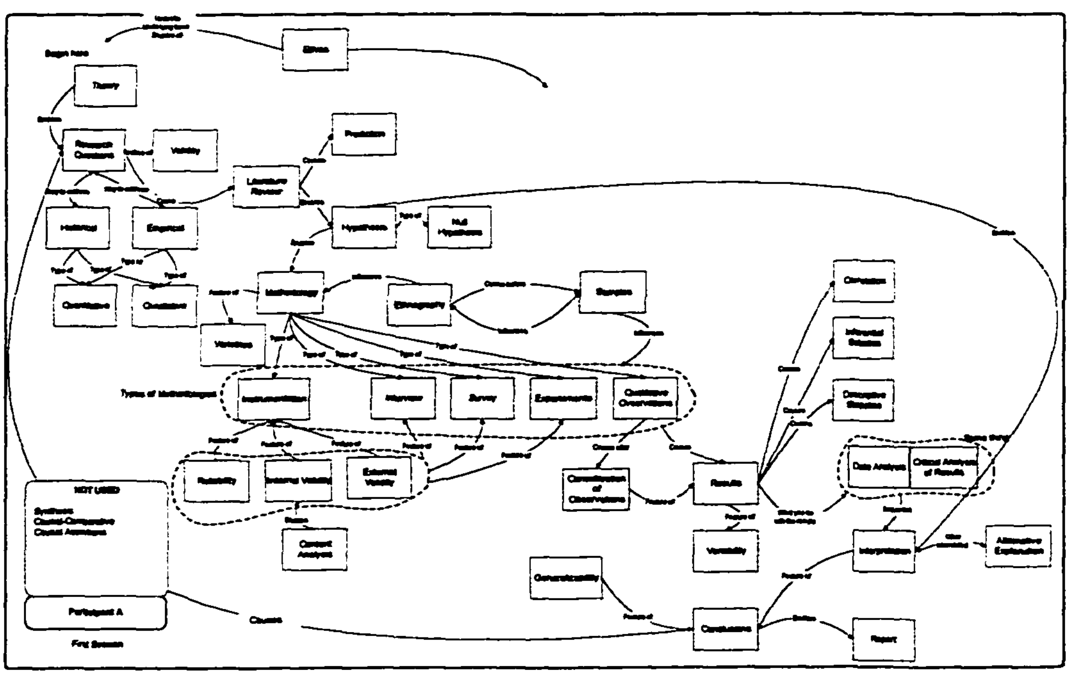


Figure 4-9. Participant A's initial diagram.

what concepts were available, before arranging them. Participant A commented that Participant A's concept would probably not be very sophisticated at this time, given an insufficient background in research methods.

Participant A did not use three of the concepts provided (i.e., *synthesis*, *causal-comparative*, and *causal assertions*) because the terms were unfamiliar. Participant A did not add any concepts to the diagram. *Ethics* is an overarching concept, according to A. While it must precede any research effort, it is somewhat removed from the details of research.

Participant A's diagram proceeds, in a very conventional manner, from *theory* to *research questions*, to *literature review*, to *hypothesis*, to *methodology*, to *results*, to *analysis*, to *interpretation*, to *conclusions*, to *report*. This core provides a simple description of the research process as described in research texts. Given Participant A's previous research experience, this is not surprising. Participant A's diagram provides structural complexity by modifying or elaborating these core concepts—and by bringing knowledge to bear on this conceptual core.

The most complex of these concepts is *methodology*. The manner in which Participant A brought knowledge to bear is noteworthy—Participant A elaborated the concept *methodology* with two tiers of concepts. Participant A described *instrumentation*, *interview*, *survey*, *experiments*, and *qualitative observations* as types of methodologies. Participant A further elaborated *instrumentation* with the concepts *reliability*, *internal validity*, and *external validity*. Referring to *instrumentation* as a type of methodology suggests an understanding of the concepts that may be rooted in Participant A's previous, but limited, experience as a research assistant.

In Participant A's diagram, Participant A used *validity* to elaborate the concept *research questions*. According to Participant A, "Research questions must have validity." However, Participant A did not link the concepts *internal validity* and *external validity* to *validity*. Instead, *internal validity* and *external validity* were used as features of *instrumentation*.

Participant A's diagram demonstrates recursion. Participant A linked *hypothesis* to *interpretation*, stating that the *hypothesis* allowed *interpretation* to occur. Participant A also linked *research questions* to *conclusions* stating that *research questions* cause *conclusions*. Again, the diagram hints at Participant A's prior experience, depicting an understanding of a research process in which ends modify beginnings and beginnings limit ends.

Participant A's diagram also suggests that Participant A worked very hard to make the simple words fit into the complex structure. Some diagrammed relationships seem to be based on the surface structure of the concept's name (i.e., use of the word in common vernacular) and not on the deeper structure of the concepts' relationship to research (Chi, Feltovich & Glaser, 1981).

In the following instance, Participant A brought seemingly relevant knowledge to bear in a way that suggests a unique understanding of the concepts involved. Participant A used *historical* and *empirical* to describe the two (exclusive) ways in which research questions could be approached, "Questions can be looked at empirically or historically." While this suggests that these concepts may be considered to be methods, Participant A did not include them in the *methodology* cluster.

Participant A provided a more unique example of such a concept with the use of *ethnography*. Participant A described *ethnography* as a factor that influenced *methodology* and *samples*. When I asked Participant A to explain this relationship, Participant A explained how researchers needed to consider *ethnography* when drawing their samples. Participant A assumed that *ethnography* was synonymous with ethnic, rather than derived from ethnic. By bringing irrelevant knowledge to bear upon the diagramming problem (i.e., the word ethnic), Participant A linked *ethnography* with *methodology* and *samples*.

Participant A's diagram demonstrates the beginnings of a *qualitative-quantitative* bifurcation. However, the concepts *qualitative* and *quantitative* are appended to *historical* and *empirical*, dissociating them from the remaining concepts. *Qualitative* and *quantitative* are concepts that Participant A expressed uncertainty about. Participant A was familiar with the terms, and understood that they represented a choice early in the research process. However, as depicted by the links, Participant A was not sure how the concepts related to the diagram as a whole.

At the conclusion of the diagramming exercise, Participant A received the repertory grid assignment. Participant A was provided with instructions on the use of the instrument and a stamped, self-addressed envelope to return the instrument. Participant A returned the completed repertory grid matrix within three weeks.

Participant A's repertory grid employed the twenty-one concepts to develop seven constructs (as shown in Table 4-10). Participant A's constructs emphasized grammatical (surface structure) distinctions between concept labels.

The principal component analysis of Participant A's first repertory grid

Table 4- 10. Participant A's first set of elicited constructs.

Concept Triads			**Resulting Constructs**	
Theory	Data Analysis	Methodology	1.	General-Specific
Prediction	Conclusion	Research Questions	2.	Beginning-End
Causal Assertions	Correlation	Validity	3.	Known-Unknown
Empirical	Quantitative	Inferential Statistics	4.	Use Numbers-Don't Use Numbers
Qualitative	Interview	Report	5.	Nouns-Not Nouns
Hypothesis	Experiment	Literature Review	6.	New Research-Research That's Already Been Done
Reliability	Generalizability	Null Hypothesis	7.	Narrow-Broad

suggests that the constructs support three components that shape the conceptual ecology. The first component consists of construct 4 (Use Numbers-Don't Use Numbers). Construct 4 provides the greatest distinction among concepts, grouping concepts into those that use numbers and those that do not. The concepts *qualitative* and *quantitative* are separated by this construct, and no other. Construct 4 suggests the beginnings of an unsophisticated *qualitative-quantitative* bifurcation. In the diagram Participant A depicted a difference between *qualitative* and *quantitative*. However, the basis for this distinction is the use of numbers, a distinction that applies to other concepts not usually considered either *qualitative* or *quantitative*. Concepts such as *theory*, *ethics*, *internal validity*, and *ethnography* (a concept Participant A experienced difficulty with during the diagramming exercise) were all placed at the Don't Use Numbers side of the construct.

Construct 1 (General-Specific) indicates an effect from Participant A's background as a research assistant. The construct name suggests basic familiarity with research methods, while the ordering of the concepts within the construct implies a simplistic concept of research methods. For example, *theory*, *ethics*, *validity*, *methodology*, *empirical*, and *variables* were all rated as General within this construct. Concepts such as *external validity*, *external validity*, *null hypothesis*, and *hypothesis* were all rated Specific. The remaining constructs (i.e., constructs 2, 3, 5, 6, and 7) seem to reflect grammatical evaluations of the concept names.

The constructs developed by Participant A did not make a distinction between several concepts. *Interview* and *internal validity* differed only slightly in that *interview* was considered slightly more of a noun and was more familiar to A. *Null hypothesis* and *research question* differed only slightly in that *research*

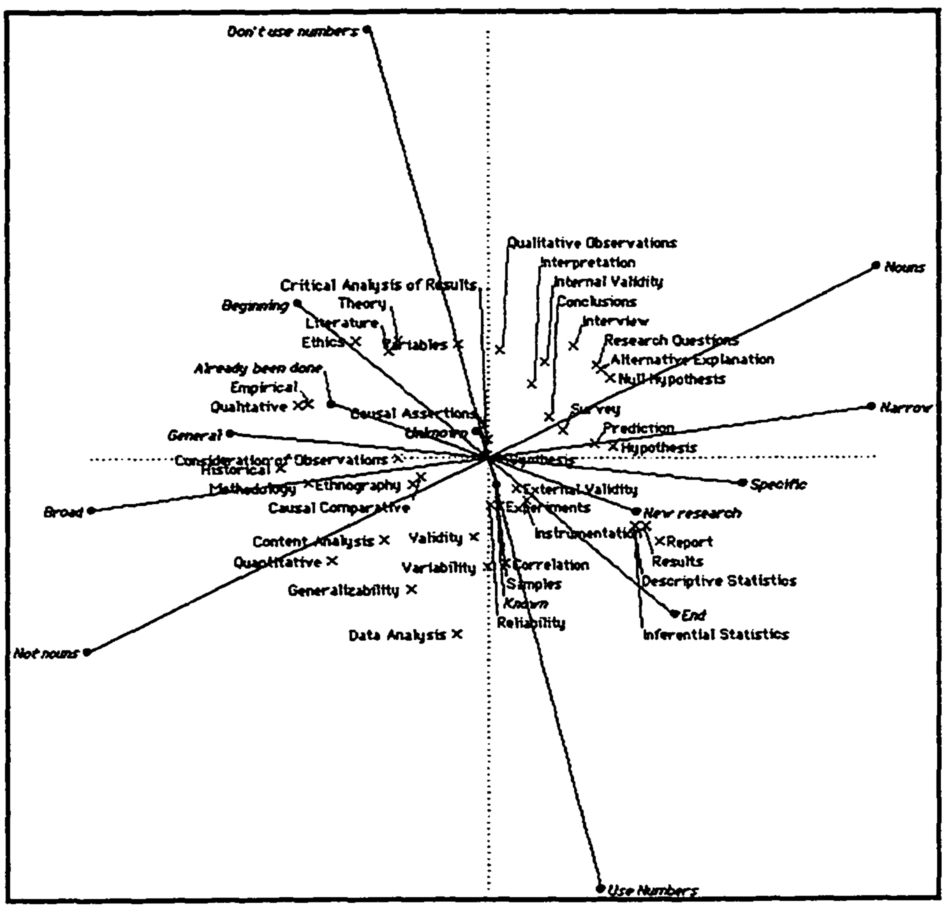


Figure 4-10. Participant A's first principal component analysis diagram.

question was evaluated as occurring more towards the beginning of the research process. *Hypothesis* and *prediction* differed only in that *hypothesis* was judged to be slightly more specific. *Results* and *report* differed only in that *report* was judged to more towards the beginning of the research process. *Instrumentation*, *samples*, and *experiments* differed only in that *instrumentation* was considered to be less of a noun. *Experiments* and *samples* were evaluated identically (i.e., within each construct the concepts received identical ratings). Likewise, *descriptive statistics* and *inferential statistics* were evaluated identically by all constructs. This suggests that the participant's constructs were incapable of differentiating between the concepts and that the participant experienced difficulty bringing relevant knowledge to bear—even superfluous knowledge given a limited understanding of these concepts.

On the other hand, the diagram demonstrates little similarity between these pairs of concepts. In fact, the only concepts Participant A evaluated as similar in the diagram were *data analysis* and *critical analysis of results*. However, on the repertory grid Participant A demonstrated no similarity between these concepts.

<u>Mid-term session.</u>

In the second phase of the project, masters-level participants (A and B) were given a research article to review, and asked to describe what made the project a good (or bad) example of research. The purpose of these interviews was to gather information on how the participants applied their conceptual knowledge to "real world" examples. The research article provided to the participants, entitled *Gender differences in predictors of college mathematics performance and in college mathematics course grades* (Bridgeman & Wendler, 1991) was extracted from the Journal of Educational Psychology, and provided to the participants for their review.

This article concerned the problems predicting student performance and subsequent grades in mathematics courses, based on predictors that are gender biased. In the article, the authors described studying the grades received by male and female college students in mathematics classes in algebra, precalculus, and calculus. As the authors noted, "Within a given college mathematics course, the average grades of women were about equal to or slightly higher than the men's average grades." (Bridgeman & Wendler, p. 275). When comparing their Scholastic Aptitude Test (SAT) scores, the men's average scores were approximately one-third of a standard deviation higher than the women's. However, when comparing men's and women's high school grade point averages (GPAs), the authors found that women's scores were much higher. Using regression analysis, the authors demonstrate the inaccuracies of single-predictor models, developing a case for models relying on multiple predictors.

Each participant received the article in advance of the interview. Participant A was interviewed three weeks after receiving the article. The interview was held at a time and location of the participant's choosing.

When asked to describe the research article, Participant A classified it as "causal comparative." *Causal comparative* was one of the concepts that Participant A chose not to use in the diagramming exercise, due to unfamiliarity. When asked to clarify this, Participant A stated that was what came to mind. It is interesting to note that *methodology* received the greatest elaboration in Participant A's diagram, although the concepts linked to *methodology* indicated that Participant A possessed a unique understanding of methodological issues related to research.

During the interview, Participant A focused on methodological issues and never discussed the authors' statistical reasoning. Participant A commented that the feature that made this article a good example of research was the broad sample. Although concerned whether the sample was truly representative of a larger, multi-ethnic population, Participant A did not use *ethnography* to describe ethnic bias in sample selection, as in the initial interview.

Participant A faulted the methodology for relying on student self-reports and for not describing the types of universities sampled. However, Participant A did not mention the use of regression analysis as a technique for analyzing the data. Self-described as a "numbers person," Participant A never commented on the use of numbers within the article. Only when asked, did Participant A comment that the charts were somewhat helpful. Participant A's acceptance of the numerical data and the construct noted in the repertory grid (i.e., uses numbers-doesn't use numbers) may suggest that Participant A considered the presence of numerical data to be sufficient support for the article's conclusions.

Participant A reported that the greatest difficulty encountered in reading the article was the writing style and the language. However, Participant A was able to develop a pragmatic synopsis that sheds some light on Participant A's unique understanding of research concepts. Participant A's synopsis consisted of the following statement, "Women, keep doing your math." The expressed intent of the article's authors was to point out the need for better testing models, not to suggest that math skills among women and men were different. However, Participant A interpreted the article from a knowledge base that suggested differences in the math skills of women and men. This suggests that although Participant A had developed a deeper understanding of educational research methods, Participant A still experienced difficulty bringing relevant knowledge to bear when given a research article to review.

Final session.

As the final phase in the project, Participant A completed a second diagramming exercise and a second repertory grid. This second exercise took place at the end of the semester, following final examinations.

When asked to describe research, Participant A stated that research was a means of studying and learning. Participant A described research as requiring data gathering, selecting problems, selecting methods, analyzing and interpreting data, and writing. Other key features of research, according to Participant A, were method, procedures, literature reviews, results, and qualitative or quantitative focus (which Participant A described as using numbers or not using numbers).

Participant A proceeded to conduct the second diagramming exercise in a manner similar to the first. Participant A took approximately one hour to complete the diagramming exercise. Participant A placed all concept labels on the backing and then began organizing them. Once Participant A was satisfied with the placement of the concept labels, Participant A drew the connecting links between them.

Participant A did not use the concept labels *causal assertion, critical analysis of results, synthesis,* and *ethnography.* This use of *ethnography* is an interesting development, if only because Participant A now recognized *ethnography* as a concept that was not fully understood. *Synthesis* and *causal assertion* were both avoided on the first diagram because Participant A was unsure what they meant.

Participant A's second diagram begins with *theory* and proceeds to *research questions*, *methodology*, *hypothesis*, *experiments*, and then *results*. This core resembles the sequence of the first, but the content has been reduced. The core concepts are elaborated upon, but elaboration is spread more evenly throughout the diagram. Also, Participant A elaborated less upon *methodology* and more on *experiments*. In this diagram, Participant A described *causal-comparative*, *correlation*, *content analysis*, and *historical* as types of methodologies.

Experiments received two tiers of elaboration, making it the most complex group within the diagram. Participant A described *experiments* as having parts (*variables*, *samples*, and *instrumentation*) and further elaborated one of the parts (*instrumentation*).

Validity was still considered a feature of *research questions* and the concepts of *internal validity*, *external validity*, and *reliability* were still not linked with the overall concept of *validity*, but were still linked to *instrumentation*. Also, *quantitative-qualitative* bifurcation is now more deeply embedded in the diagram,

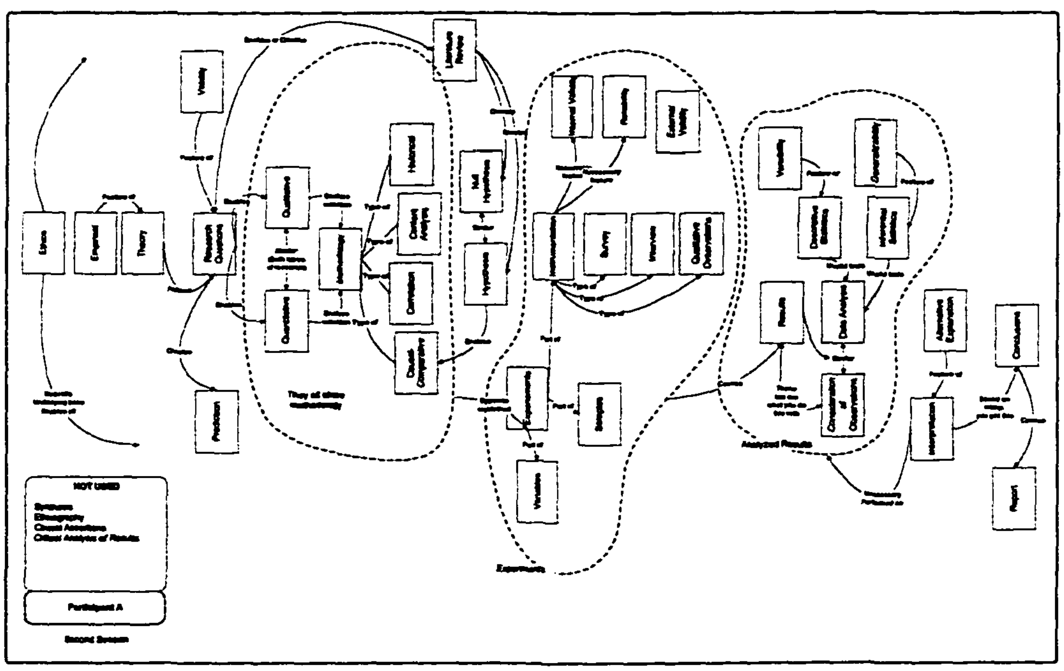


Figure 4-11. Participant A's second diagram.

depicted as the two ways in which *methodology* can answer the *research question*. *Quantitative-qualitative* bifurcation still exerts no appreciable influence on the rest of the diagram.

Participant A's second diagram depicted no recursion. However, Participant A did include the use of dashed lines to better describe the significance of the clusters of concept labels. Participant A was not satisfied with the explanations provided by the links—Participant A needed to explain the meaning of the clusters, themselves. Participant A's explanation of the meaning of the clusters shed further light on the role of the core concepts.

The clusters depicted by dashed lines form the scaffold for organizing the conceptual ecology. Beginning with a basis in *theory*, the researcher develops a *research question* and a *hypothesis*. The researcher then selects a *methodology* to evaluate the *research question* and the *hypothesis*. That evaluation usually takes the form of an *experiment*, which produced *results* that must be analyzed. At each step of that process, Participant A linked information to the core, defining choices and describing requirements.

As with the first interview, Participant A completed a repertory grid. Participant A developed seven constructs, based upon the same concept triads as the first exercise. Participant A provided much more descriptive construct titles in the second repertory grid, than in the first. One construct title, however, remained the same—Participant A still based construct 4 on the use of numbers.

The principal component analysis of Participant A's second repertory grid suggests that the seven constructs combine to form three components. The analysis noted that construct 4 (Use Numbers-Doesn't Have To Use Numbers) was still dominant—and still the only construct that differentiated between the concepts *qualitative* and *quantitative*. Participant A evaluated concepts such as *correlation*, *internal validity*, and *report* as concepts that use numbers. Examples of concepts that did not require numbers were *variables*, *hypothesis*, and *methodology*.

Table 4-11. Participant A's second set of elicited constructs.

Concept Triads			**Resulting Constructs**	
Theory	Data Analysis	Methodology	1.	More Directly Associated With Research—Preexisting to Research Project, Can Exist Without Reference to Research
Prediction	Conclusion	Research questions	2.	What You Say About Your Research Question—The Thing You Are Studying, Predicting, & Conclusion Are Said About This
Causal assertions	Correlation	Validity	3.	Independent Statements/Concepts—Relationship Relational
Quantitative	Empirical	Inferential statistics	4.	Use Numbers—Doesn't Have To Use Numbers
Qualitative	Interview	Report	5.	Specific—General
Hypothesis	Experiment	Literature review	6.	Process—Statement
Generalizability	Reliability	Null hypothesis	7.	"Ability" Something You Can Do (Positive) —Negative, No Relationship

Constructs 5 and 1 combine to suggest a component that ordered concepts in terms of their specific application to the research process. Concepts such as *hypothesis*, *literature review*, and *research questions* were viewed as specific to the research process within this component. Concepts such as *theory*, *empirical*, *methodology*, and *experiments* were viewed in this component as broadly related to the research process. Other concepts, such as *internal validity* and *external*

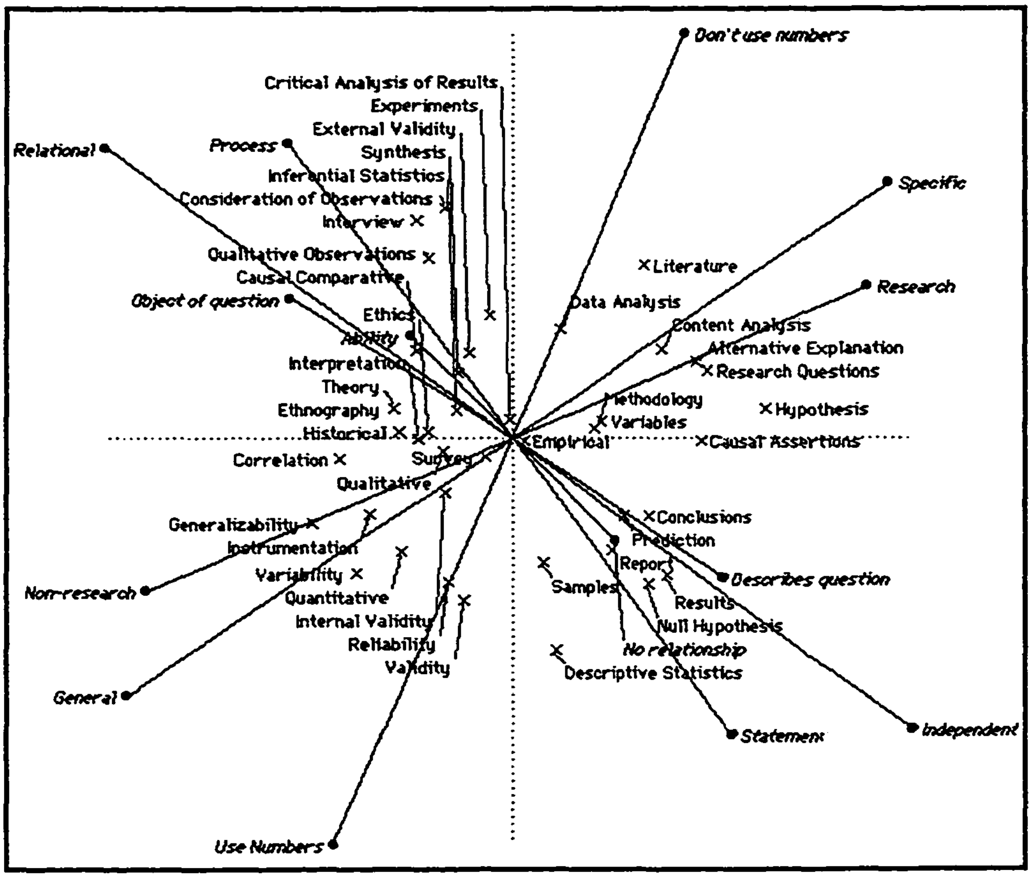


Figure 4-12. Participant A's second principal component analysis diagram.

validity were viewed as general terms that were not specific to the research process.

Constructs 2, 3, 6, and 7 combined to form a component that ordered concepts in terms of process versus product. Within this group of constructs, concepts such as *synthesis*, *correlation*, and *experiments* appear to assume a more process-oriented nature while concepts such as *hypothesis*, *prediction*, and *report* take on a more product-oriented nature.

The constructs elicited by the second repertory grid allowed Participant A to discriminate more effectively between concepts. Participant A evaluated one pair, *ethnography* and *theory*, identically within each construct. Participant A evaluated two other pairs of concepts (*interview* and *consideration of observations*; *report* and *prediction*) similarly. *Interview* and *consideration of observations* differed only slightly in construct 1; *consideration of observations* was judged to be slightly less specific to the research process. *Report* and *prediction* differed only slightly in terms of construct 4. Participant A determined that *report* required the use of numbers (somewhat) but was unsure as to whether *prediction* required the use of numbers—a very pragmatic observation on Participant A's part.

Participant A also developed a core of concepts that were more integrated than the previous diagram. In developing these integrated structures, Participant A brought more seemingly relevant knowledge to bear. However, while the structure became more elaborate and integrated, the diagram still suggests that Participant A possess some very unique understandings of research methods, especially with regards to *experiments*. Additionally, while *qualitative* and *quantitative* are included in the *methodology* cluster, they are still dissociated from the other concepts. The *qualitative-quantitative* bifurcation affects only the concepts *qualitative* and *quantitative*. Combined with the increased discrimination in the repertory grid, the clustering in the diagram (i.e., the dashed lines), suggests that Participant A employed the concept labels with a better (but not complete) understanding of the concept's deep structure. Combined with the information from the first diagram and the information from the mid-term interview, Participant A appeared to be developing more shared understandings and more elaborate conceptual structures.

Participant B

During the first session, Participant B completed the diagramming exercise and a repertory grid matrix. This was followed with a mid-term interview in which Participant B described a research article that I had selected and provided. At the end of the semester, Participant B completed another diagramming session and repertory grid matrix. Throughout the semester, Participant B's diagrams reflected a chaotic structure and suggested an understanding of educational research methods that somewhat unique (due to unfamiliarity with the concepts).

Initial session

Participant B also performed the initial interview during the second week of the masters' research methods course. Participant B was self-described as an absolute novice at the research process, having conducted no research prior to the masters level research course. The purpose for taking the masters-level research methods class was, as with Participant A, a course requirement for a degree in counseling. Participant B also expressed a desire to learn the fundamental parts of research and be better equipped to do conduct research individually.

Participant B described research as a way of evaluating concepts and ideas to define or develop them further. Participant B used words like validity, articles, protocol, experiment, data, and subject to describe research. One word that Participant B used to describe research stood out; the word was relativity. Participant B used the words "relativity" and "validity" together, probably confusing relativity with reliability. According to Participant B, research requires instruments, tools, examiners, subjects, surveys, and studies.

Participant B took less than an hour to complete the diagramming exercise. Unlike Participant A (and the rest of the participants), Participant B laid very few concept labels on the backing before arranging them. As Participant B progressed, Participant B would rearrange the concept labels, if necessary. Participant B chose not to use the concepts *null hypothesis*, *causal comparative*, *ethnography*, *variability*, *synthesis*, *causal assertions*, and *critical analysis of*

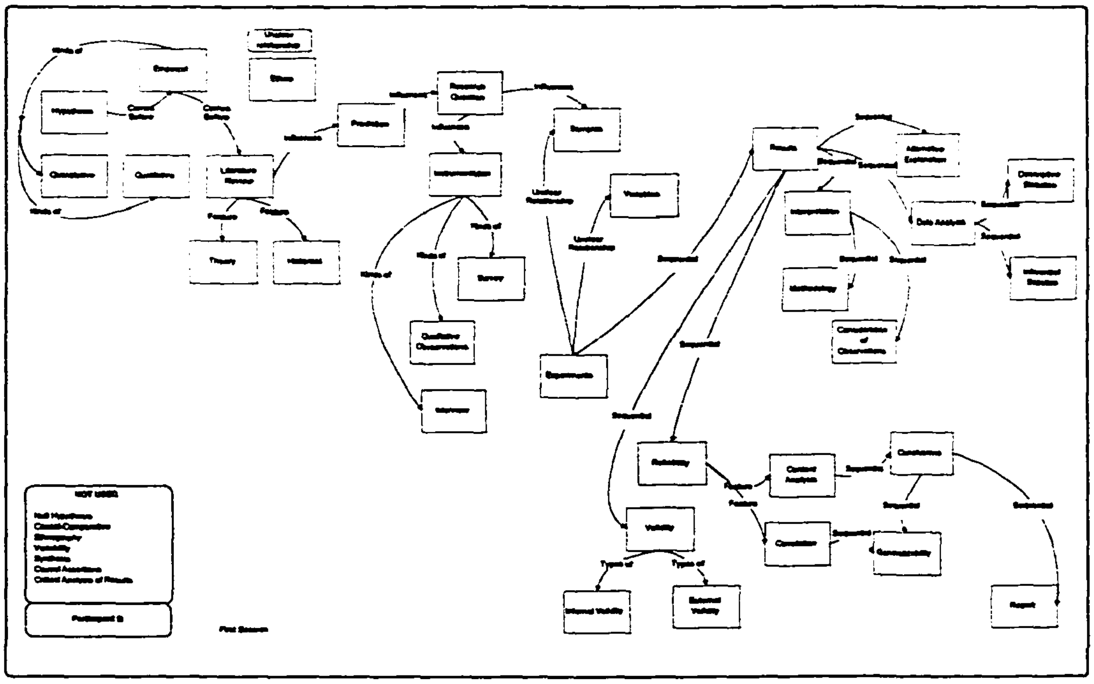


Figure 4-13. Participant B's initial diagram.

results. The reason for not using these concepts was that Participant B did not know what they meant.

Participant B did not add any concepts to the diagram. Participant B was uncertain how *ethics* related to any of the other concepts. Participant B explained the process as beginning with *hypothesis*. This leads to a decision concerning the type of study. Participant B described this decision as *empirical*, that is what kind of study one wants to perform. Participant B stated that the study could be *qualitative* or *quantitative*, but the researcher needed to choose. Next the researcher conducts a *literature review* which influences the *prediction* and the subsequent *research question*. *Research question* then influences the choice of *instrumentation* and the *samples*.

At this point, the diagram and the relationships become very muddled. Although implying that *experiments* was sequentially related to *samples,* Participant B preferred to label the relationship as unclear. The remaining relationships consist primarily of parallel sequential realitionships. Participant B recognized that *results* came after *experiments*. Then, following several other concepts came *report*, the final concept in the process. A few interesting points arise from this jumble of sequential relationships, however.

According to Participant B, *methodology* follows *interpretation*. *Methodology* refers to the type of *interpretation* the researcher selects. The more conventional use of *methodology* is subsumed by *instrumentation* where the researcher determines how to pursue the project. Participant B's diagram indicated that *reliability* and *validity* both occur after the results are produced. Participant B described *reliability* as having the traits of *content analysis* and *correlation*. Participant B depicted two types of *validity*, *internal validity* and *external validity*. Participant B's diagram suggests that after *results* many things happen. However, Participant B's use of the concepts also suggests that Participant B was more familiar with the words than the concepts themselves.

In a repertory grid, Participant B used the twenty-one concepts to develop the constructs listed in Table 4-12 (below). Interpretation of Participant B's repertory grid becomes problematic in that Participant B chose to describe the constructs using terminology from the triads. However, Participant B did evaluate each of the concept labels in terms of the elicited constructs. Analysis of these constructs yielded information that substantiated the diagram's depiction of Participant B's conceptual ecology.

The principal component analysis of Participant B's repertory grid revealed three components that order the conceptual ecology. The first component consists of construct 4. Seems to divide the ecology along the lines of technical terminology and common use terminology.

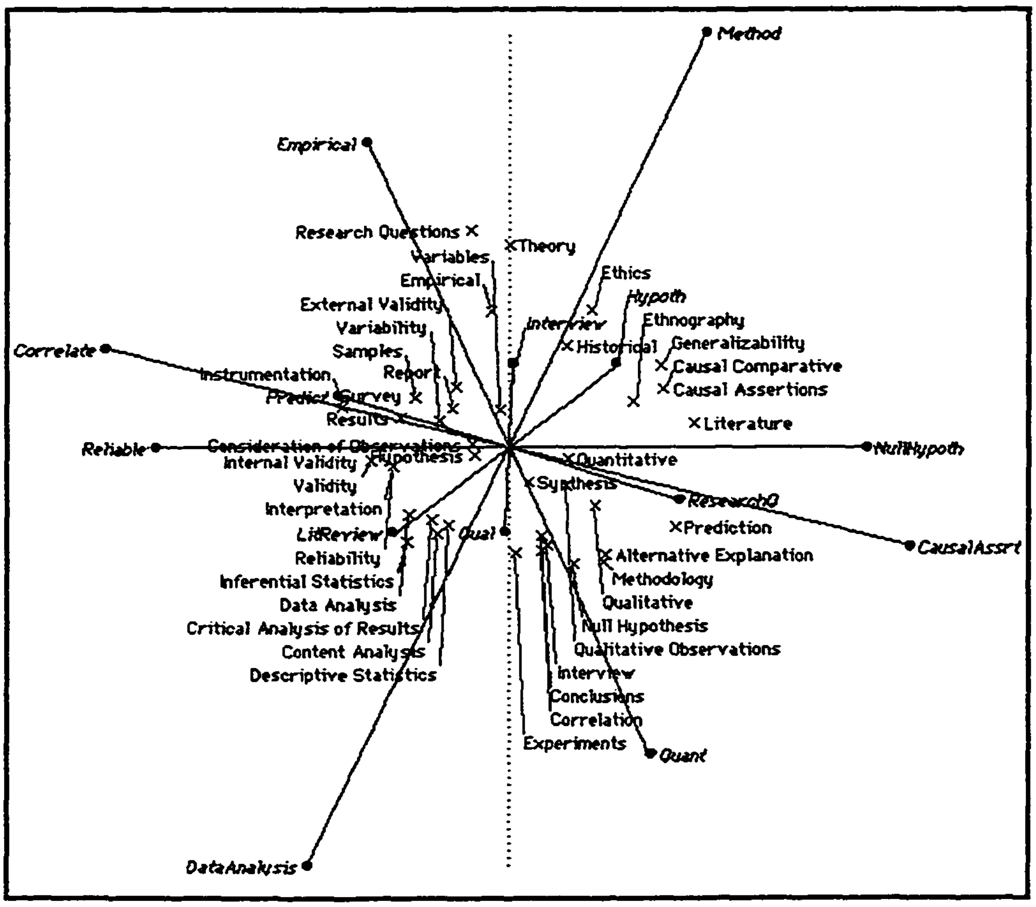
Constructs 7, 3, and 2 order the ecology somewhat in terms of grammatical familiarity and methodological unfamiliarity. Five of the seven concept labels that Participant B chose not use, because of unfamiliarity, were given similar

Table 4- 12. Participant B's triads and resulting elicited constructs.

Concept Triads			**Resulting Constructs**
Theory	Data Analysis	Methodology	1. Data Analysis-Methodology
Prediction	Conclusion	Research questions	2. Prediction-Research Questions
Causal assertions	Correlation	Validity	3. Causal Assertions-Correlation
Empirical	Quantitative	Inferential statistics	4. Empirical-Qualitative
Qualitative	Interview	Report	5. Qualitative-Interview
Hypothesis	Experiment	Literature review	6. Hypothesis-Literature Review
Reliability	Generalizability	Null hypothesis	7. Reliability-Null Hypothesis

evaluations within this component (i.e., *ethnography*, *causal comparative*, *causal assertions*, *synthesis*, and *null hypothesis*).

Other concept labels, which Participant B depicted with grammatical familiarity (e.g., the hierarchy of *validity*, *internal validity*, and *external validity*) were given opposite evaluations within this construct. Constructs 1, 5, and 6, although they evaluate concept labels similarly, do not appear to order the ecology in any describable fashion.



<u>Figure 4-14</u>. Participant B's first principal component analysis diagram.

Just as with Participant A, Participant B's constructs do not support differentiation between all concepts. Six pairs of concepts received identical or highly similar evaluations within all constructs, suggesting that none of the constructs differentiate between the concept pairs.

Four pairs of concept labels, *causal assertions* and *causal comparative*, *survey* and *samples*, *reliability* and *interpretation*, and *internal validity* and *validity* were evaluated identically within each pair (e.g., *internal validity* and *validity* were evaluated identically within each construct). *Null hypothesis* and *methodology* differed only in that *methodology* was judged to be slightly different within construct 7. *Content analysis*, *descriptive statistics*, and *critical analysis of results* differed only slightly within construct 2 (*content analysis* and *descriptive statistics*) and only slightly within construct 6 (*descriptive statistics* and *critical analysis of results*).

It is interesting to note that, unlike Participant A, Participant B's diagram demonstrates some congruence with these concept labels. Participant B did not evaluate *causal assertions*, *causal comparative*, and *critical analysis of results* because Participant B was unfamiliar with the terms. On Participant B's repertory grid Participant B evaluated these concepts similarly. Participant B's diagram suggests that Participant B experienced difficulty bringing relevant knowledge to bear during the diagramming task, hence the structure is not very elaborate. When Participant B did bring seemingly relevant knowledge to bear, the result suggested unique understandings of many of the concepts. The use of *qualitative* and *quantitative* underscores this unique understanding. Participant B labels *qualitative* and *quantitative* as types of *empirical*. Just as with Participant A, the *qualitative-quantitative* bifurcation is dissociated from the other concepts in the diagram, not integrated. Unlike other participants (including the instructors) there is no evidence of a core concept. Unfamiliarity and an almost arbitrary structure characterize Participant B's initial diagram. The repertory grid supports this characterization.

<u>Mid-term session.</u>

Participant B also completed a mid-term interview Participant B received a research article to review. After reviewing the article, Participant B was asked to describe what made the project a good (or bad) example of research. Again, the purpose of this interview was to gather information on how Participant B applied conceptual knowledge to "real world" examples. Participant B was provided the same article as Participant A. The article, entitled *Gender differences in predictors of college mathematics performance and in college mathematics course grades* (Bridgeman & Wendler, 1991) was extracted from the <u>Journal of Educational Psychology</u>.

To briefly review, this article concerned the problems predicting student performance and subsequent grades in mathematics courses, based on predictors that are gender biased. The authors studied the grades received by male and female college students in mathematics classes in algebra, precalculus, and calculus. They noted that while the average college math grades of women were about equal to or slightly higher than the men's average grades, men's Scholastic Aptitude Test (SAT) scores were approximately one-third of a standard deviation higher than the women's (Bridgeman & Wendler, p. 275). However, the women's high school grade point averages (GPAs) were much higher than the men's. The authors demonstrated the inaccuracies of single-predictor models and developed a case for models relying on multiple predictors. Participant B received the article in advance of the interview. However, I interviewed Participant B approximately sixty days after receiving the article, due to Participant B's health problems. Again, interview was held at a time and place of the participant's choosing.

Participant B described the article as, "Quantitative" and classified it as a good example of research. Participant B also stated that the feature most important in making this article a good example of research was the large sample size. Unlike Participant A, Participant B commented on the numerical data, noting that the men's SAT scores were one-third of a standard deviation higher than the women's. However, Participant B was unable to describe how the authors arrived at their conclusions, or what the significance of that difference meant to the authors' arguments. Also unlike Participant A, Participant B commented on the clarity with which the article was written and the logical organization. Participant B expressed the greatest concern over the topic of the article, questioning the need for research on predictors of college grades between men and women. While accepting that the article was valid, Participant B also considered the article to have little value.

Participant B interpreted the article in much the same manner as Participant A. While the expressed intent of the article's authors was to point out the need for better testing models, Participant B focused on the perceived difference in math skills among women and women. As with Participant A, this suggests that Participant B still experienced difficulty bringing relevant knowledge to bear when given a research article to review.

Final session.

As the final phase in the project, Participant B completed a second diagramming exercise and a second repertory grid. This second exercise took place at the end of the semester, following final examinations.

During the second interview, Participant B described research as an effort to gain additional knowledge or information on a particular subject or idea. In describing research, Participant B used terms and expressions that were similar to those used in the first interview. These included *validity*, *reliability*, *subject*, *internal consistency*, *inferential statistics*, and *descriptive statistics*. During the second interview, however, Participant B included *reliability* instead of *relativity*. Participant B described the typical features of research as the use of subjects, the development of hypotheses, and the collection of data. Participant B commented that Participant B's research skills were still quite limited, and that the primary area in which Participant B had improved was in the ability to evaluate literature reviews.

As in the first interview, Participant B participated in a diagramming exercise. Participant B completed the diagramming exercise in less than one-half hour. Unlike the first exercise, however, Participant B laid all of the concept labels on the backing before determining their final arrangement. Participant B chose not to use *ethnography*, *variability*, *synthesis*, and *causal assertions*. Just as in the first interview, the reason provided was that Participant B did not know what they meant.

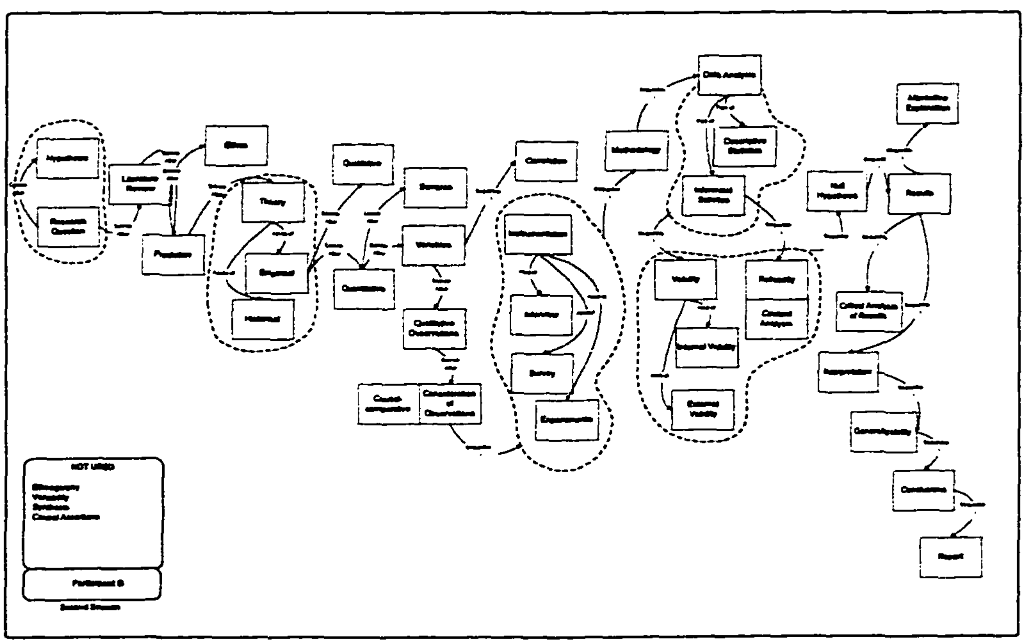


Figure 4-15. Participant B's second diagram.

Whereas in the first interview Participant B was unsure of *ethics'* relationship to the other concept labels in the diagram, this time Participant B linked it to *prediction.* The relationship Participant B described between the two was sequential. First the researcher makes a *prediction* and then ensures it is *ethical.*

Participant B provided no discernable conceptual core in the diagram. According to Participant B, the process of research begins with the *research question* and then develops the *hypothesis.* Next the researcher conducts the *literature review*, develops a *prediction*, and considers *theory.* Participant B carefully noted that *empirical* and *historical* were two types of theories that researchers could select. Participant B distinguished between *qualitative* and *quantitative*, noting that *samples* and *variables* only applied to *quantitative* research. However, Participant B then linked *qualitative observations* to *variables.*

Participant B's unique understanding of the concepts suggests that Participant B still encountered difficulty grasping the deeper structure of the concepts. While Participant B distinguished between the concepts, Participant B did not demonstrate an ability to employ the concepts in appropriate relationships. In most instances, Participant B treated all concept labels as steps that the researcher performed. In linking *correlation* to *variables*, Participant B noted that, "You need to see what your correlation is to your variables." According to Participant B, if the variables correlated, then instrumentation was unnecessary because the

Table 4- 13. Participant B's second set of elicited constructs.

Concept Triads			Resulting Constructs
Theory	Data analysis	Methodology	1. Theory-Methodology
Prediction	Conclusion	Research questions	2. Prediction-Research Questions
Causal assertions	Correlation	Validity	3. Causal Assertions-Correlation
Empirical	Quantitative	Inferential statistics	4. Empirical-Quantitative
Qualitative	Interview	Report	5. Qualitative-Report
Hypothesis	Experiment	Literature review	6. Hypothesis-Experiment
Reliability	Generalizability	Null hypothesis	7. Reliability-Null Hypothesis

to organize and manipulate groups of related concepts. Participant B's use of clusters is very similar to Participant A's, but less complex in that they contain fewer concept labels and are less central to the diagram. Participant B's second diagram evidenced more elaborate structures, but they did not support the level of integration found in the other participants' diagrams, especially the instructors' diagrams.

Participant B completed a repertory grid, using the concept triads to elicit seven constructs. Again, Participant B chose to describe the constructs with terms from the concept triads, themselves. Additionally, Participant B did not evaluate all concepts in the repertory grid. Subsequently, unmarked concepts were evaluated as unsure.

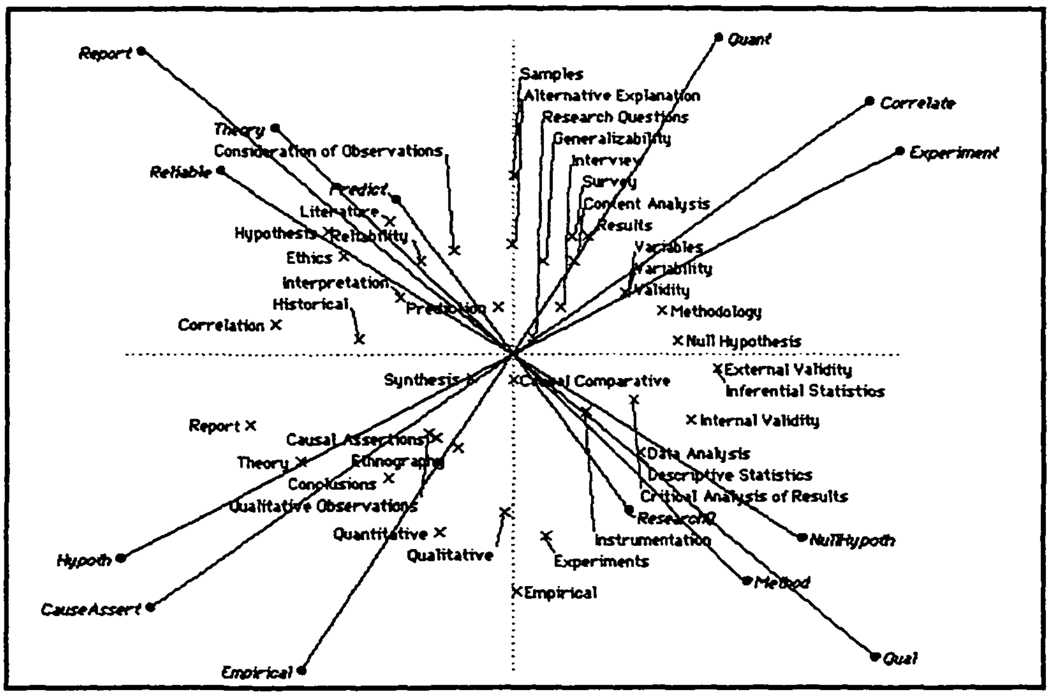


Figure 4-16. Participant B's second principal component analysis diagram.

The principal component analysis of Participant B's repertory grid suggests the presence of two general components. Both components were affected by an apparent unfamiliarity with the concepts being evaluated. The first consists of constructs 3, 6, and 4. This component groups concepts into sets that occur at the beginning of the research process and those that occur towards the end. Concepts such as *prediction, literature review,* and *hypothesis* (concepts which Participant B placed at the beginning of the diagram) group together at one end of the component. Similarly, concepts such as *data analysis, descriptive statistics,* and *critical analysis of results* cluster towards the opposite end.

The second component consists of constructs 1, 2, 5, and 7. This component suggests grammatical influences such as the breadth or specificity of use associated with the concept's name. Within this component, concepts such as *theory*, *qualitative*, and *quantitative* are grouped at one end while concepts such as *samples*, *variables*, and *survey* appear at the other.

As before, Participant B's constructs do not differentiate between all the concepts in the diagram. The concepts *descriptive statistics* and *data analysis* are evaluated equally within each construct. So are the concepts *external validity* and *inferential statistics*, and the concepts *variability*, *validity*, and *variables*. Within each construct, these sets of concepts received identical evaluations, suggesting that the constructs did not differentiate between them. One other pair of concepts, *content analysis* and *results*, received highly similar evaluations within each construct, differing only slightly in that Participant B rated *results* as occurring slightly more towards the end of the research process.

Whereas Participant A's second repertory grid demonstrated a greater ability to differentiate between concepts, Participant B's repertory grid does not. However the convergence of Participant B's constructs into two components in the repertory grid, and the use of clustering in the diagram, does suggest that Participant B's conceptual ecology was somewhat more ordered in the second session. However, when combined with Participant B's unique understanding of many of the concepts, this ordering is most likely quite shallow and dependent upon word recognition.

Summary of Participants A and B

Looking back at the data collected from Participants A and B, in light of the previous participants discussed, I observed a primary difference between Participants A and B and their instructor (Instructor I1) was the presence of a conceptual core. Participant A's diagram suggests the formative stages of such a core, but Participant B's diagrams revealed no such development. Both Participant A and Participant B developed more elaborate second diagrams. Both Participants A and B employed clustering to varying degrees. However, when compared to their instructor's diagram, the clustering is somewhat dissociative (i.e., the clustering does not contribute to an integrated whole). Participant A's second diagram is more integrated than Participant B's, but both link concepts in ways that suggest very unique understandings.

One prominent feature that lends itself to this observation is the *qualitative-quantitative* bifurcation. In their diagrams, Participants A and B link the concepts *qualitative* and *quantitative* to other concepts but nothing more. The concepts are almost tangential to the diagram. Additionally, Participant A links them to *experiments* while Participant B links them to *empirical*. In both instances, the unique understandings of both participants are evident. These unique understandings bring with them connotations that seem inappropriate within the context of educational research methods.

Barsalou (1982) and Wilson and Tessmer (1990) noted that concepts carry with them connotations, factors determine, in part, the appropriateness of actions taken with regards to the concept. Wilson, Tessmer, and Driscoll (1990) noted that the use of concepts depends in large part on the context in which they are used, suggesting "that learners acquire declarative and procedural knowledge for the specific settings in which they use a given concept." (p. 47). Participants A and B acquired their understanding of *qualitative* and *quantitative* in settings other than educational research methods. The placement of these concepts within the diagram suggests that Participants A and B are relying on this understanding to employ them. From the perspective of the larger community of educational research, in which Participants A and B find themselves, their understanding is not shared—it is unique.

Doctoral Student Sessions

Doctoral Participants

The two doctoral student participants (Participants C and D) performed the same tasks as the instructors and the masters participants. Each doctoral participant selected the time and place of the interview. The first interview covered the purpose of the exercise and the rules. Each participant answered questions and then proceeded to complete the diagramming exercise. At the

Table 4- 14. Concept labels used by doctoral students.

Accuracy	Experiments	Methodology	Results
Alternative hypothesis	External validity	Naturalistic inquiry	Samples
Causal-comparative	Field notes	Null hypothesis	Single subject
Causation	Generalizability	Observations	Statistics
Coding	Guiding questions	Prediction	Survey
Conclusions	Hypothesis	Qualitative	Theory
Correlation	Inductive theory	Qualitative data	Trustworthiness
Data	Instrumentation	Quantitative	Understanding
Deductive theory	Internal validity	Quantitative Data	Validity
Empirical	Interview	Quasi-experimental	Variability
Ethics	Legal issues	Research Problem	Variables
Ethnography	Literature review	Reliability	

conclusion of the diagramming exercise, each participant was given a repertory grid matrix to complete and a self-addressed, stamped envelope with which to mail it back.

The doctoral students used a concept set developed by their instructor, I2. Doctoral students used the concepts shown in Table 4-14 (following page).

Participant C

During the first interview, Participant C completed the diagramming exercise and a repertory grid matrix. This was followed with a mid-term interview in which Participant C described a research article that Participant C had selected. At the end of the semester, Participant C completed another diagramming session and repertory grid matrix. Throughout the semester, Participant C's diagrams and discussions suggested an understanding of educational research methods that resembled the instructors' (i.e., Participant C's understanding was less unique and more shared with the instructors).

Initial session.

Participant C was self-described as having thirty to forty years of research experience. This description, however, deserves some clarification. Participant C approached the subject of research from a very broad perspective. In Participant C's view, research refers to a "methodical study of something." This includes "studying and finding meaning" in life experiences at home or in the work place. Participant C described problem-solving requirements in the educational field that required Participant C to develop new understandings of people and situations. This, according to Participant C, was a type of research. When asked for some features of research, Participant C used terms such as correlation, sample, library, data, analyze, and study. Although Participant C provided what might be considered an unconventional view of research, Participant C still described research activities in very conventional terms.

Participant C provided an historical perspective on the changing view of what constituted research. As an undergraduate, Participant C believed that research consisted of controlled experiments. Studies that involved only one subject was considered inappropriate by the institutions of the time. As a graduate student, some years later, Participant C discovered that research might also include such things as studies of individual differences, which interested C.

Participant C stated that the primary reason for taking the doctoral-level research methods course was to fill a course requirement. However, Participant C hoped to use the course as an opportunity to focus on those types of research that Participant C found interesting.

Participant C began the diagramming exercise by carefully peeling the concept labels off of the pad and sticking them on the backing. Once all the concept labels were revealed, C proceeded to arrange them. C completed the diagramming exercise in approximately two hours.

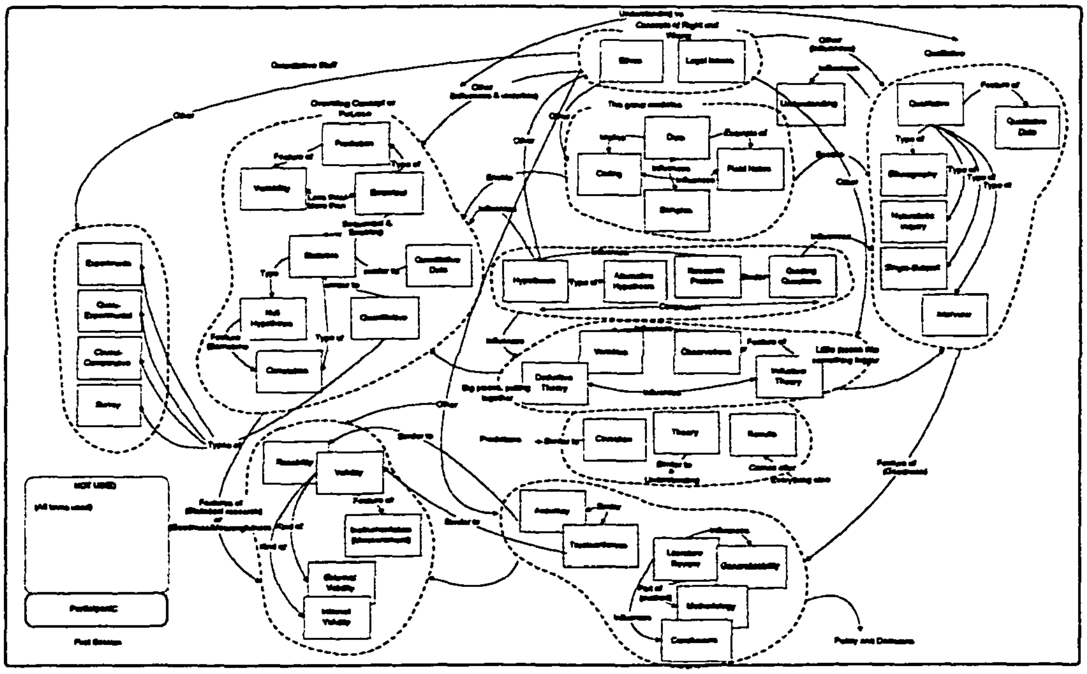


Figure 4-17. Participant C's initial diagram.

C's diagram began with the concepts *ethics* and *legal issues*. C clustered these concepts into a single unit that C referred to as concepts of right and wrong. C linked this cluster to other clusters throughout the diagram, explaining carefully how it influenced all aspects of the research effort.

Participant C did not provide a single conceptual core (i.e., a single linked set of elaborated concepts) in the same manner as Participants A and B. Instead, Participant C developed clusters of concepts that shared features and interacted with each other during the research process. This elaborate, integrated structure suggests Participant C brought considerable knowledge to bear on the diagramming exercise. Participant C employed knowledge of the concepts under consideration by linking them extensively to the other concepts in the diagram. Participant C drew multiple concepts to describe the role of single concepts. Participant C also employed knowledge from outside the concept set by structuring the concepts in to highly integrated clusters.

The multiple clusters provided Participant C a means of bringing relevant knowledge of research methods to bear on the diagram. The loose conceptual core, consists of those concepts and clusters that Participant C placed in the center of the diagram. Participant C referred to this column of clusters as the "trunk of the tree."

Qualitative-quantitative bifurcation begins quite early and structures Participant C's entire diagram. Participant C arranged the concepts to highlight their applicability to either *prediction* or *understanding*. A cautionary note is in order at this point. Participant C drew the arrows (at the top of the diagram) describing how the diagram depicted *prediction* versus *understanding*. However, Participant C did not realize the arrows were backwards until they were already on the backing. Rather than try to redraw them, Participant C explained how *prediction* related to *quantitative* requirements and *understanding* related to *qualitative* requirements.

The sequence of concept clusters in Participant C's diagram does not reflect a sequence of steps—Participant C's diagram was not a procedural diagram, it was much more of a state diagram. Each cluster depicted internal relationships that support the cluster's identity while interacting with the other clusters. The clusters in Participant C's diagram suggest strong quantitative influences. Three clusters support the *prediction* or *quantitative* side of the diagram, while only one supports the *understanding* or *qualitative* side. The largest and single most populated cluster contains *prediction* and the concepts that elaborate it.

The clusters on the periphery (i.e., those that are more *qualitative* or *quantitative*) elaborate upon the core clusters, but they do not act upon them. In Participant C's diagram, it is the core clusters that demonstrate action through enabling or influencing links to peripheral clusters. According to Participant C, these types of research share corresponding features such as *reliability* or *accuracy*, and *validity* or *trustworthiness*.

At the conclusion of the diagramming exercise, Participant C was provided a repertory grid exercise based on the same concepts as the diagramming exercise. A principal component analysis of Participant C's initial repertory grid suggested that two components acted upon the domain to organize concepts. The first

Table 4- 15. Participant C's first set of concept triads and elicited constructs.

Concept Triads			Resulting Constructs
Trustworthiness	Generalizability	Reliability	1. "Truth" In A Particular Sense-"Truth" In A Broader Application
Prediction	Conclusion	Research problem	2. Goals of "Old" Research-Goal Of All Research
Theory	Methodology	Data	3. Ideas, Meaning Created-Form & Substance of Information
Causation	Correlation	Validity	4. Strong, Direct Connection-Weak, Indirect Connection
Instrumentation	Coding	Internal validity	5. Objective, Cold, Disengaged-Flexible, Subjective, Human
Ethnography	Field notes	Coding	6. Being Present, Being There-Making Assessment Valuation
Hypothesis	Guiding questions	Literature review	7. Starting Place-Information Added
Empirical	Quantitative	Statistics	8. Data Through Senses-Numbers
Quasi-experimental	Causal-comparative	Single-subject	9. Study of One Particular-Study of Several

component consisted of constructs 1, 2, 5, 6, 8, and 9. This component draws heavily upon distinctions between *qualitative* and *quantitative* concepts. During the initial interview, Participant C described this distinction as the old and new views of research.

The *qualitative-quantitative* bifurcation in Participant C's diagram paralleled this distinction. Participant C's repertory grid placed *prediction* and *understanding* at opposite ends of the component. With these concepts were *quantitative* and *qualitative*, respectively. Grouped with *quantitative* were concepts such as *statistics, causation, survey,* and *experiments.* Grouped with

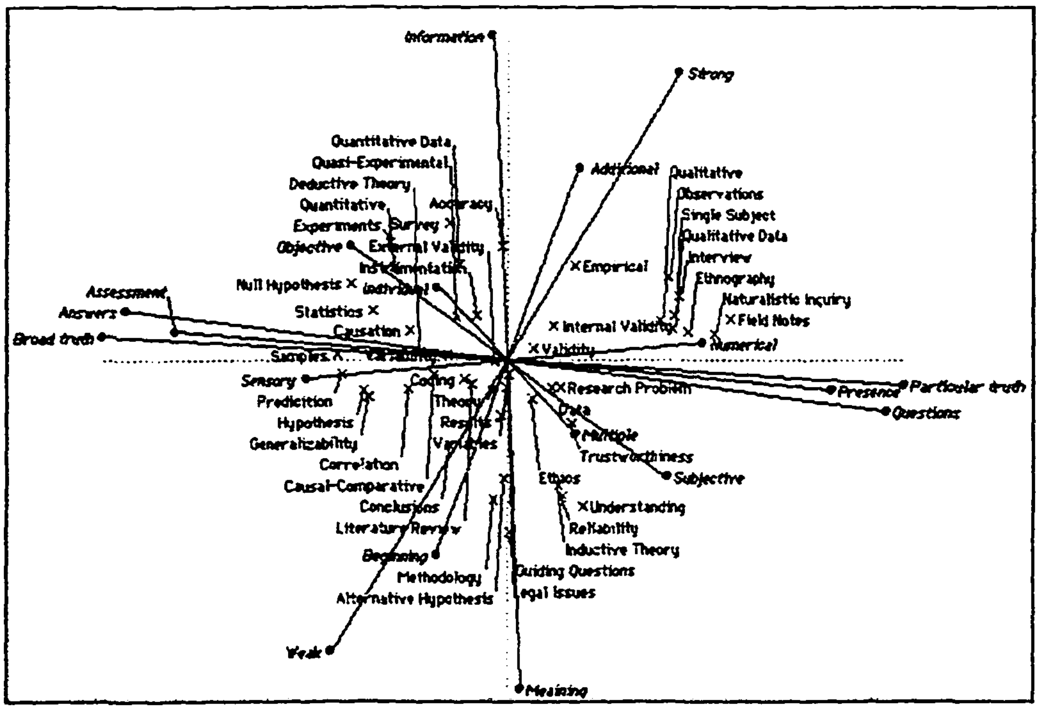


Figure 4-18. Participant C's first principal component analysis diagram.

qualitative were concepts such as *ethnography*, *field notes*, and *single subject*. The *qualitative-quantitative* bifurcation of Participant C's diagram was reproduced in Participant C's repertory grid.

The second component consists of constructs 3, 4, and 7. This component suggests an analysis-collection division in the conceptual ecology. This component produced a subtle division in Participant C's conceptual ecology. Participant C tended to group concepts that analyze on one side of the component. Examples of these concepts include *generalizability*, *conclusions*, and *hypothesis*.

On the other side of the component were concepts that concern collection of data, such as *observations*, *interview*, *accuracy*, and *empirical*. It is interesting to note, that both *qualitative* and *quantitative* are grouped in the "data collection" side of this construct.

Unlike Participants A and B, Participant C's constructs provide for differentiation between all concepts within each construct. When compared to Participants A and B and to Instructors I1 and I2, Participant C's *qualitative-quantitative* bifurcation resembles that of the instructors. While Participant C placed *qualitative* and *quantitative* into separate clusters, they are not dissociated from the other concepts. Instead *qualitative-quantitative* bifurcation is highly integrative. Participant C employed the concepts to organize the diagram. Participant C then carefully tied the clusters back to other concepts in the diagram. Repertory grid data also suggests that the concepts *qualitative* and *quantitative* play a major organizing role in Participant C's conceptual ecology. However, the diagram suggests that this role is not dissociative—it is integrative. Participant C emphasized that the *qualitative* and *quantitative* clusters supported similar goals within the research process.

Participant C depicted a core of concepts that were highly integrated and elaborately structured. In developing these integrated structures, Participant C brought truly relevant knowledge to bear. The similarities between Participant C's diagram and those of Instructors I1 and I2 suggest that Participant C's understanding of the concepts is less unique and much more shared (with the instructors) than the other participants.

Mid-term session.

In the second phase of the project, Participant C selected a research article to review. As with the masters-level participants, each was asked to describe what made the project a good (or bad) example of research. Participant C was interviewed midway through the semester. Just as in the initial interview, the mid-term interview was held at a time and place of the Participant C's choosing. The purpose of this interview was to gather information on how Participant C applied conceptual knowledge to "real world" examples. Participant C selected a research article that was related to Participant C's dissertation topic and occupational field.

Participant C selected an article concerning traditional education practices in classroom settings. Participant C had encountered this research article several years previously, while pursuing masters-level studies. An instructor, who was one of Participant C's committee members, presented it to Participant C as part of a class project. Participant C explained that the research article was an ethnographic study in which the researcher documented a single public school teacher's enculturation to traditional, accepted classroom practices. The purpose of the study was to identify and describe factors that made traditional instructional practices durable and resistant to reform.

Participant C described initially rejecting the article on the grounds that with a sample of one, it did not constitute a research project. However, upon subsequent readings, Participant C realized that the author was supporting an understanding of phenomena that Participant C had also encountered, but never fully conceptualized. This understanding caused Participant C to re-evaluate the concept of research. It was difficult to distinguish between Participant C's paradigm shift to a different research methodology and Participant C's cathartic acceptance of the article's subject matter content. By Participant C's own admission, the article was a source of enlightenment. Since that time, Participant C has continually reviewed the article and shared it with other students and faculty.

Participant C criticized the author's conclusions, however. In this article, the author advocated a particular "constructivist" approach to classroom instruction as the answer to difficulties observed in the classroom. Participant C, however, noted that based on personal experience any single instructional approach would have limited efficacy.

Participant C's mid-term interview did not provide many additional insights to the participant's conceptual ecology. Participant C's conceptual ecology was characterized by a significant, but integrated, *qualitative-quantitative* bifurcation. During the mid-term session interview Participant C emphasized the importance of accepting research methods that drew from more qualitative approaches.

Final session.

After the semester had concluded, Participant C completed another diagramming exercise and repertory grid. During this interview, Participant C described research in much the same manner as the initial interview. The purpose of research, according to Participant C is to find knowledge, information, or understanding. Participant C described how the process that supports that purpose involved developing questions, searching primary sources to find out what's already known, developing a research design, analyzing data, developing a perspective, and sharing or using the research.

Participant C provided a somewhat cynical description of a new feature that Participant C now described as critical—who is doing the research and why. Participant C explained that without that understanding, anyone reading the research lacked the necessary perspective of the researcher's biases.

Participant C began the diagramming exercise in the same manner as before, peeling the labels off of their pad and sticking them all on the backing before attempting to arrange them.

Participant C placed *ethics* and *legal issues* at the top o the diagram, much the same as in the initial session. However, this time Participant C depicted how

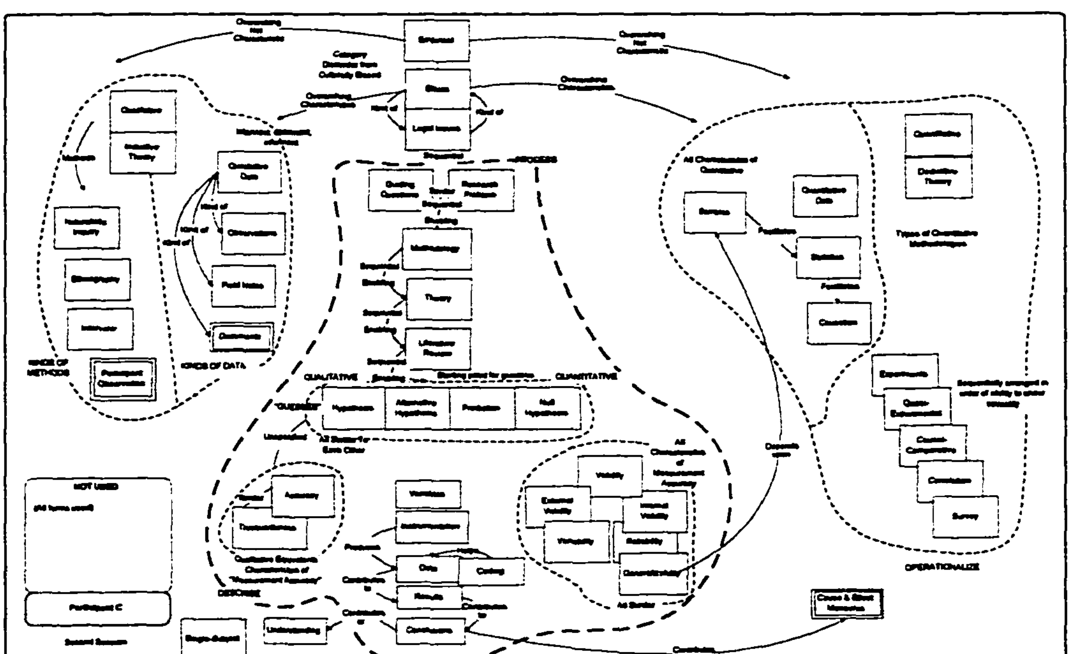


Figure 4-19. Participant C's second diagram.

ethics and *legal issues* were related to other concepts. According to Participant C, *ethics* and *legal issues* function as characteristics, or features of methodologies and processes. Participant C developed a more pronounced conceptual core. Participant C developed clusters of concepts that shared features and interacted with each other (i.e., clusters that were integrative). A new feature in this diagram was the presence of compound clusters (i.e., clusters nested within larger clusters). These compound clusters served to elaborate the central cluster.

Qualitative-quantitative bifurcation was very evident in the second diagram, as it was in Participant C's first diagram. Two clusters, placed on either side of the central cluster contained the *qualitative* and *quantitative* elements of the diagram. Additionally, Participant C structured the central cluster somewhat along *qualitative* and *quantitative* dimensions. Participant C did not differentiate between *qualitative* and *quantitative* in terms of *understanding* and *prediction* in the second diagram. However, Participant C did place *understanding* on the *qualitative* side of the central cluster and *prediction* on the *quantitative* side. This aspect of Participant C's second diagram suggests a *qualitative-quantitative* bifurcation that is slightly more integrative than the first. As with Instructor I1, the *qualitative-quantitative* bifurcation was employed to order a series of concepts, not divide them.

Participant C added three new concepts to the diagram, bringing more relevant knowledge to bear. Two of these, *participant observation* and *documents* were added to the *qualitative* cluster. These two additions suggest that Participant C's knowledge of *qualitative* methods had developed somewhat since the beginning of the semester. The other new concept, *cause and effect measures* was added to the end of the central cluster.

Participant C's diagram, while still appearing similar to a state diagram, revealed more procedural dimensions in the central cluster, which Participant C labeled "process." This cluster provides the closest semblance to a conceptual

Table 4- 16. Participant C's second set of elicited constructs.

Concept Triads			**Resulting Constructs**
Trustworthiness	Generalizability	Reliability	1. Truth of Measures /Observations-Application of Measures/Observations
Prediction	Conclusion	Research problem	2. Methods-Question
Theory	Methodology	Data	3. How-Abstract Result
Causation	Correlation	Validity	4. Types of Data Relationships-"Truth"
Instrumentation	Coding	Internal validity	5. Instrumentation Issues-Other
Ethnography	Field notes	Coding	6. Methods-Research Design
Hypothesis	Guiding questions	Literature review	7. Direct-Indirect
Empirical	Quantitative	Statistics	8. Reduced to Numbers-Includes Other Observable
Quasi-experimental	Causal-comparative	Single-subject	9. Cause/Effect-Not Cause/Effect

core. Beginning with *research problem* and *guiding questions*, Participant C proceeded through *methodology*, *theory*, and *literature review* to eventually arrive at *conclusions*. This core suggests changes in the state of a research project as it progresses from conception to completion.

At the conclusion of the diagramming exercise, Participant C was provided a repertory grid exercise. A principal component analysis of Participant C's second repertory grid suggests the presence of two components. The first consists of constructs 5, 8, and 9. This component draws heavily upon distinctions between *qualitative* and *quantitative* concepts. As in the first session, *qualitative-quantitative* bifurcation is predominant in Participant C's conceptual ecology.

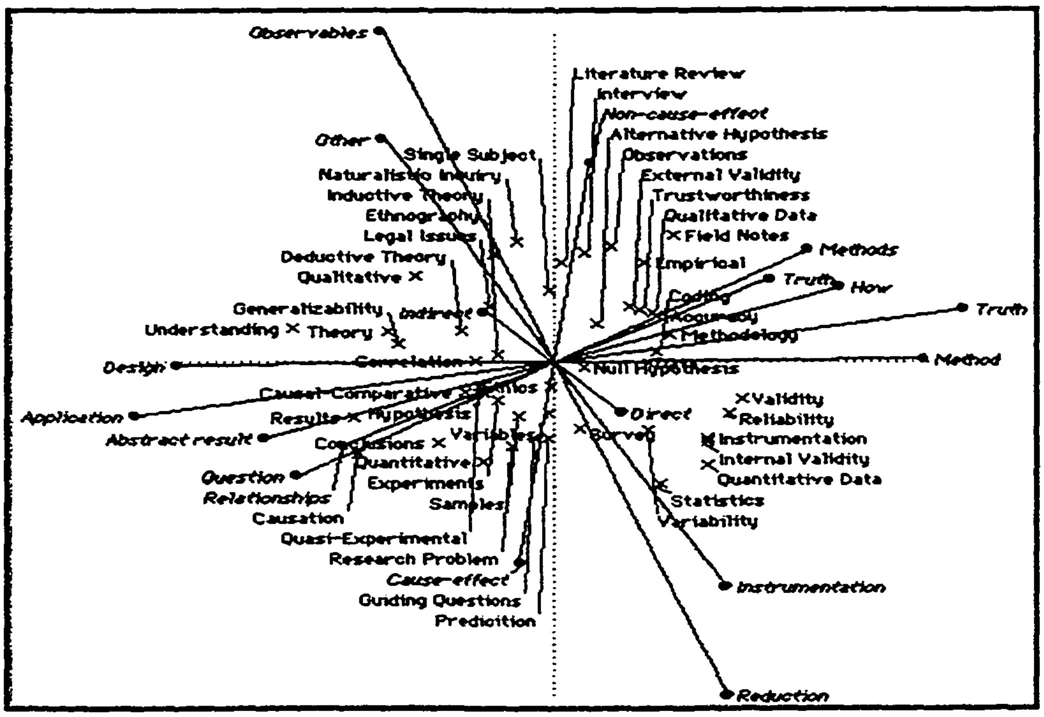


Figure 4-20. Participant C's second principal component analysis.

Constructs 5, 8, and 9 contributed to a *qualitative-quantitative* component in Participant C's initial repertory grid. Concepts such as *validity, reliability, experiments,* and *statistics* were grouped with *quantitative*. At the same time, concepts such as *single subject*, *naturalistic inquiry*, and *ethnography* were grouped with *qualitative*. Again, the *qualitative-quantitative* bifurcation of Participant C's diagram was evident in Participant C's repertory grid.

The second component consisted of constructs 1, 2, 3, 4, 6, and 7. This component appears to order concepts in analytic-synthetic terms, again. In the first repertory grid constructs 3, 4, and 7 supported a similar distinction. Again, concepts such as *generalizability*, *theory, understanding*, and *conclusions* were grouped at one end of the component, while at the other end concepts such as *interview*, *observations*, and *empirical* were grouped at the other end.

Participant C began with a highly elaborated, well-integrated diagram structure. Participant C's diagram became much more integrated by the end of the semester. Most noteworthy was the way Participant C developed a core concept that was more integrated than the previous diagram, as demonstrated by the use of nested clusters. As noted earlier, Participant C's *qualitative-quantitative* bifurcation resembles that of the instructors. Participant C placed *qualitative* and *quantitative* into separate clusters, on opposite sides of the diagram, in each diagram. However, they are not dissociated from the other concepts. In the first diagram, *qualitative-quantitative* bifurcation is highly integrative. Participant C employed the concepts to organize the diagram, and then carefully tied the clusters back to other concepts in the diagram. In the second diagram this effect goes one step further. Participant C employed *qualitative* and *quantitative* to form a continuum that ordered several concepts (i.e., hypothesis, alternative hypothesis, prediction, and null hypothesis) in the central core.

Participant C also noted that this continuum provides a link to the qualitative and quantitative "wings" of the diagram. According to Participant C, after literature review a researcher starts to become concerned with the necessity of selecting a qualitative or quantitative approach. Repertory grid data also suggests that the concepts qualitative and quantitative play a major organizing role in Participant C's conceptual ecology. The diagram suggests an understanding that is much more shared than unique. By bringing truly relevant knowledge to bear. The similarities between Participant C's diagram and those of Instructors I1 and I2 suggest that Participant C's understanding of the concepts is less unique and much more shared (with the instructors) than the other participants.

Participant D

During the first interview, Participant D completed the diagramming exercise and a repertory grid. This was followed with a mid-term interview in which Participant D described a dissertation that Participant D had selected. At the end of the semester, Participant D completed another diagramming session; however, Participant D did not return the repertory grid matrix. Throughout the semester, Participant D's diagrams and discussions suggested an understanding of educational research methods that was highly unique.

Initial session.

Participant D was self-described as a novice researcher and "critical theorist" with limited experience in qualitative research methods and no experience in quantitative methods. Participant D's view of research was significantly different from that of the instructors and any other participants. Participant D described research as, "a process of getting information and presenting a picture with information that tells a story" and "an investigative process that brings enlightenment to a particular life situation or problem."

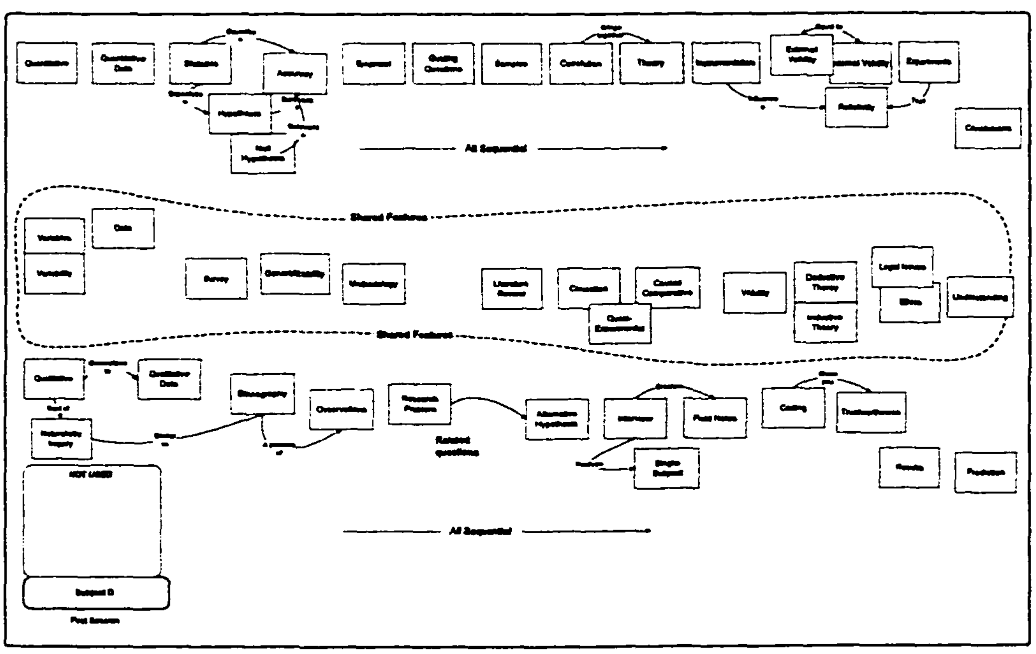


Figure 4-21. Participant D's initial diagram.

The goal of research, according to Participant D, should be to understand life-situations and the aspects of life that brought the situation about. Throughout the research project, Participant D emphasized the need for research to "put a face" on the data. In Participant D's opinion, the strongest research is personalized—that is, it sends a stronger message to those reading about the research. To Participant D research was investigative, interpretive, and phenomenological.

Participant D's purpose in taking the research methods class was to meet requirements in Participant D's program of study. However, Participant D expected to gain the skills necessary to conduct research in educational settings. This included designing studies, selecting methodologies, and explaining the outcomes.

A highly suggestive feature of Participant D's first diagram is the obvious *qualitative-quantitative* bifurcation. In the diagrams of Instructors I1 and I2, and in the diagram of Participant C, this feature organized concepts that were integrated into the diagrams. In the diagrams of Participants A and B, this feature was dissociated from the other concepts within the diagrams. In Participant D's diagram however, the *qualitative-quantitative* bifurcation segregates concepts almost totally between their perceived "qualitative-ness" or "quantitative-ness." Participant D's diagram was based, almost entirely, on the distinctions between *qualitative* and *quantitative*, suggesting that this was the pre-eminent knowledge that Participant could bring to bear on the diagram.

Participant D engineered this *qualitative-quantitative* bifurcation into the diagram from the onset. Participant D began the diagramming exercise by exposing all of the concept labels to view. Participant D then quickly organized the labels by placing *quantitative* in its position and *qualitative* in its position. Participant D then organized the concepts into three sets. The first were concepts that Participant D considered *quantitative*. The second were concepts Participant D considered *qualitative*. The third set of concept labels Participant D considered to be shared concepts (i.e., concepts that applied to both *quantitative* and *qualitative*).

From left to right Participant D placed concepts sequentially. The sequence, according to Participant D, reflected the order in which the concepts occur in the research process. However, a review of the diagram suggests that the sequence is less temporal and more associative—which reveals a very unique understanding on the part of Participant D. The implication is that one begins the research process by selecting either a *qualitative* or *quantitative* approach. If the approach is *quantitative* then the research will require *statistics*, a *hypothesis*, a *null hypothesis*, and the implication of *accuracy*. If, on the other hand, the approach is to be *qualitative*, then the research will entail either *naturalistic inquiry* or *ethnography*. In both of these examples, concepts were sequenced associatively. Another association that Participant D's diagram depicted was *hypothesis* and *null hypothesis*. While placing the concept labels on the backing, Participant D commented that the *null hypothesis* was an outcome that the researcher did not expect (i.e., the opposite of the hypothesis). Participant D placed *hypothesis* and *null hypothesis* together, associating them as positive and negative concepts. *Alternative hypothesis*, on the other hand, was placed in the *qualitative* cluster. Participant D described this concept as the *qualitative* equivalent of *hypothesis*. This grouping suggests that Participant D grouped concepts on unique understandings of certain concepts—*qualitative* and *quantitative,* especially.

Participant D's first diagram is by far the simplest of all the participants' diagrams. The structure is virtually linear with little elaboration. Participant D

Table 4- 17. Participant D's elicited constructs.

Concept Triads			Resulting Constructs
Trustworthiness	Generalizability	Reliability	1. Trustworthiness-Non-Trustworthiness
Prediction	Conclusion	Research problem	2. Observable-Unobservable
Theory	Methodology	Data	3. Facts-Non-Facts
Causation	Correlation	Validity	4. Measureable-Non-Measurable
Instrumentation	Coding	Internal validity	5. Pattern-Un-Patterned
Ethnography	Field Notes	Coding	6. Written-Un-Written
Hypothesis	Guiding questions	Literature review	7. Explainable-Un-Explainable
Empirical	Quantitative	Statistics	8. Numerical-Non-Numerical
Quasi-experimental	Causal-comparative	Single-subject	9. Theoretical-Non-Theoretical

depicted only one large, central cluster. However, the remaining concepts are clustered by default, into *qualitative* things and *quantitative* things. This simple clustering also produced the most predominant *qualitative-quantitative* bifurcation. From this perspective, clustering is also quite simple—concepts are either *qualitative* or its opposite, *quantitative*, or they are neutral.

Participant D completed a repertory grid using the diagrammed concepts. The resulting constructs were also quite simple. Participant D's construct descriptors limit graduated evaluations and lend themselves to yes-or-no choices.

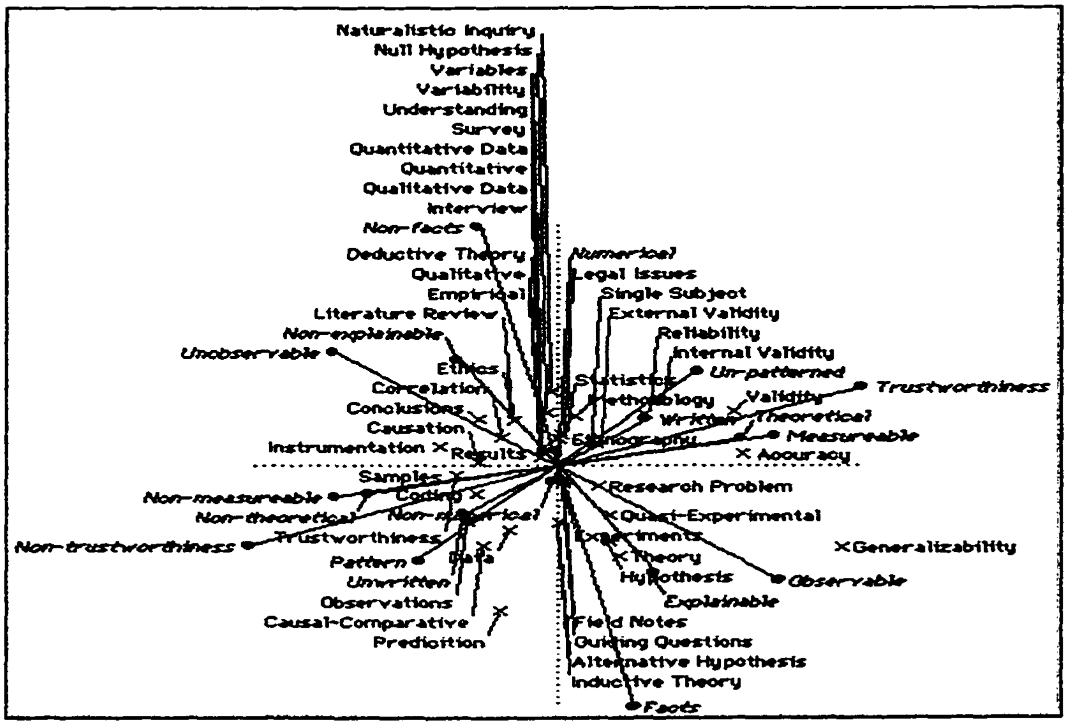


Figure 4-22. Participant D's first principal component analysis diagram.

A principal component analysis of Participant D's repertory grid reveals that Participant D applied the same evaluation strategy to the repertory grid as to the diagram. Participant D evaluated most concepts in the extreme. That is to say, to Participant D concepts were generally very much like one pole of the construct or very much like the other pole of the construct. Given this evaluation scheme, most of the concepts were given neutral evaluations. As shown by the principal component analysis, Participant D's constructs allow for only the most limited discrimination between concepts.

Perhaps related to this inability to discriminate between concepts, Participant D's constructs produced seven pairs of identical concepts (i.e., concept pairs that were evaluated equally within each construct). Participant D's constructs also produced a cluster of eight concepts that were evaluated identically among all concepts (i.e., each construct evaluated all eight concepts identically).

Alternative hypothesis and *inductive theory* were evaluated equally within each construct, and equally among all constructs except construct 3, in which Participant D evaluated both concepts as very factual. *Samples* and *trustworthiness* were evaluated equally within each construct, and equally among all constructs except construct 1, in which Participant D evaluated both concepts as very trustworthy. *Guiding questions* and *experiments* were evaluated equally within each construct, and equally among all constructs except construct 7, in which Participant D evaluated both concepts as very explainable.

Ethics and *literature review* were evaluated equally within each construct, and equally among all constructs except construct 7, in which Participant D evaluated both concepts as very unexplainable. *Ethnography* and *legal issues* were evaluated equally within each construct, and equally among all constructs except construct 6, in which Participant D evaluated both concepts as very written.

Quantitative data and *quantitative* were evaluated equally within each construct, and equally among all constructs except construct 8, in which Participant D evaluated both concepts as very numerical. *Empirical* and *qualitative* were evaluated equally within each construct, and equally among all constructs except for construct 8, in which Participant D evaluated both concepts as very non-numerical.

In each instance, the concepts are only differentiated by a single construct, and within that construct, they are identical. Participant D's repertory grid provided the greatest number of identical concept pairs of all participants. Participant D's repertory grid also provided the only cluster that was evaluated equally among all constructs. Participant D evaluated *variables*, *understanding*, *results*, *interview*, *deductive theory*, *qualitative data*, *survey*, and *variability* as neutral in every construct. The either-or nature of Participant D's constructs limited Participant D's ability to differentiate between concepts.

Participant D's initial repertory grid resembles Participant B's in one respect—unfamiliarity and a somewhat chaotic structure characterize both. However, Participant B's and Participant D's diagrams differ in that Participant D employed all concept labels and described each as it was placed on the backing. Participant B's unfamiliarity stemmed from non-recognition of the concept names, hence Participant B chose not to use them in the diagram. Participant D's unfamiliarity stems from unique understandings of the concepts.

Mid-term session.

In the second phase of the project, Participant D selected a dissertation to review, instead of a research article. As with the masters-level participants, Participant D was asked to describe what made the project a good (or bad) example of research. I interviewed Participant D midway through the semester. Just as in the initial interview, I scheduled the mid-term interview at a time and location of Participant D's choosing. The purpose of these interviews was to gather information on how Participant D applied conceptual knowledge to "real world" examples.

Participant D selected a dissertation related to Participant D's occupational interests. The dissertation was written by one of Participant D's committee members. The subject of the dissertation was perceived gender-based differences in the abilities of campus administrators. Participant D referred to the dissertation as a quantitative work with qualitative elements. This particular dissertation was based on a survey of administrators and employed statistical methods to analyze and present the survey findings.

The dissertation did have an extensive literature review, which Participant D commented on. Participant D criticized the dissertation for not delving deeper into the survey responses. Participant D would have liked to read more survey participant commentary and background information. In Participant D's opinion, a more phenomenological, perspective-seeking approach would have made the dissertation a stronger work. Participant D also criticized the survey's topic (i.e., gender differences). Participant D felt that the author had covered old ground only to develop a finding of no significant difference (a finding that Participant D felt should have been expected). Participant D's final criticism of the dissertation was that it provided no information that practitioners could use. Participant D attributed this to the scholarly nature of dissertations. Participant D emphasized that research should serve a pragmatic or socially relevant end. Ultimately, according to Participant D, researchers should explore and seek answers to real life problems.

Participant D's mid-term interview provided few additional insights to the participant's conceptual ecology. Participant D's conceptual ecology was characterized by a significant, and dissociative, *qualitative-quantitative* bifurcation. The basis of this bifurcation appeared to be Participant C's emphasis of social significance as a goal of *qualitative* research.

Final session.

After the semester had concluded, Participant D completed another diagramming exercise. Unlike the other participants, Participant D completed only the diagramming exercise, and did not complete the repertory grid.

Participant D's description had changed since the initial interview, if not in intent, at least in word. Participant D described research as an in depth examination of phenomena, and presenting the analyses of phenomena. When asked for some words related to research, Participant D provided word such as study, people, places, things, explanations, and solutions.

Similar to Participant C, Participant D provided a somewhat cynical

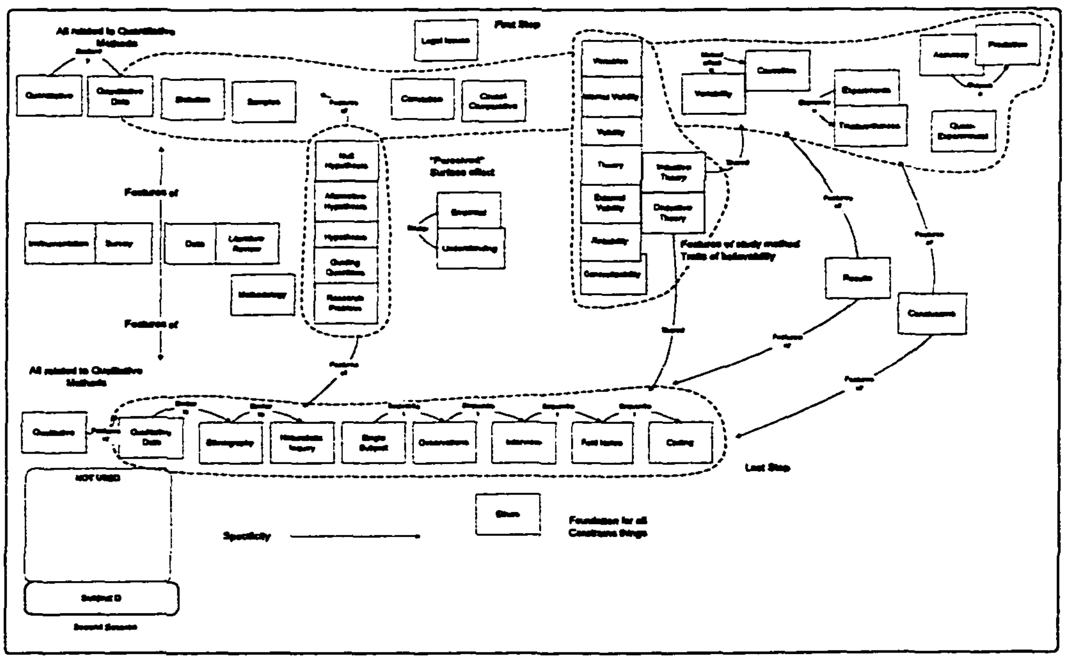


Figure 4-23. Participant D's second diagram.

description of a critical feature of research—packaged information. Participant D explained that research is too often just a compilation of facts and figures. Although Participant D had earlier stated that the reason for taking the research methods course was to comply with program requirements, Participant D provided a somewhat different reason this time. Participant D explained that the primary reason for taking the course was for scholarly development—to discover methodologies that lent best to Participant D's philosophy.

Participant D's diagram resembled the previous diagram in many ways. The *qualitative-quantitative* bifurcation still dominated the diagram, and was still just as dissociative as previously noted. Once again, Participant D set out to group the concepts into groups that were *qualitative* and *quantitative*. However, Participant D employed far more clusters and links, and seemingly recognized that the concepts in the middle represented knowledge that could be brought to bear on either *qualitative* or *quantitative*. In the center several concepts were clustered and linked to specific concepts in other clusters. Overall, the diagram was more elaborate, and more integrated than the first diagram.

Participant D began, again, with *qualitative* and *quantitative* placing them on opposite sides of the backing. As Participant D developed the diagram, Participant D aligned concepts in *qualitative* or *quantitative* clusters. Central clusters, or shared clusters, were also ordered in terms of *qualitative-quantitative*.

Many of the unique understandings, evidenced in the first diagram, were no longer present. *Hypothesis*, *null hypothesis*, and *alternative hypothesis* were grouped together. Another change from the first diagram was the placement of *prediction*. Previously, this concept had been classified as *qualitative*. This was a rather unique understanding, since a qualitative research project might only concern a single subject. *Prediction,* in such an instance, would be rather problematic. Other concepts reveal new instances of unique understandings. *Trustworthiness*, usually associated with *qualitative* techniques, was placed in the *quantitative* cluster and linked to experiments.

As in the first diagram, Participant D labeled many relationships as sequential in nature. However, the associative organization of Participant D's diagram still persisted. A look at the *qualitative* cluster should suffice to illustrate this point. In this cluster, Participant D linked *single subject* and *observations* with a sequential link. However, Participant D did not describe the sequence as temporal, per se. Participant D described how selection of a *single subject* design would imply making *observations*, which would imply *interviews*, which would lead to *field notes*, and *coding*. Participant D linked these concepts within the context of their association with *qualitative* methods, not time.

Summary of Participants C and D

The mid-term interviews of Participants C and D provided perspective on each participant's conceptual structure. Participant C progressed from a discussion of qualitative versus quantitative to a discussion of the researcher's findings. Participant D, on the other hand, kept the interview centered on the differences between qualitative and quantitative methods. In both instances, the participants did reveal why they were interested in qualitative research methods. Both Participant C and Participant D were confronted with research concerns that accepted quantitative methods were unable to address—the development of meaning.

When compared to the diagrams of Instructors I1 and I2, Participant C's diagrams resemble theirs, more so than do Participant D's. Structurally, Participant C's diagrams present a much more integrated use of the concepts than do Participant D's diagrams. While both demonstrate a pronounced *qualitative-quantitative* bifurcation, Participant C's links back to the other concepts in the central core—one conducts research recognizing that qualitative and quantitative paradigms are useful in various situations. In Participant D's diagrams the *qualitative-quantitative* bifurcation parcels the diagram into two separate domains—one does not conduct research, one conducts either qualitative or quantitative research.

Participant C demonstrated an understanding of research methods that was comparable to that of the instructors. In this respect, Participant C "shares" understanding with the instructors, not with the other participants. Participant D, on the other hand, demonstrated fairly unique understandings of the concepts in both diagrams.

Characterizing Student Conceptual Ecologies

Conceptual ecology theory offers one possible way of exploring conceptual change. The overall objective of this study was to explore the development of a method that offers a means of describing and characterizing changes to individual conceptual ecologies. As suggested by Chi, Feltovich, and Glaser (1981), the manner in which subjects classify stimuli characterizes their underlying knowledge structure. By employing concept labels, and classifying them relative to each other, the diagramming technique might lend itself to a characterization of individual conceptual ecologies. The diagramming technique supports highly structured interviews similar to those used by Posner, Strike, Hewson, and Gertzog (1982).

Throughout the semester, participants' diagrams demonstrated varying levels of structure. Depending upon the participant's level of experience, this structure ranged from seemingly chaotic and dissociated to highly elaborate and integrative. In particular, the ways in which participants chose to link and group the concepts suggested that the participants were bringing what they thought to be relevant knowledge to bear (Medin, 1989) upon the diagramming task. When combined with data from interviews and repertory grids, the diagrams suggested levels of understanding (Chi, Feltovich & Glaser, 1981) that appeared congruent with the participant's experience level.

Participant interviews yielded three types of data—diagrams, repertory grid matrices, and transcripts. Transcripts, taken while participants performed the diagramming task, provided insight into the participants' understanding of the concepts being considered. Repertory grid matrices, performed with diagramming tasks, assessed conceptual structure by comparing 1) the terms used to describe concepts, and 2) the distinctions made between concepts (Kelly, 1955). Combined, transcripts and repertory grid matrices provided the means for evaluating the effectiveness of the concept mapping approach to diagramming the conceptual ecology.

The transcripts suggest that Participant A underwent the greatest shift in understanding, while Participant C underwent the least. As noted earlier, however, Participant C was fairly experienced in educational research, while Participant A was a relative novice. Hence, Participant C's understanding of the concepts tended to coincide with accepted usage at the outset of the study. The transcripts for Participants B and D suggest some shift towards an understanding that might be shared with the instructors, but not a dramatic shift.

A difficulty arises in applying the value-laden term "misconceptions" (Posner, Strike, Hewson, & Gertzog, 1982) to these understandings. The term carries with it connotations of "correct" and "incorrect" which become difficult to support in every instance. What the transcripts and diagrams of Participants B and D do suggest, however, is that their understanding of the concepts was not congruent with that of their instructors. The concepts they linked together and their explanations for linking them suggest that Participants B and D retained many of their respective unique understandings of the concepts. The transcripts suggest that Participant A, on the other hand, underwent a shift from unique understandings to more shared understandings while Participant C maintained shared understandings.

The repertory grid matrices also provided some insight into the participants' relative levels of understanding. In the first repertory grid matrix, Participant A was unable to discriminate between several concepts. However, in the second repertory grid matrix, Participant A was able to discriminate between all concepts. Both of Participant C's repertory grid matrices demonstrated an ability to discriminate between all concepts. Participant B's repertory grid matrices did not demonstrate an increased ability to discriminate between concepts. However the convergence of Participant B's constructs into two components in the repertory grid does suggest that Participant B's conceptual ecology was somewhat more ordered in the second session. However, when combined with Participant B's observations and comments, this ordering is most likely quite shallow and dependent upon word recognition.

All participants' second diagrams reflected greater elaboration than their initial diagrams. This elaboration was manifested primarily in clustering, but also in additional and more complex linking patterns. Additionally, participants demonstrated, to some extent, movement towards shared understanding in their use of the concepts. Structure and understanding provide one means of characterizing participants' conceptual ecologies and their changes.

In the following diagram, the relationship structure and understanding represent two continuums that define four quadrants. With the exception of Participant C, all participants' diagrams (substantiated by their interviews and

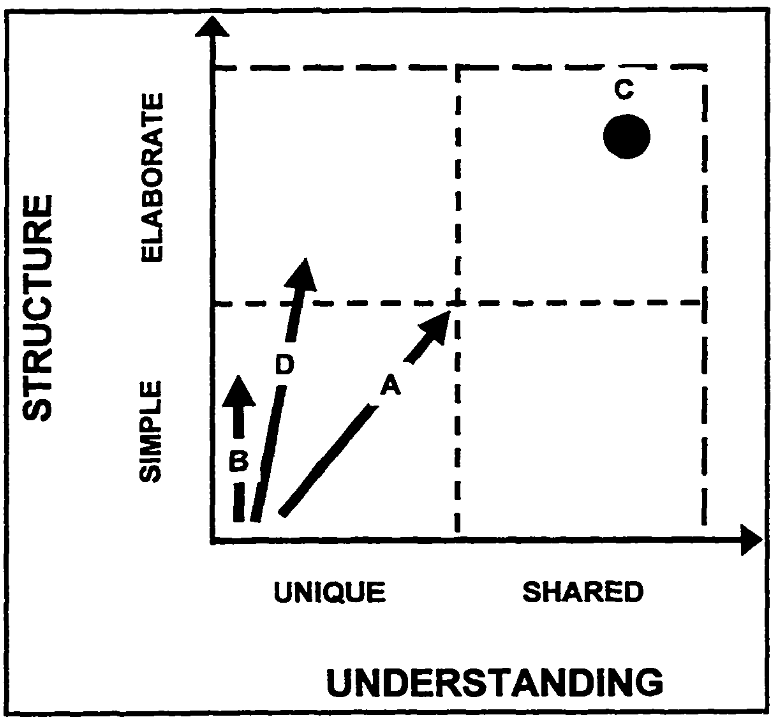


Figure 4-24. Characterization of participant's conceptual ecologies during the course of the semester.

repertory grids) placed them in the lower left quadrant. Participants A, B, and D all demonstrated simpler structure and unique understandings in their initial diagrams. In their second diagrams, Participants A, B, and D all demonstrated increased elaboration and more shared understandings.

Not all participants demonstrated the same changes, however. Participant A demonstrated shared understandings and moderate elaboration in the initial diagram. In the second diagram A had increased the elaboration but still demonstrated some unique understandings. Participant B demonstrated limited shared understanding and almost no elaboration in the initial diagram. In the second diagram, Participant B demonstrated increased elaboration but almost no increased shared understanding.

In Participant D's initial diagram, understanding was highly unique, and elaboration was almost nonexistent. However, in the second diagram Participant D demonstrated significantly increased elaboration and some shared understanding. The structure-understanding relationship suggests one way in which conceptual ecologies and their changes may be characterized.

Review with Instructor I1

Stewart (Stewart, 1976; Stewart, 1979) and Strike and Posner (1976) criticized diagramming techniques because the results were often uninterpretable and decontextualized. Their concern was demonstrating that the changes noted in assessments needed to be meaningful characterizations of conceptual change.

While characterizing conceptual ecologies in terms of structure and understanding may provide utility, the question remains whether it dependably characterizes the subject's conceptual ecology. Champagne, Klopfer, DeSena, and Squires (1978) employed structural complexity as one method of characterizing conceptual change.

Schwandt recommended that researchers judge interpretation in terms of "thoroughness, coherence, comprehensiveness" and whether the interpretation is "useful" (Schwandt, 1994, p. 122). Guba (1980), noted that relevance was as important as rigor (p. 136) and suggested that researchers can best verify the truth value (analogous to internal validity) of interpretations by "testing the data with members of the relevant data source groups" (p. 140). In a similar manner, consistency (analogous to reliability) is not invariant but demonstrates that "changes that occur must be meaningful, not random, and their meaningfulness must be able to be established" (p. 140).

Having the instructor (i.e., a member of the relevant data source group) conduct a "blind" review of the diagrams provided the means for assessing the 'usefulness' of the characterization and the 'meaningfulness' of changes captured by the characterization. The participant's instructor was the single common-factor (human factor) of each data source group and as such was in a unique position to assess the utility and meaningfulness of participant data. The completed diagrams were reviewed by I1. Instructor I2 was unavailable for a similar review due to a change in employment. In this instance, Instructor I1 was asked to identify Instructor I1's own diagram, the diagrams of Instructor I1's students, and to match initial diagrams with second diagrams.

Instructor I1 noted that each of the diagrams exhibited the traits of structure (simple or elaborate) and understanding (unique or shared). Instructor I1 correctly associated and sequenced two sets of participant diagrams (i.e., Participants B and D). Instructor I1 also recognized that Participant C's diagrams, and Instructor I2's diagram, all suggested individuals that were quite knowledgeable about research methods.

Instructor I1 did not associate any specific individual with a specific diagram. With regards to participant diagrams, this was to be expected. Instructor I1 only instructed Participants A and B, and one year had passed since that time. Instructor I1 only knew of Participant C by reputation, and had never met Participant D. Interestingly, Instructor I1 incorrectly identified Instructor I2's diagram as a student diagram.

Evaluation of Participant A's diagrams.

Instructor I1 spent very little time on Participant A's diagrams, only reviewing Participant A's second diagram briefly. However, based on Participant A's clustering of concepts (elaboration) and Participant A's use of concepts (understanding), Instructor I1 stated that the diagram suggested a naive knowledge of the research process. Instructor I1 based this evaluation primarily on Participant A's separation of *Experiments* and *Methodology*. Instructor I1 noted that this separation appeared to be illogical was evidence a unique understanding. Instructor I1 also noted that Participant A's second diagram relied heavily upon clusters (elaboration) to provide a knowledge structure.

Evaluation of Participant B's diagrams.

Instructor I1 correctly associated and sequenced Participant B's first and second diagrams, and stated they suggested a naive knowledge of the research process. Instructor I1 also noted that there appeared to be little change between Participant B's first and second diagrams, except for an increased elaboration. Instructor I1 based this evaluation on several unique understandings and simple structures that Instructor I1 observed in both diagrams.

Instructor I1 noted that *hypothesis* and *empirical* were linked sequentially in Participant B's first diagram. *Empirical* was sub-divided into two types, *qualitative* and *quantitative*. Instructor I1 noted that the simple elaboration was confusing. Similarly, Instructor I1 noted that C's linking of *prediction*, to *literature review* suggested a novice approach since most students only experience the literature review portion of research. Instructor I1 also noted that Participant C linked the concepts *inferential statistics* and *descriptive statistics* in a subordinate relationship to the concept *data analysis.* This implied to Instructor I1, that Participant C understood that both types of statistical methods played an important role in research. Instructor I1 also noted that C's first diagram suggested that there were two types of *literature review*; *theory* and *historical.* Instructor I1 noted that this is a very unique understanding.

Evaluation of Participant D's diagrams.

Instructor I1 correctly associated and sequenced Participant D's two diagrams, and determined that they depicted a naive knowledge of research; a knowledge that was most likely subject to a strong belief in the relative values of qualitative and quantitative methods.

Instructor I1 stated that the Participant D's diagrams showed unique understandings because the concepts were linked in ways that Instructor I1 did not understand. The most outstanding feature that Instructor I1 observed in Participant D's diagrams was the *qualitative-quantitative* bifurcation. In this instance, Instructor I1 noted that in Participant D's diagrams the bifurcation is a value-based dichotomy, instead of a methodological-evaluative continuum.

At this point, however, Instructor I1's characterization was influenced by the context of previous experience. Initially, Instructor I1 suggested that Participant D's diagram divorced *qualitative* from the research process. Instructor I1 based this judgement on Participant D's placement of *qualitative* (i.e., at the bottom of the diagram) and the fact that Participant D did not link *qualitative* with *research problem.* This judgement confuses the issues of understanding and elaboration.

In fact, Participant D did not link *qualitative* with *research problem* because Participant D used the term with a very unique understanding (i.e., Participant D believed that Research Problem was a term restricted to a quantitative use). Instructor I1, however, assumed that this was because Participant D probably believed that *qualitative* was not a true research method. Instructor I1 explained several times that many graduate students view qualitative methods as inferior to quantitative methods. Based on this experience, Instructor I1 interpreted Participant D's diagrams within that frame of reference.

Instructor I1 also noted that the sequentiality depicted in Participant D's diagrams was not temporal in nature, but rather an associative grouping with qualitative or quantitative methods. Instructor I1 noted the unique meanings that Participant D associated with *Empirical* and *Qualitative*. Participant D's diagram indicated that Participant D considered *Empirical* to be a more quantitative concept. The basis for Instructor I1's determination of sequence was the increased elaboration, and limited increase in shared understanding depicted in the second diagram. In Instructor I1's opinion, Participant D's diagrams reflected a belief system that was resistant to instructional-based change.

Evaluation of Participant C's diagrams.

Instructor I1 reviewed both of Participant C's diagrams, Instructor I1 noted that the individual who developed them was much more knowledgeable about research methods. However, Instructor I1 did not associate Participant C's diagrams with each other. Instructor I1 did note that Participant C's first diagram, while not naive, still demonstrated novice traits, and that Participant C's second diagram reflected a much more advanced knowledge of research processes.

Instructor I1 noted that both of Participant C's diagrams displayed considerable elaboration and shared understandings. Instructor I1 keyed, initially, on Participant C's depiction of the concept *Empirical* as an overarching trait, applicable to either qualitative or quantitative methods. The next point that Instructor I1 noted was Participant C's logical clustering. Instructor I1 stated that the clustering in Participant C's first diagram was still somewhat confusing, but that the clustering in the second diagram was quite advanced and very logical.

Instructor I1 stated that both diagrams suggested an individual that understood qualitative methods, based on Participant C's relative placement of the concepts *theory* and *literature review* before the planning of the study.

In comparison with Participant D's dichotomous *qualitative-quantitative* bifurcation, Instructor I1 described Participant C's *qualitative-quantitative* bifurcation as more of a methodological-evaluative continuum. In Instructor I1's opinion, although the diagrams were clearly divided into qualitative and quantitative domains, Participant C depicted a logical structure between the domains that linked them to a common goal.

Evaluation of Instructor I2's diagram.

Instructor I1's evaluation of Instructor I2's diagram is interesting in that it demonstrates the effect that context, or frame of reference, can have on interpretation. Instructor I1 characterized Instructor I2's diagram as one that was developed by a knowledgeable person that had probably taken a qualitative methods class. Instructor I1 noted that Instructor I2's diagram demonstrated a unique knowledge of qualitative methods, however, Instructor I1 attributed that to probable attendance in a qualitative methods class. Instructor I1 noted the use of unique concepts, and the fact that the individual had added several of these concepts to the diagram during the interview. However, Instructor I1 suggested that Instructor I2's diagram demonstrated a unique understanding of *content analysis*, perhaps confusing this concept with content validity.

This suggests that there are probably no distinctive traits in the diagram itself. Rather, the previous episodes in which instructors identified specific students from the diagrams may have been the result of the immediate context of having taught the class (the immediate frame of reference). Given time, the immediate frame of reference changed, and prevented Instructor I1 from recognizing Instructor I2's diagram.

Chapter 5
Discussion and Summary

Review of Findings by Research Question

In this study I investigated a method of identifying and describing changes in diagrammed relationships between concepts. I intended that these descriptions should provide a mechanism for identifying and describing (i.e., characterizing) aspects of participants' conceptual structures. By characterizing aspects of these structures, I did not seek to explain the phenomena of concept formation and change. Rather, I attempted to gain insight into each participant's structured knowledge and into the use of diagramming methodologies for developing that insight.

With regards to the latter, the methodology used in this project suggested that "structure" and "understanding" were evidenced in the participant data. That is not to say that "structure" and "understanding" are by any means new; they are not. However the suggestion that a diagramming methodology may provide the means to explore these dimensions warrants, in my opinion, further inquiry into the potential uses of diagramming.

With regards to the questions, this study focussed on questions that may have been premature for the methodology. This study sought to answer the following questions:

1. Do the characterizations suggest unique conceptual ecologies?
2. Does the methodology provide consistent characterization of the subject's conceptual ecology, given a test-retest application?
3. How trustworthy are the characterizations of the ecological structures?

4. Is the methodology sensitive to changes in the conceptual ecology? That is, given a pre-post assessment, is there a perceptible change in the conceptual ecology, and if so does it (i.e., the post-assessment) more closely resemble the instructor's?

Although intended as an idiographic approach, the questions beg a nomothetic answer. Attempting to employ idiographic data towards these nomothetic conclusions represents, in retrospect, a flaw in the application of the selected methodology. Therefore, I will proceed with a discussion of the research questions, and will follow with a discussion of the implications and methodological issues. This chapter will conclude with recommendations for further uses of diagramming as a form of idiographic inquiry.

Do the Characterizations Suggest Unique Conceptual Ecologies?

Murphy and Medin (1985) argued that for a concept to be useful, it must be based (at least in part) on a person's theories of the world around them. These theories are entirely subjective and may not be entirely accurate. Initially, this study sought to determine if the conceptual ecologies depicted in the diagrams were truly unique to each participant.

The "blind" review of participant data by Instructor I1 suggested the presence of conceptual ecologies that were somewhat unique. Instructor I1 was able to identify novices and experts and to identify which diagrams occurred early in the semester and which occurred late in semester. Instructor I1 was not able to point out specific aspects of the student data that provide the "clues" to identifying the participant by name. Rather, Instructor I1 was able to point out traits pertaining to structure and understanding that indicated each participant's level of expertise.

The consistent and unique element of each diagram appeared to be the pattern or gestalt used by the participant to arrange the concept labels. All participants "reconstructed" their diagrams each time, using similar patterns but changing many of the relationships. I should point out that none of the participants were given the opportunity to review their first diagrams. Especially among the more experienced participants, the consistency of patterns suggests an underlying set of structural rules.

Does The Methodology Provide Consistent Characterization Of The Subject's Conceptual Ecology, Given A Test-Retest Application?

Consistency (analogous to reliability) demonstrates that "changes that occur must be meaningful, not random, and their meaningfulness must be able to be established" (Guba, 1980, p. 140). It was important to determine whether the diagram provided a consistent characterization of a conceptual structure or if it reflected other confounding influences that would yield the characterization unreliable.

A test-retest approach, similar to that used by Chi, Feltovich, and Glaser (1981), attempted to answer that question. Using this technique, I had hoped that the diagrams would yield similar characterizations when employed after a short period of time—twenty-four hours in this instance.

The characteristic elements of each participant's diagrams remained in tact between sessions. Participant P1 continued to structure the diagram around the concept *methodology*. Participant P2 continued to structure the diagram around the concept *experiments*. In both instances, these concepts provided an integrating function for other concepts in the diagram—tying the other concepts together and allowing the participant to then bring that knowledge to bear on the whole diagram in an organized manner.

There were some changes in the pattern of their diagrams. One possible explanation for this is reflection on the part of P1 and P2. Both were presented with a novel experience that was repeated within 24 hours. Both P1 and P2 would have had time to reflect and second-guess their diagrammed responses. This reflection could have been a source of interference because the participants would have been focusing their second effort on new ways of diagramming, rather than on explaining their conceptual ecology.

The remaining participants were evaluated with a much greater interval between treatments, and it is unlikely that these participants remembered the pattern of their initial diagrams. The data gathered on the other participants also provides support for the consistency of the diagrams in characterizing the conceptual ecologies. As noted by Instructor I1, participants' initial and second diagrams retained characteristic traits (e.g., the *qualitative-quantitative* bifurcation of Participants C and D).

How Trustworthy Are the Characterizations of the Ecological Structures?

Guba and Lincoln (as cited in Guba, 1980, p. 139) noted that "trustworthiness" must be determined through the criteria of truth value, applicability, and consistency. One of the most effective ways to assure this is by "testing the data with members of the relevant data source groups" (Guba, 1980, p. 140). In this instance, the relevant data source groups were the students and the instructors.

The participants and I provided an element of trustworthiness during diagramming by ascertaining and confirming the truth value of each participant's statement. This helped to ensure that subsequent evaluations were not based on faulty assessments of the participant's intent. Second, the researcher also conducted a "blind" review with instructor I1. This review suggested the conceptual changes noted appeared to be explainable and consistent (from the instructor's perspective) within the context of the data. Diagrams that suggested the participant was a novice (e.g., Participants B and D) changed in ways that appeared to be consistent with their level of expertise.

Comparisons of the diagrams with the repertory grids and interview data suggest that there is a basic element of trustworthiness in the diagrams. For example, the consistency with which *qualitative-quantitative* bifurcation was evidenced in both diagrams and repertory grid matrices. However, the diagrams require interpretation, and users must exercise caution lest they read too much into the diagram. When combined with the repertory grids, the diagrams become much more interpretable.

Is the Methodology Sensitive to Changes in the Conceptual Ecology?

That is, given a pre-post assessment, is there a perceptible change in the conceptual ecology, and if so does it more closely resemble the instructor's? Over the course of time, and given exposure to instruction, one would expect conceptual ecologies to demonstrate some change (Posner, Strike, Hewson & Gertzog, 1982). Answering the second question first, in their work with diagramming, Champagne, Klopfer, DeSena, and Squires (1978 and 1981) found that student diagrams (and the implied cognitive structure) more closely resembled those of the curriculum and the teacher following instruction. However, their study employed a very "broad" evaluation that based evaluations of similarity on increased structural complexity (i.e., the more complex, the more it resembled the instructor). By the same measure, a conceptual structure that shifted towards shared understanding might be considered to resemble the instructor—it might also be considered to resemble several other peoples', as well. This study did not uncover any data that would suggest a resemblance between a specific instructor's conceptual ecology and the students'.

Answering the first question, to gauge sensitivity to change, I employed repertory grid matrices (Kelly, 1955) as an external assessment of change to conceptual structure. Rooted in personal construct psychology, the repertory grid matrix can provide an empirical method of gauging conceptual structure and its changes. "Repertory grid techniques elicit knowledge indirectly by prompting individuals for critical elements and relevant constructs in a coherent sub-domain." (Shaw & Gaines, 1995, p. 1). The repertory grid matrix provided additional insight into each participant's frame of reference. Also, comparing repertory grid matrix data with diagram and interview data should allow a fuller understanding of the individual conceptual ecology.

Comparisons between Participant C's repertory grid matrices suggested a highly developed conceptual ecology that resembled the instructors' more than the other participants; Participant C's diagrams also suggested a highly developed conceptual ecology. Unfortunately, Participant D did not complete the final repertory grid matrix, so the diagrams cannot be used to provide a sensitivity check on Participant D's diagram. However, comparisons of Participant A's and B's respective pre- and post-treatment repertory grid matrices suggested that conceptual structures had changed slightly. Participant A's repertory grid matrices suggested that Participant A was much more capable of discriminating between the concepts and that participant B was only slightly more capable. In both instances, their respective diagrams also suggested this. As evidenced by the repertory grid matrices, the diagramming was sensitive to changes in the participants' conceptual ecologies.

Implications

In performing this study I assumed, at least initially, that conceptual change is in many respects unique to individuals, although the changes may be influenced by shared understandings among groups. I sought to develop characterizations of cognitive structure (conceptual ecologies) derived, in part, from diagramed relationships. As an idiographic effort (as opposed to a nomothetic effort), this study represents a grounded theory approach that incorporated elements of comparative analysis.

The data suggested that the utility of the diagrams lay not only in the relationships between the concepts, but in the gestalt created by the entire diagram. Participants' diagram data, combined with data gathered through repertory grids and interviews indicated two areas in which conceptual change might be characterized. These areas are "structure" and "understanding."

Structure generally progressed from simple to elaborate, a finding supported by Champagne, Klopfer, DeSena, and Squires (1978). Understanding, in terms of the degree to which concept use was congruent with that of the instructors (as representatives of a larger community), was demonstrated by an increase in shared understanding in the use of concepts. With the exception of participant C, all participants' diagrams demonstrated somewhat more elaborate structure and increased shared understanding.

All second diagrams, except Participant C's, were characterized to some extent by structural change and shifts towards shared understandings, when compared to their respective initial diagrams. (Participant C's understanding of the concepts were already highly shared). The most interesting feature of this structural change was the use of clustering. Although not directed to do so, each participant employed clustering to a much greater extent in their second diagrams than in their first diagrams. Even Participant C developed a more elaborate second diagram, employing nested clusters in the central core. The increased elaboration evidenced by clustering suggests changes in the intensional and extensional relationships within the conceptual ecologies.

Extensional relationships, when viewed within a given domain or context, suggest conceptual relationships that determine set membership, either inclusively or exclusively. Changes to this structuring suggest that concept learning has taken place (Jonassen, Beissner & Yacci, 1993; Klausmeier, 1976). In such instances, concept learning influences how the learner includes (or structures) the new concept to his or her current ideas (Strike & Posner, 1985). Recognition that multiple concepts are related to each other in the context of a larger (superordinate) concept implies an ecological state of relatedness and class membership; change to that superordinate or subordinate relationship suggests that the ecology has been altered.

Intensional relationships are coordinate – successive (Tennyson & Rothen, 1977) relationships. These relationships bridge between concepts of differing classes and sets based on the connotations (implications) of each concept within a given context. By linking or clustering between concepts in the diagrams, participants attempted to bring relevant knowledge to bear (Medin, 1989). Changes in these relationships suggest an increased ability to recognize, and to discriminate between concepts with similar or overlapping attributes or properties; something that is fundamental to concept learning (Gagné, Briggs & Wager, 1992; Klausmeier & Feldman, 1975; Klausmeier, 1976; Tennyson & Cocchiarella, 1986; Tennyson & Park, 1980; Tennyson, Tennyson & Rothen, 1980).

As diagrams became more elaborate, participants brought more knowledge to bear on the diagramming task. The relevance or irrelevance of the knowledge, in the context of the instructors' diagrams, suggests the degree to which the participant's understanding of the concept is shared with that of the instructor. What is unclear, however, is whether the development of more elaborate structures and shared understandings are interrelated, or if they are independent factors related to the diagramming process—and by inference to conceptual change.

As depicted in Figure 5-1, the most advanced participant, Participant C, provided the

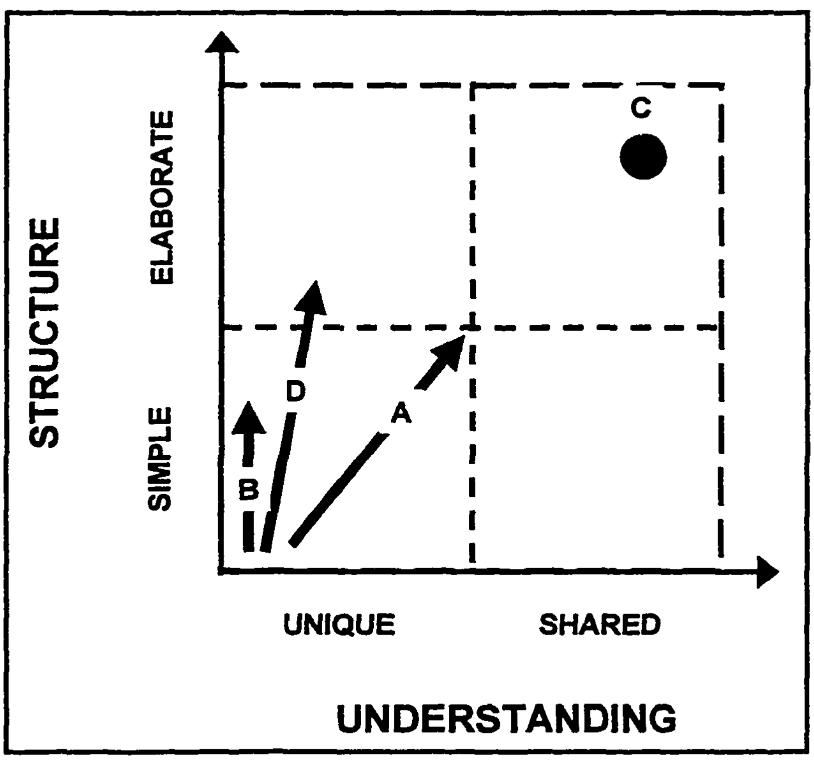


Figure 5-1. Relationship between structure and understanding.

most elaborate diagrams. Increased numbers of unique understandings seemed to be consistent with less elaborate levels of structure (Participants A, B, and D). It would seem that the development of shared understandings was related to the development of elaborate structure. However, before these relationships can be pursued further there are important methodological issues that must be answered concerning the value of the data collected.

Methodological Issues

Of all the methodological issues remaining, three strike me as fundamental to future use of diagramming. At the heart of the matter is whether the diagram actually reflects the participants' conceptual structures and the actual meaning of the diagrammed relationships. Even more fundamental to this discussion is the manner in which this methodology relies on idiographic data, and the attempt in this project to draw nomothetic conclusions from that data.

Meaning of Linked and Clustered Relationships

All participants demonstrated clustering in their diagrams. Even though no participant was asked to cluster, all participants employed this method of describing ways in which concept labels were related. Asch and Zuckier (1984) noted a tendency for subjects to organize attributes around a central trait. Clustering provided the participants the opportunity to do that.

Differences in clustering and linking were exhibited between participants with less experience and those with greater experience. Chi, Feltovich, and Glaser (1981) noted that the kinds of categories imposed on stimuli were fundamentally different between experienced and unexperienced subjects. While novices (within a selected discipline) tended to categorize the problems by their surface features, experts (within the same discipline) tended to organize problems in terms of underlying principles. Chi, Feltovich, and Glaser (1981) referred to this difference as surface and deep structure. In this case, participants used two bases of similarity to establish coherence within categories, one by novices and the other by experts.

This could provide an explanation into the unique understandings exhibited by some of the participants. In general, it would appear that the less experienced participants linked and clustered the concepts from a standpoint of surface structure (e.g., Participant A's use of *ethnography*). Likewise, it would appear that the more experienced participants (i.e., Participant C and the instructors) drew upon a deep structure to organize their diagrams.

One way to explore that relationship would be to collect more information on the traits and features attributed by the participant to each concept. This would support gathering critical information concerning each concept of the ecology. The benefit would be that instead of just learning that the concepts were linked or clustered, the methodology would gather information on the possible reasons they were linked or clustered. If we knew this we would have a better understanding of what the links represented. It would give us a better idea of what knowledge they were bringing to bear and why.

The Role of Discipline Structure and Varying Levels of Experience

The strongest evidence that the methodology tapped into some aspect of conceptual structure is *qualitative-quantitative* bifurcation. In Participants A and B *qualitative* and *quantitative* were separate concepts, but concepts that did not structure the conceptual ecology. Participant C's diagram evidenced a prominent *qualitative-quantitative* bifurcation; one which influenced the placement of many other concepts in the diagram. Furthermore, Participant C's repertory grid also suggested that this participant structured their conceptual ecology in terms of *qualitative* and *quantitative*. Participant D's diagram also evidenced a prominent *qualitative-quantitative* bifurcation, as did Participant D's repertory grid, although to a lesser degree.

Participant C's and Participant D's *qualitative-quantitative* bifurcations differ, however, in terms of integration. Participant D's *qualitative-quantitative* bifurcation was much more dissociative (i.e., it divided the domain into two separate functions). This points to a role for varying levels of expertise in the diagramming process. As noted by Ryan (1984), inexperienced students typically develop "primitive conceptions of knowledge" that are unorganized, discrete, and absolute—a description that seems to fit Participant D's diagrams. Participant C's *qualitative-quantitative* bifurcation, on the other hand, was much more integrative. Only Participant C's *qualitative-quantitative* bifurcation evidenced what Ryan referred to as a more mature conception of knowledge, an interpreted and integrated array (Ryan, 1984, p. 248).

There also appears to be a role for discipline structure that the diagramming methodology must address. Regardless of the level of organization evidenced in diagrams, one must ask whether a principal concern of Strike and Posner (1976) was answered by the methodology. That is, does the *qualitative-quantitative* bifurcation evidenced in the diagrams reflect the participant's conceptual structure or only the conceptual organization of the discipline? The *qualitative-quantitative* bifurcation may be nothing more than the participants' attempts to describe information from the domain structure with their existing conceptual ecologies.

West, Farmer, and Wolf (1991) also noted that the relationships used in this project (to describe the diagrammed links) tend to reflect curricular distinctions, recognized by bodies of experts, not necessarily conceptual relationships. Furthermore, they noted that there is still a question as to whether changes in these relationships, captured during concept mapping, reflect true conceptual change. One possible means for addressing this question would be to investigate whether this bifurcation would be evidenced while the participants performed intellectual tasks in the discipline of educational research, as suggested by Strike and Posner (1976).

Using idiographic data for idiographic purposes.

An important concern for this methodology is reliance upon idiographic data for nomothetic conclusions. If this methodology is to provide utility to future research efforts, then we must find a way to draw idiographic conclusions. The source of this fault lies in the comparisons between participants, especially participants with limited experience. Each participant developed their own diagram, based on differing experiences and expectations. Comparisons across participants are rather suspect. While the data suggest that general conclusions are appropriate (i.e., general differences in structure and understanding), these findings gloss over the deeper issues of individiual conceptual structure.

A more productive approach would be to focus on idiographic data concerning what each participant understood about the reasons that they changed their diagrams. (We cannot really assume that changes in the diagram reflect changes in the cognitive structure; however we can expect that explanations of why participants changed their diagrams might shed light on the metacognitive aspects of conceptual change). By using the same diagram, and periodically revisiting it, we might gain access to metacognitive insights that allow the participants to address what they think they know about their knowledge, and to inquire as to what triggered any changes in the diagram. Additionally, the methodology could support idiographic comparisions if participants completed at least diagrams, one from a discipline in which they were experienced, one from a discipline in which they were inexperienced.

Further Questions

Reviewing the data collected, and questioning its utility, suggests where the methodology should be changed. To better understand the meaning of participants' linking and clustering, the methodology needs to provide for the gathering of additional information concerning the traits and attributes of the concepts used in the diagramming process. This would necessitate using a much smaller set of concepts, in order to maintain manageability but would support analysis of the links and clusters in terms of the participants' use of surface or deep structure. The issues of discipline structure and expertise indicate that diagramming should take place within the context of the discipline performance and varying levels of expertise. If the methodology relies upon idiographic data, then comparisons across participants become less useful, and there must be a means of comparing data from the same participant. Comparisons of participant data over time, which the current methodology supported, should be augmented with additional information that includes varying levels of expertise.

One way to accomplish this would be to ask participants to complete at least two diagrams; one in a discipline with which they had experience and another in a discipline with which they had little experience. Comparisons of expertise would not take place between participants, rather they would take place between the diagrams of the same participant. This also would require using a smaller set of concepts, in order to facilitate the development of multiple diagrams per participant; it would also reduce the problems associated with the development of nomothetic conclusions based on idiographic data.

In addition to these issues, the data raises other questions that suggest areas for future research. For example, what role does discipline structure, and factors such as level of experience and degree of specialization, play in characterizing shared understanding? This project studied educational research; a discipline in which shared understanding is somewhat open to question, given the encouragement of multiple perspectives. This makes assessments of the degree to which understanding is shared very problematic. Some disciplines (i.e., theology) encourage multiple perspectives to some degree, however others (i.e., military art and science) may not. How would the development of shared understanding compare between a structured and less structured disciplines, for example military disciplines and theological disciplines?

Also, the question of when to administer the diagramming exercise must be addressed. This concerns when the initial diagrams should be developed and the frequency with which the diagrams should be revised. Supposedly, idiographic data would be collected at different times and frequencies for each participant. However, this could prove to be logistically unsupportable given a large body of participants. This also raises the issue of identifying the events in a partcipant's experience that would necessitate data collection. If one is willing to accept some imperfection, then the question can be reduced to frequency of data collection. Extensive lists of concepts to be mapped become burdensome to the participant when administered with great frequency. If the methodology calls for collecting additional information on each of the concepts, then the burden on the participant is increased. Reducing the concept list will reduce the burden on the participant and allow for more administrations.

Determining the actual frequency is difficult. However data from the test-retest pilot suggests that short intervals between collection efforts may gather questionable data when administered to participants with less experience in the selected discipline. The test-retest pilot was conducted within a 24-hour period. There was a possibility that short-term reflection on the concepts under consideration may have affected P2's second diagram. If conducted in conjunction with scheduled instruction, a collection schedule that is synchronized with the class schedule might be advisable (e.g., weekly or bi-weekly data collection).

Related to frequency, is the issue of whether to create new diagrams each session or to revisit the same diagram each time. During this project, participants constructed new diagrams each session. This approach created difficulties in determining why changes occurred. By revisiting the same diagrams, however, participants would be able to comment, reflectively, on how they would change their diagrams.

In addition to experience and specialization, maturation must be addressed. Specifically, what features of the diagrams can be attributed to the participant's age? I limited this study to adults. However, what can we learn about the development of conceptual ecologies (and conceptual development in general) by investigating the role of structure and understanding among participants of other age groups? For example, can we show developmental differences that compare to Piaget's Genetic Epistemology?

In this study, the participants demonstrated a tendency to develop elaborate structures as they developed shared understanding (i.e., as their understanding, as depicted in the diagrams, became more congruent with that of the instructors). This suggests that elaboration may go hand-in-hand with the development of shared understanding. With changes in the instructional process, could students progress towards the development of shared understanding without appreciable elaboration?

Part of gaining insight to the elaboration attendant to conceptual structures should be determining what knowledge participants are bringing to bear in each instance. The technique shows where participants bring knowledge to bear, in some places (i.e., participants demonstrate how they bring knowledge to bear by linking concepts). However, the links still provide limited information on why that information was brought to bear. Requiring participants to attached descriptors or characteristics to each concept label might provide researchers with a better idea as to why participants brought select knowledge to bear. By gathering more comments, the diagramming technique would develop a stronger base of data concerning the knowledge and information that each participant is employing, with regards to that concept.

This project focused (almost exclusively) on self-reporting and comparing to self-reporting. However, to assess "shared understanding" this technique requires a means of anchoring itself within a "shared" context. The instructor provided some sense of a "shared" context during this effort, but to truly understand “shared understanding” requires additional shared data. Observing classroom activities more rigorously might provide this. Additionally, similar efforts might benefit significantly from direct observations of student performance.

Why Pursue Diagramming and Concept Mapping?

Naveh-Benjamin, McKeachie, Lin, summed up the state of measurements of cognitive structure by stating, "There is clearly a need for other techniques that not only measure distance from a standard but can also make comparisons in terms of other dimensions, such as amount of organization." (Naveh-Benjamin, McKeachie & Lin, 1986, p. 131). They noted several problems with assessments of cognitive structure. These include missing potentially important characteristics of cognitive structure through the use of averaging techniques, dependence on recall, passivity (they fail to take into account the dynamic aspects of cognitive structure), and reliance upon relatively small amounts of information (e.g., one to two chapters in a text over a short instructional period). (p. 131).

Assessments of cognitive structure should help us understand how the interconnections between concepts support procedural knowledge (Jonassen, Beissner & Yacci, 1993). It is the structural knowledge that allows the learner to link the concepts together in a manner that supports schemas, scripts, and procedures to function (Jonassen, Beissner & Yacci, 1993, p. 4). Goldsmith, Johnson, and Acton (1991) noted that knowledge of an area or domain requires an understanding of the relationships among its concepts. Diagramming methodologies may allow us to describe and explore those relationships.

Summary

In this study, I used the concept "research" to study the ways in which people combine concepts into meaningful structures called conceptual ecologies (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992). Conceptual ecology theory suggests that concepts "adapt to an intellectual environment [prior learning] much as organisms adapt to a biological environment" (Strike & Posner, 1976, p. 111). Conceptual ecology theory offers one avenue to examine changes in knowledge structures, but it requires methodologies that assess changes in the ecologies.

In this study I investigated one possible method for characterizing those changes. The participants of this study developed diagrams that depicted their perceptions of the relationships between concepts. In every instance, the diagrams appear to reflect a level of development consistent with the participant's expertise. I characterized the diagrams themselves, and by inference changes to the participants' conceptual ecologies in terms of structure and shared understanding. I based these characterizations on my observations and those of Instructor I1. However, further research is necessary to answering questions concerning those factors that, on the surface, appear to make the diagrams reflective of unique conceptual ecologies.

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Appendix A—Participant Concept Diagrams

Individual participant interviews were administered prior to each session of diagramming. Following the interview, participants were provided a set of concept labels and a sheet of backing material. The researcher read the instructions aloud and the participants then commenced to place their concept labels on the backing. The diagrams for participants P1 and P2 were part of the test-retest pilot. For each of these participants, their respective diagramming sessions were separated in time by approximately twenty-four hours. Participants P1 and P2 employed generic sets of concepts labels (i.e., the labels did not reflect a particular instructor's concepts) developed for a previous diagramming exercise.

The diagrams for participants I1 and I2 (the instructors) employed the same generic sets of concept labels. However, as the exercise progressed, I1 and I2 each contributed (or excluded) concept labels to clarify their diagrams. As a result, each instructor developed a relatively unique set of concept labels (i.e., I1's labels were unique to the masters-level instruction, I2's were unique to the doctoral instruction). Each instructor developed only one diagram.

Participants A, B, C, and D each developed two diagrams, employing the same procedures described above. Participants A and B were masters students; participants C and D were doctoral students. The important difference in these diagrams is that for each of these participants, their respective diagramming sessions were separated in time by one semester.

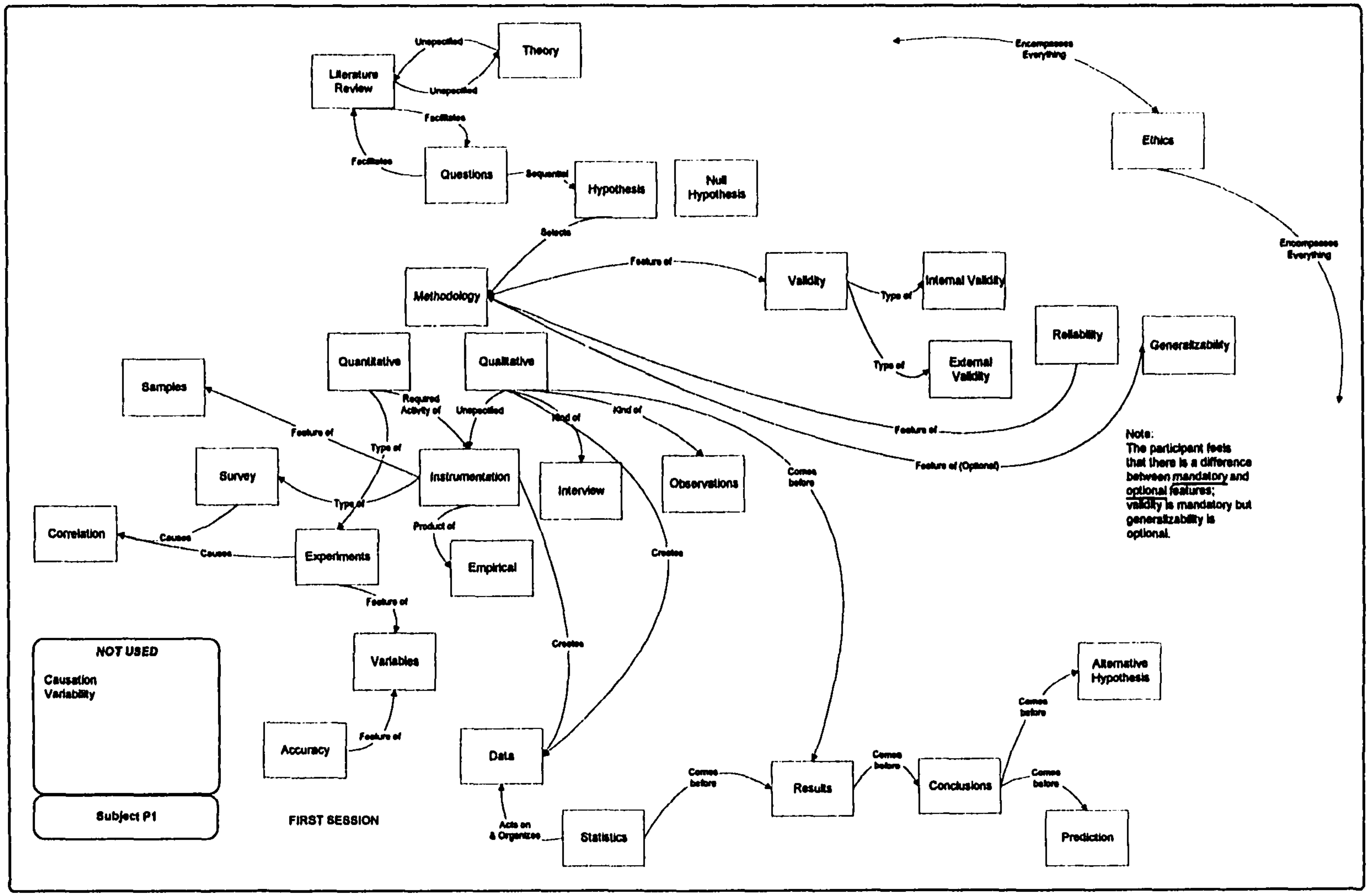

Figure A-1. Initial concept diagram for P1.

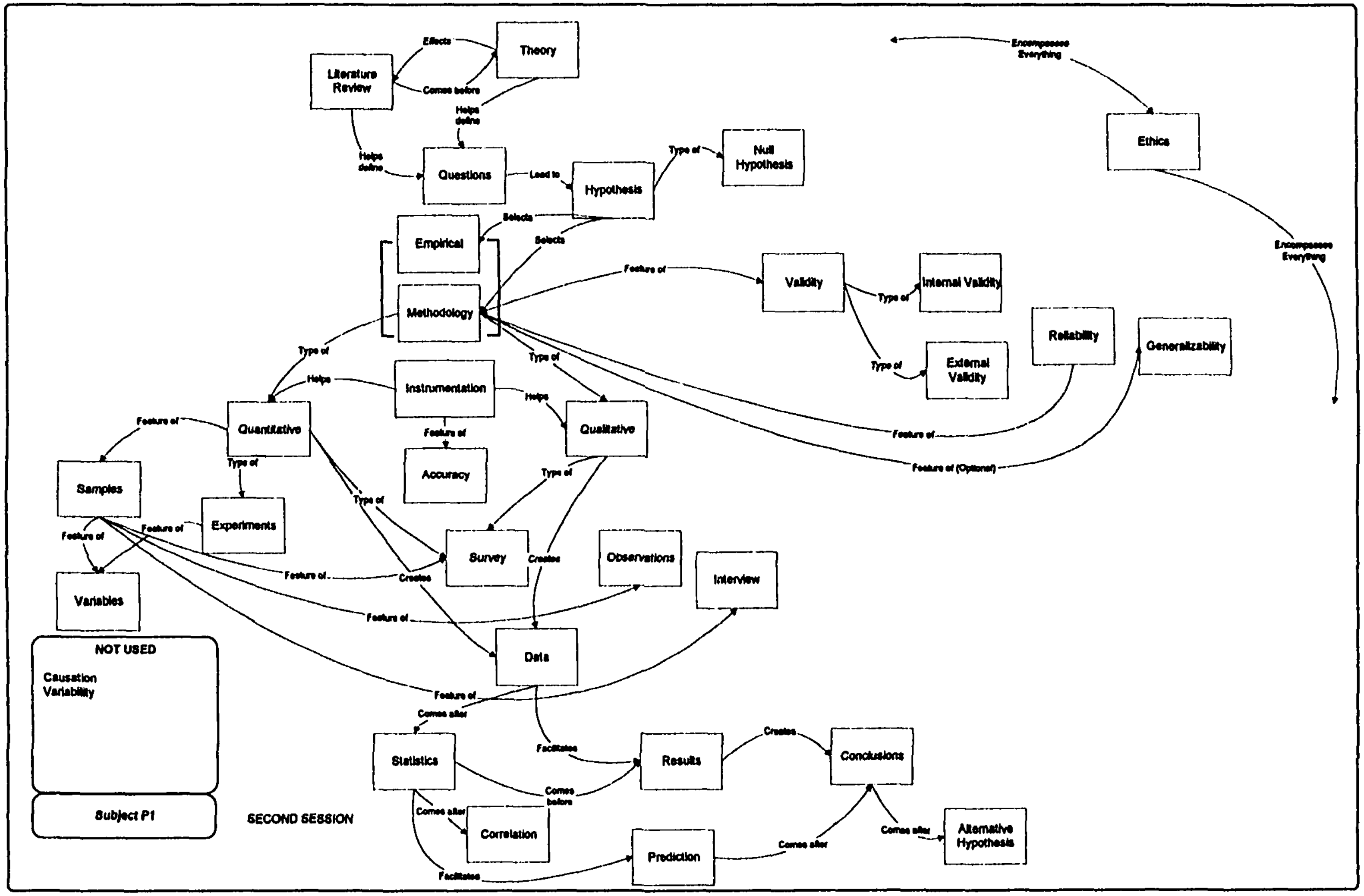

Figure A-2. Second concept diagram for P1.

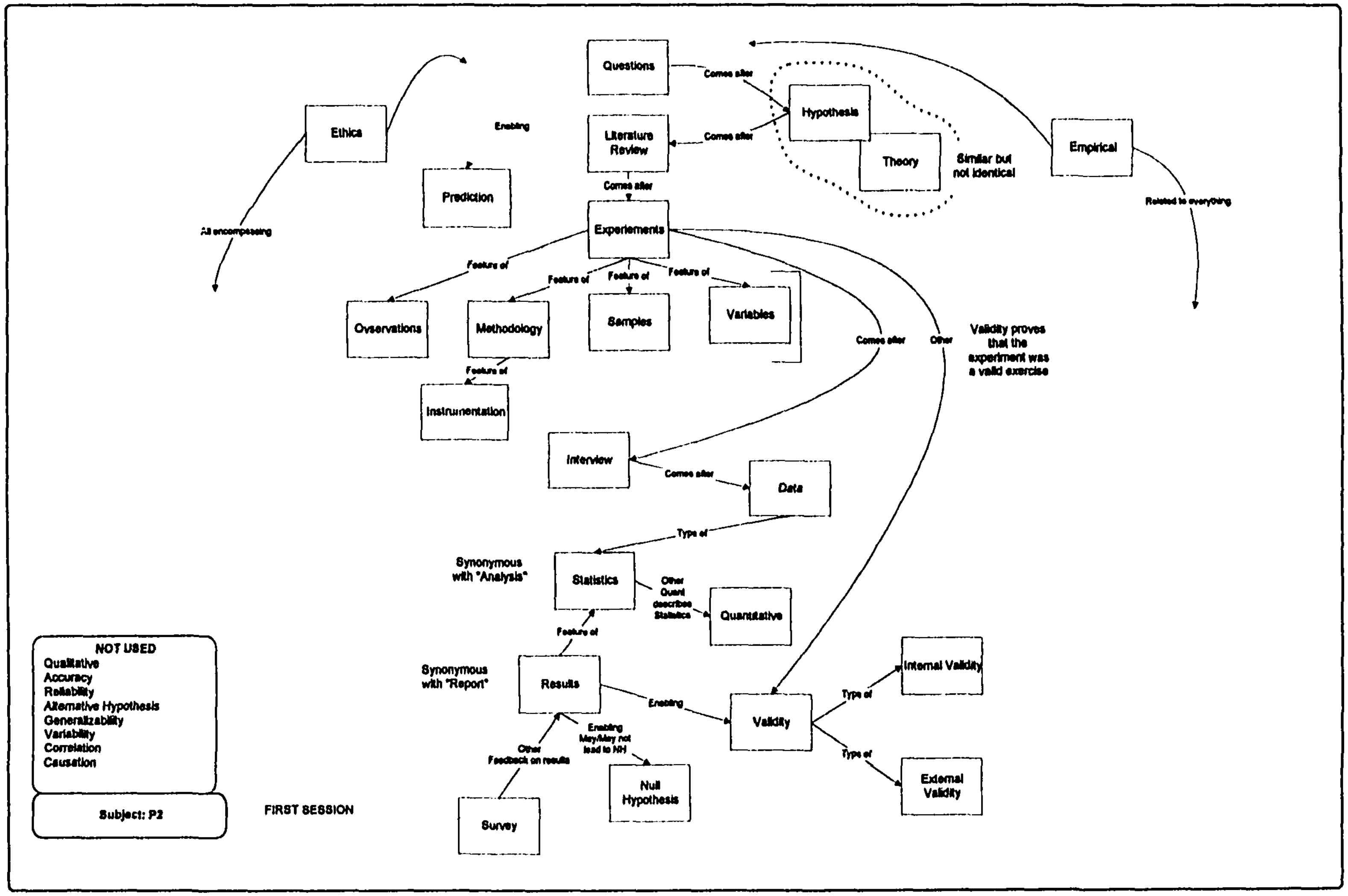

Figure A-3. Initial concept diagram for P2.

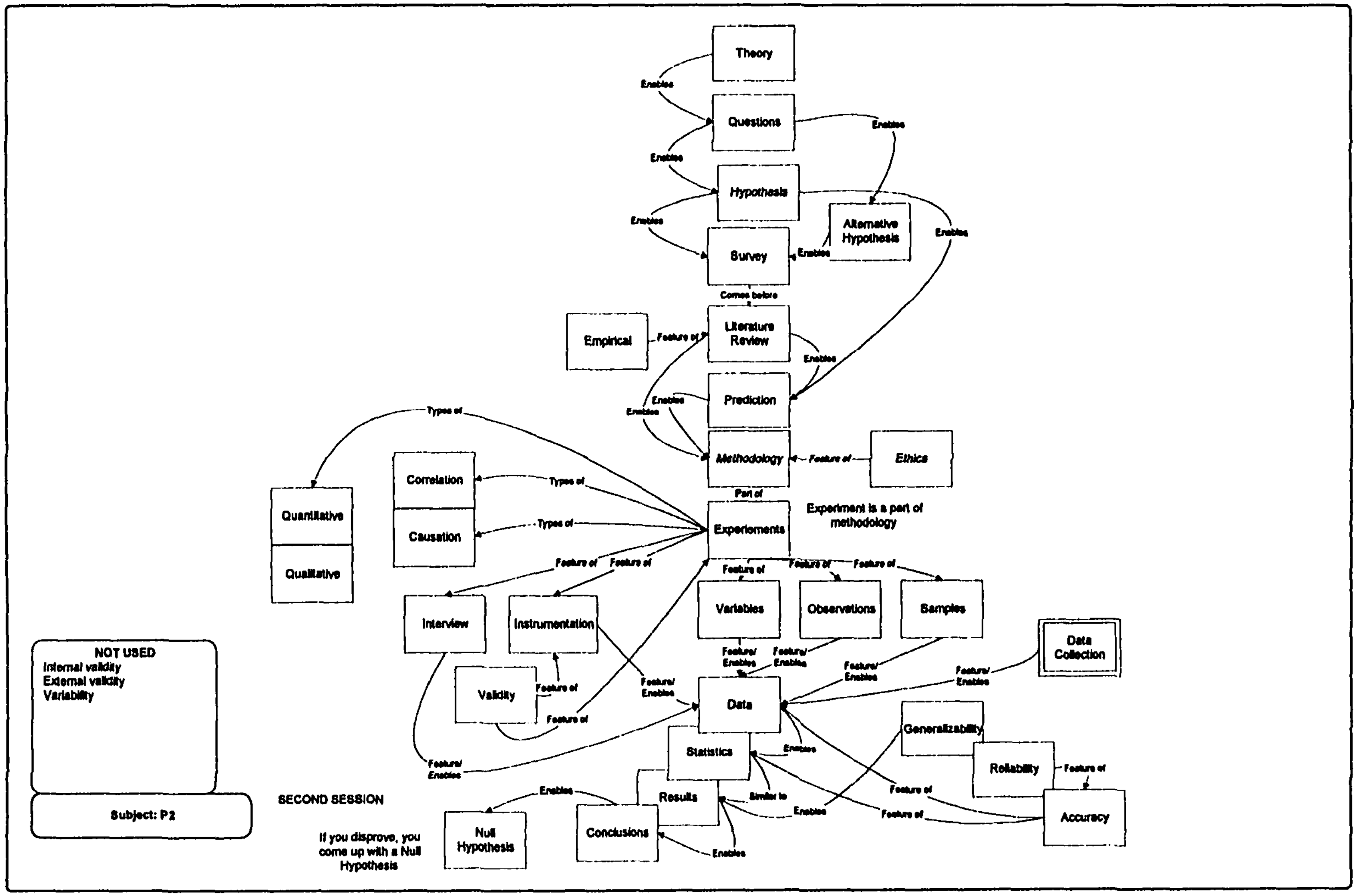

Figure A-4. Second concept diagram for P2.

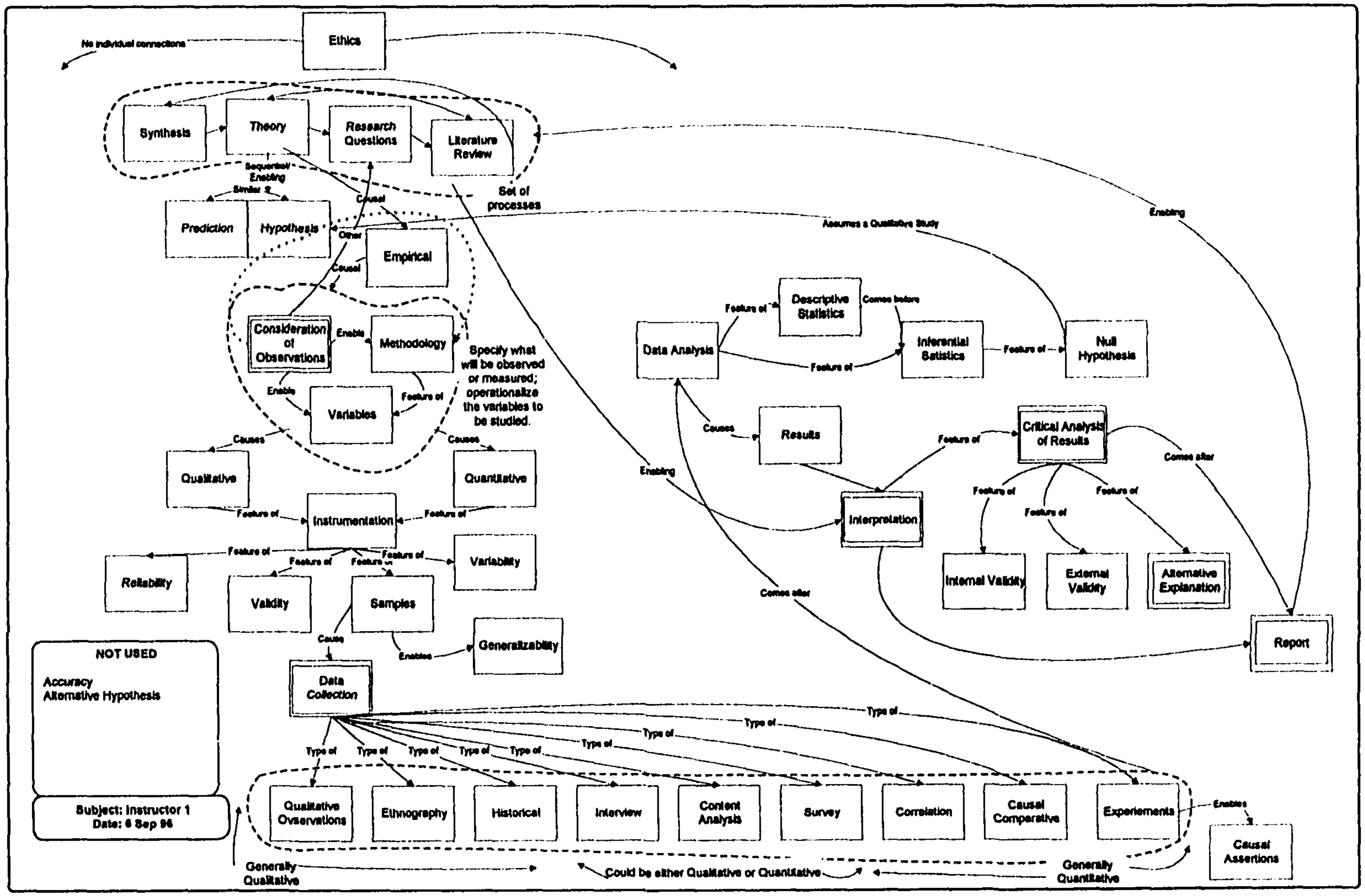

Figure A-5. Concept diagram for I1.

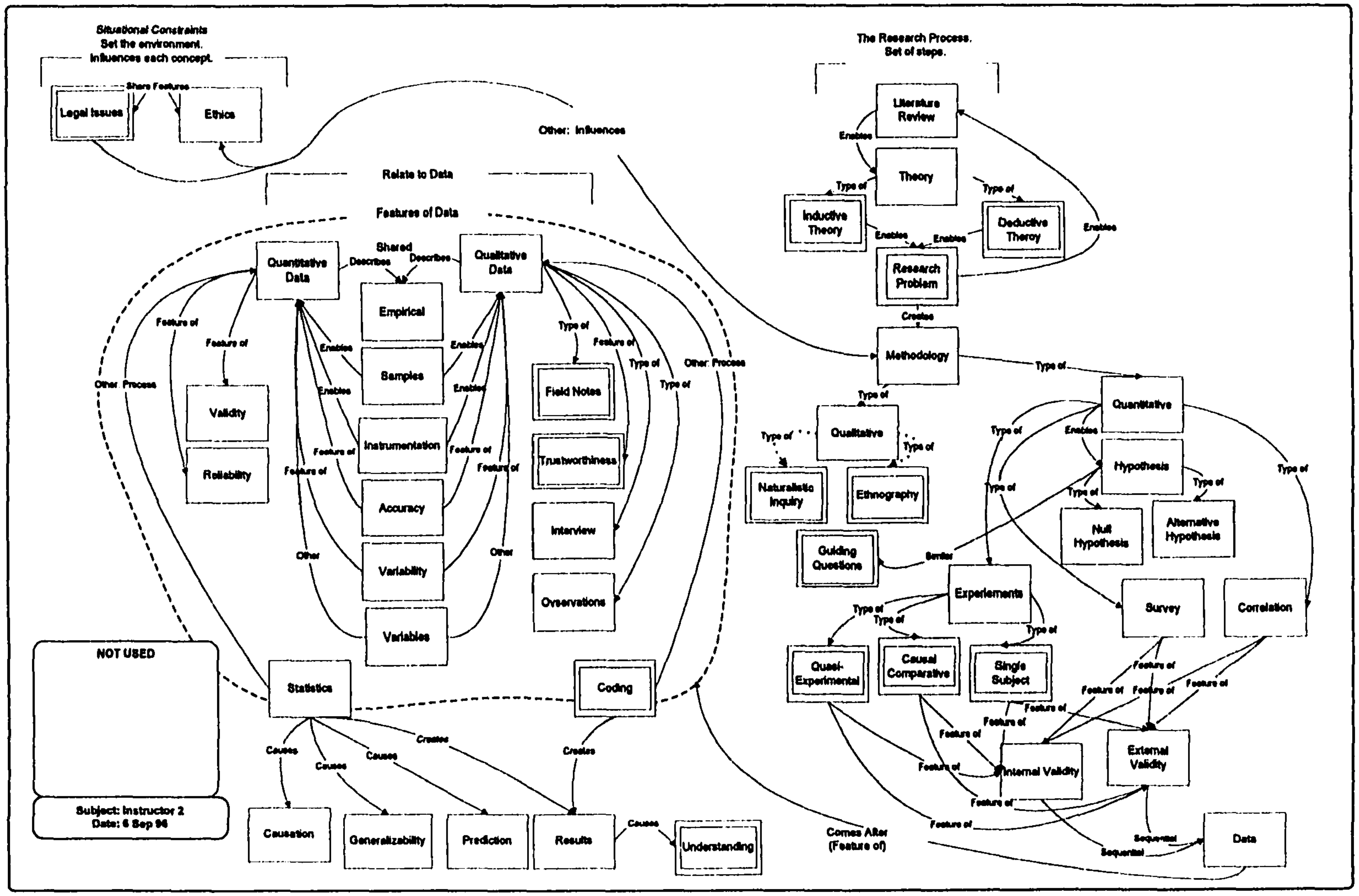

Figure A-6. Concept diagram for I2.

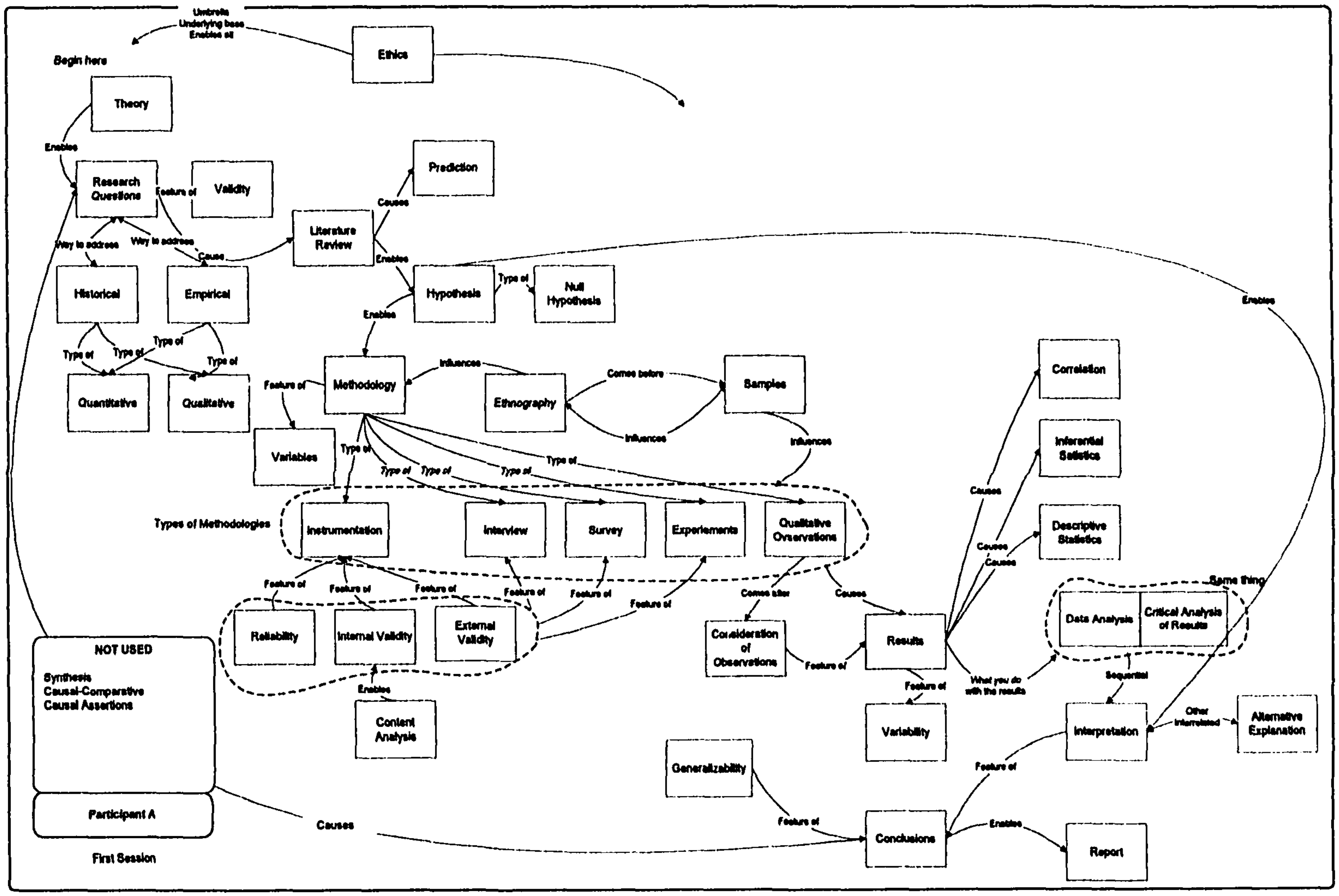

Figure A-7. Initial concept diagram for Participant A.

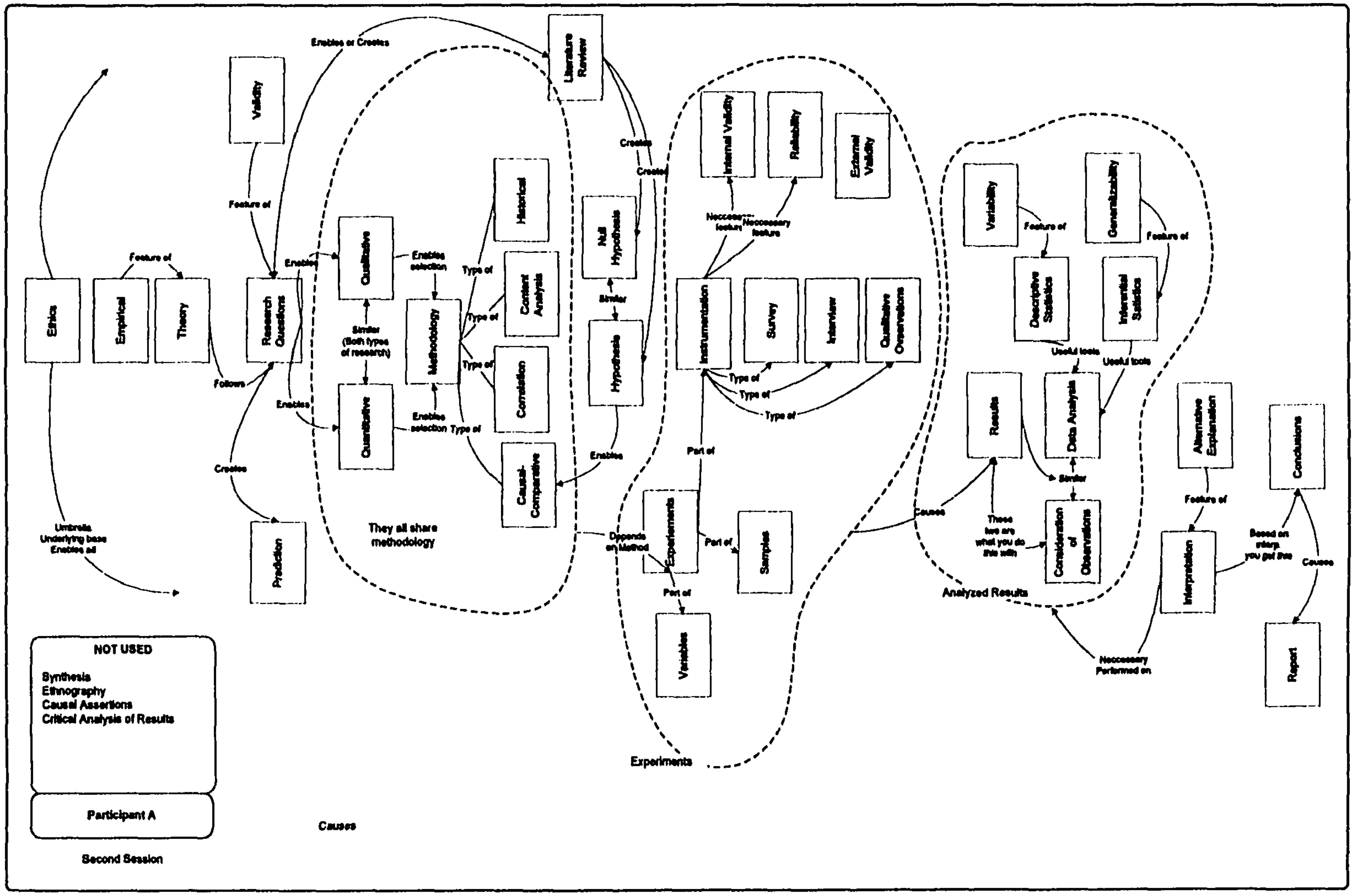

Figure A-8. Second concept diagram for Participant A.

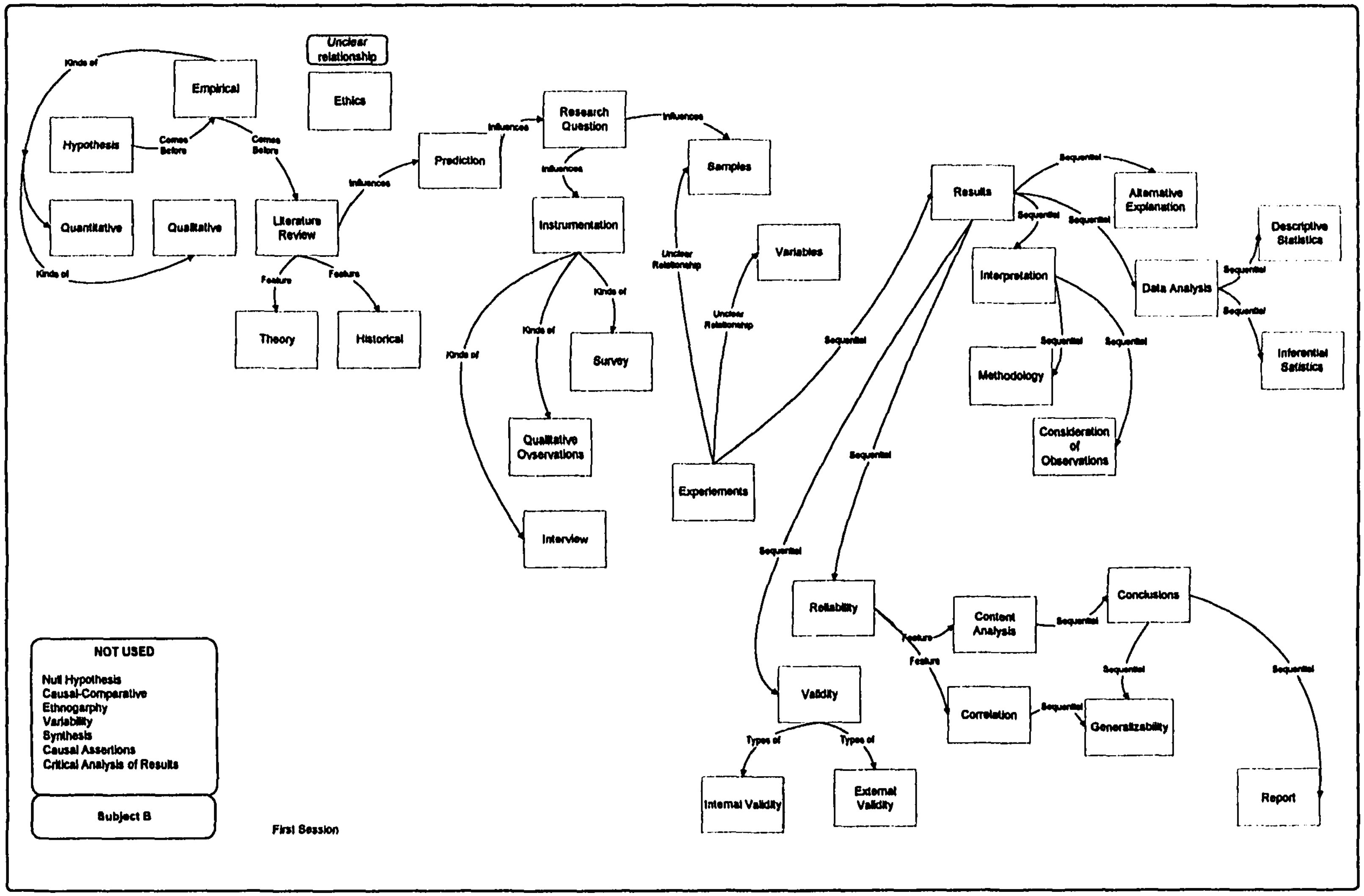

Figure A-9. Initial concept diagram for Participant B.

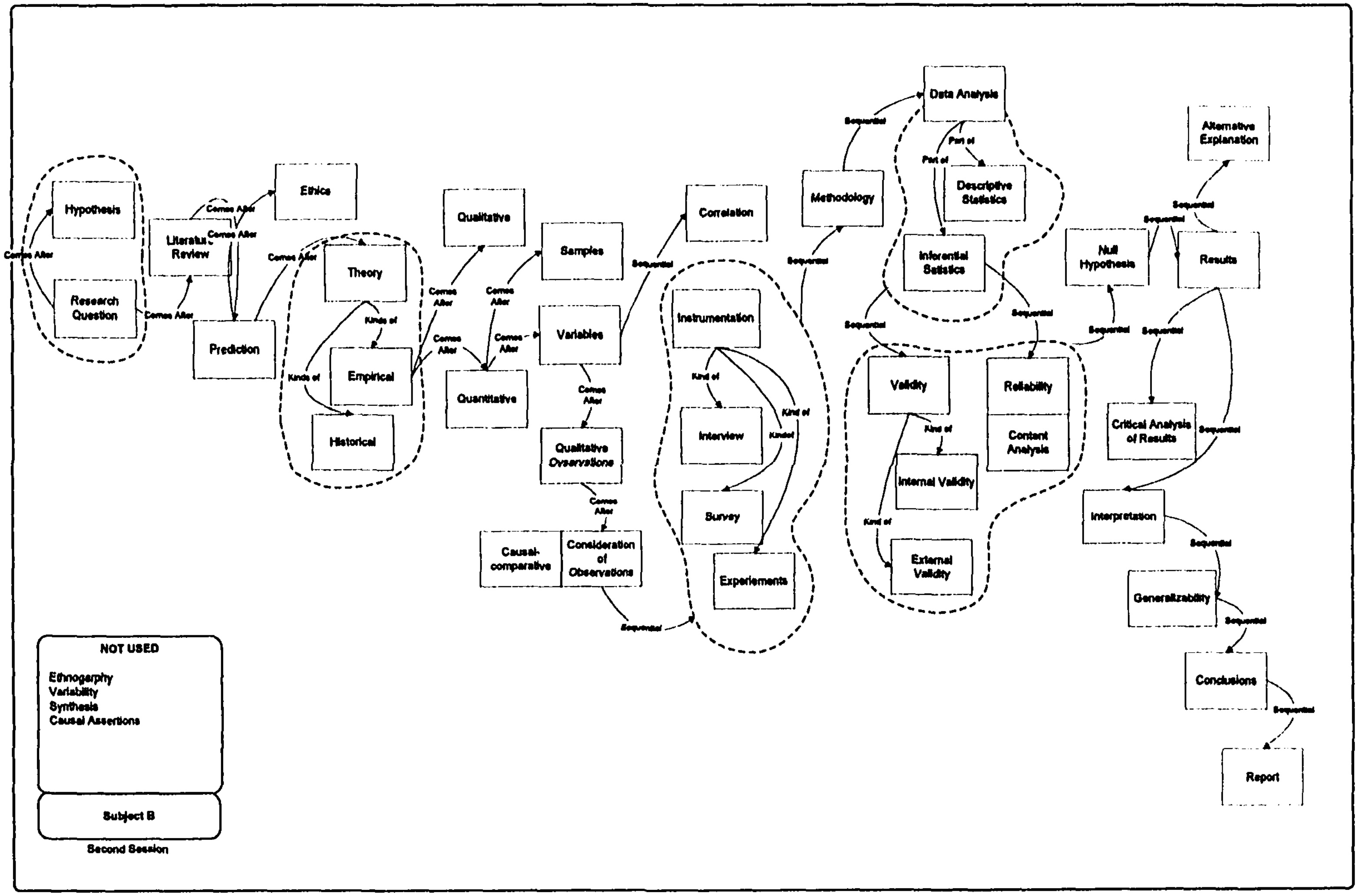

Figure A-10. Second concept diagram for Participant B.

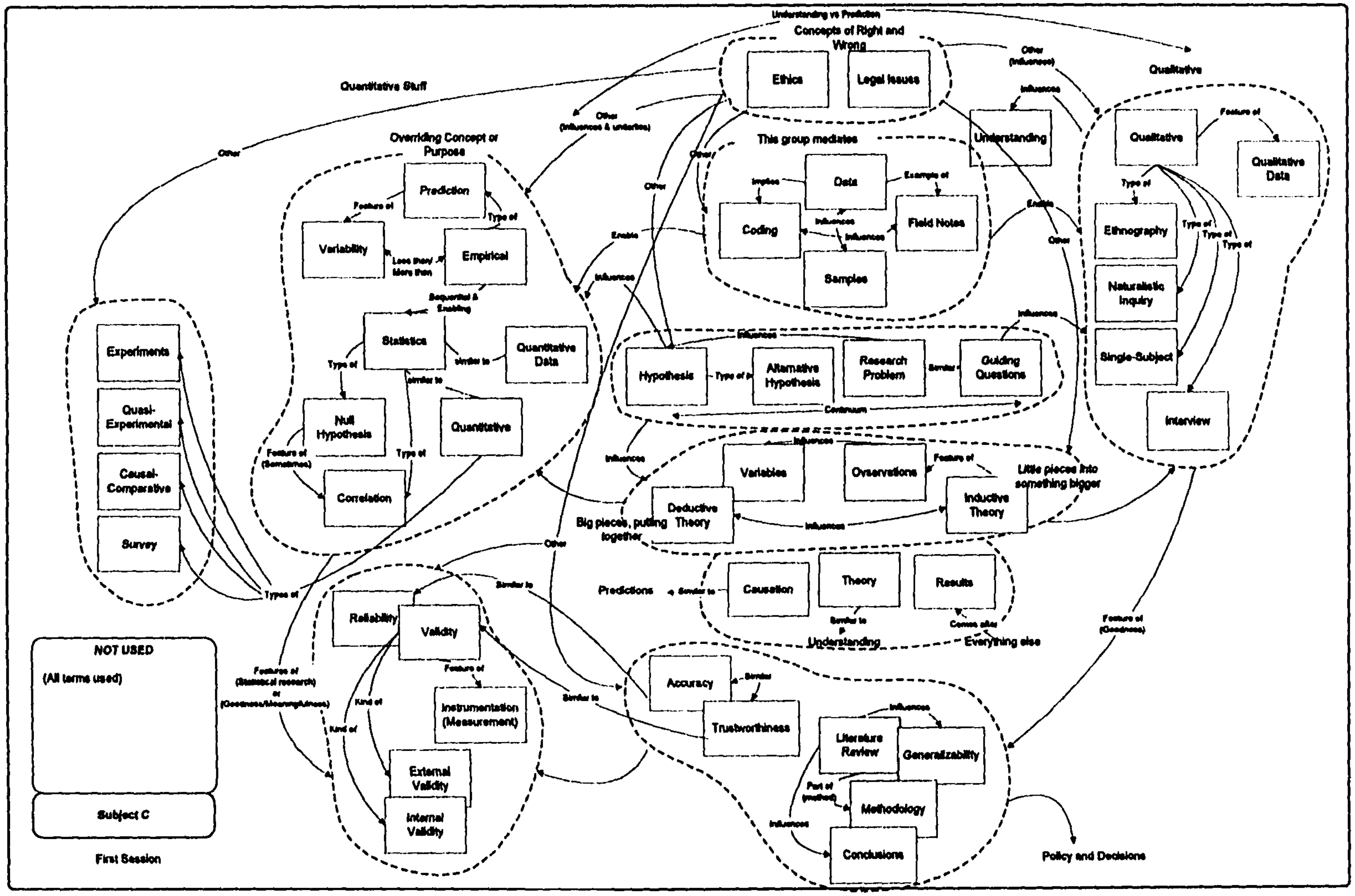

Figure A-11. Initial concept diagram for Participant C.

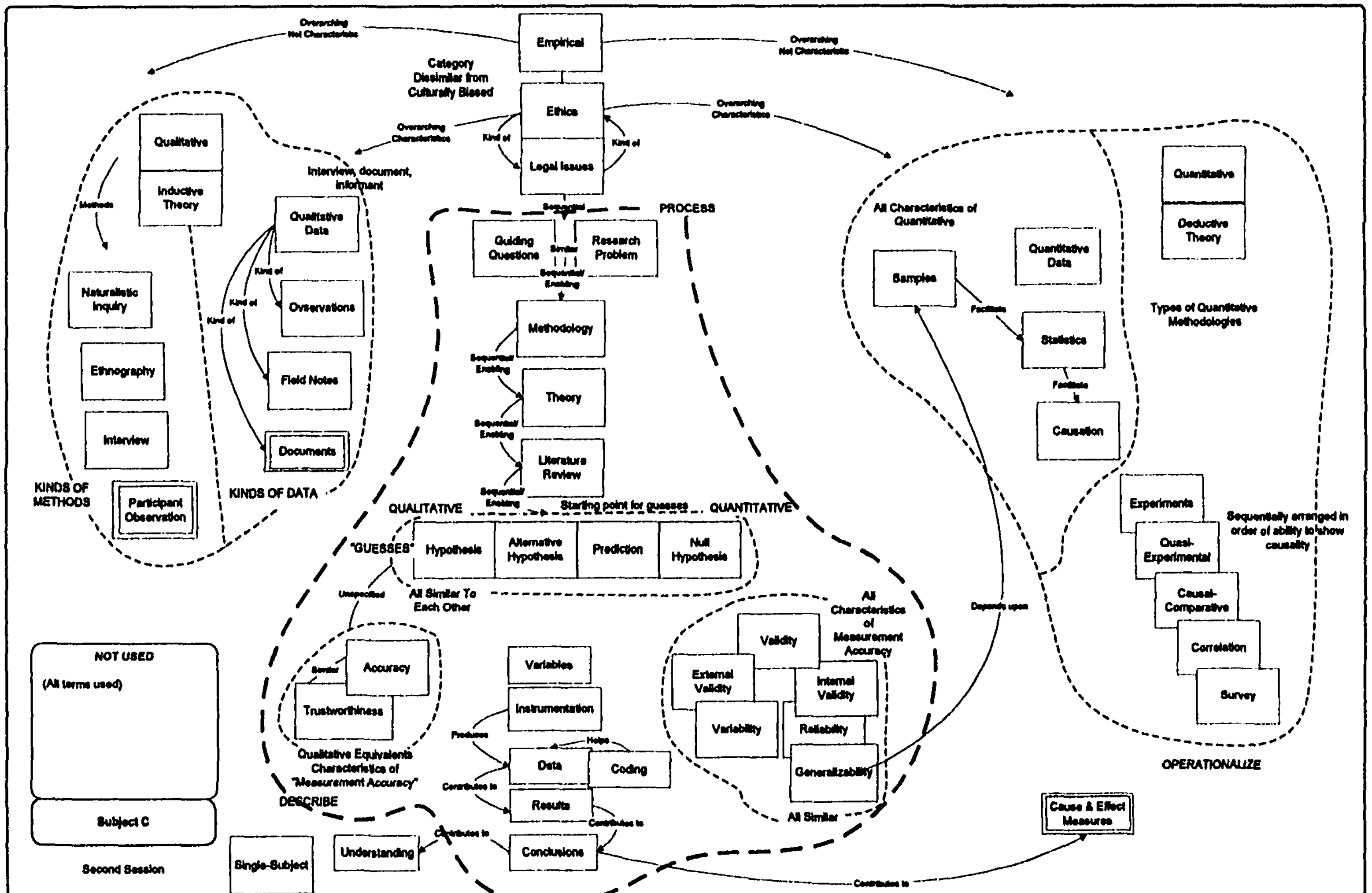

Figure A-12. Second concept diagram for Participant C.

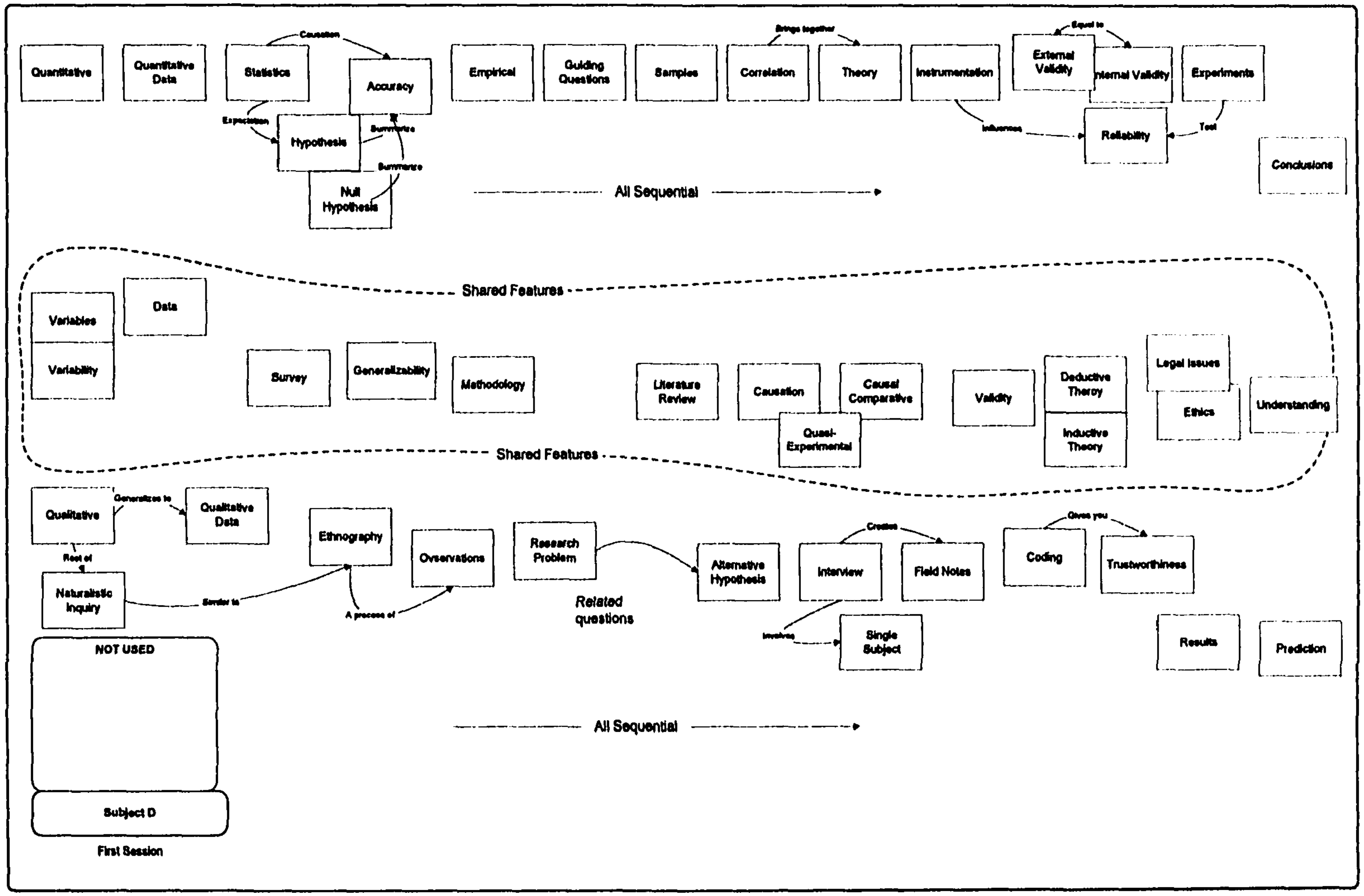

Figure A-13. Initial concept diagram for Participant D.

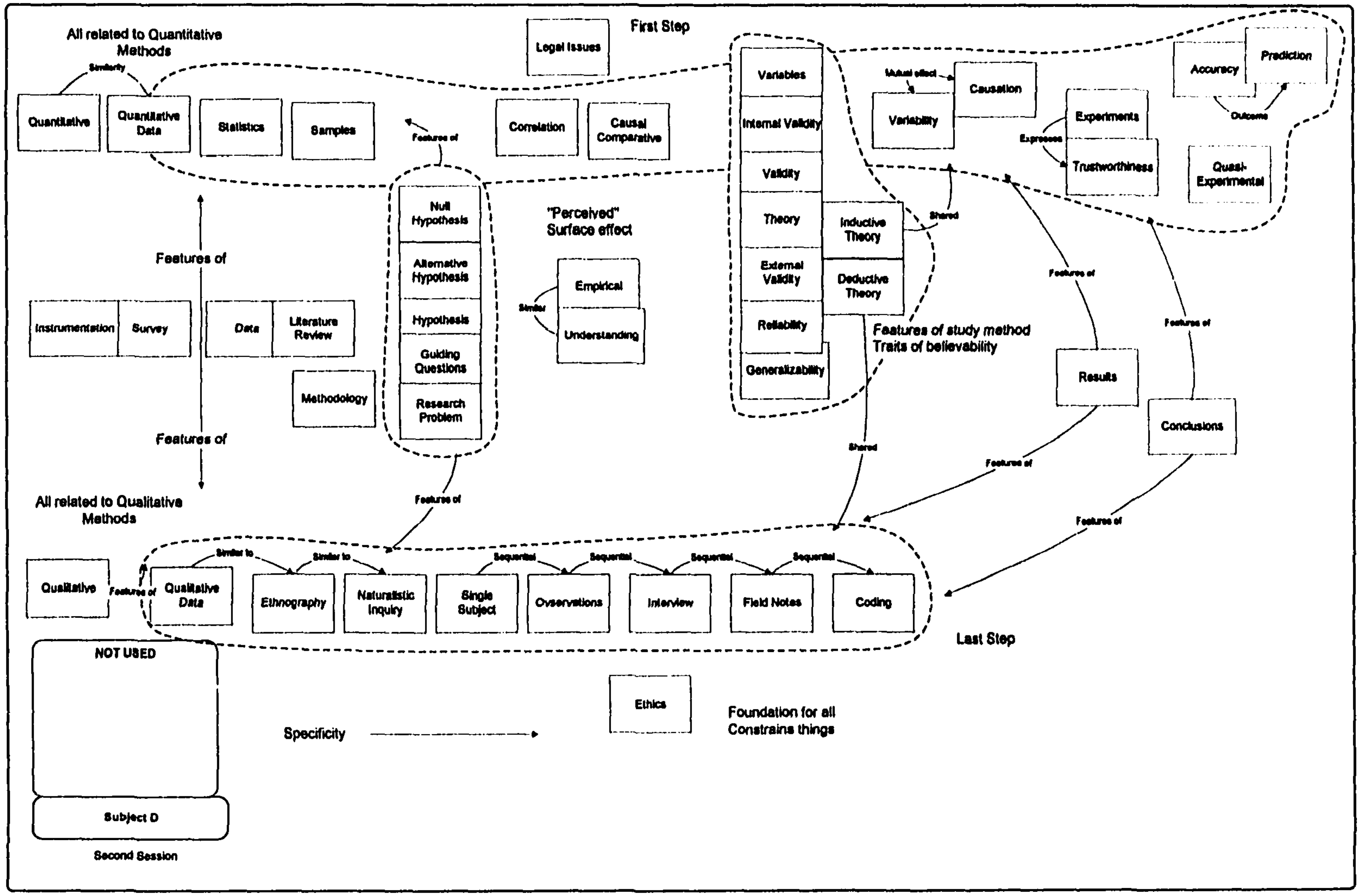

Figure A-14. Second concept diagram for Participant D.

Appendix B—Repertory Grid Elicitation Questionnaires

The purpose of the repertory grid was to gather additional information on participants' conceptual ecologies. Masters students (participants A and B) and doctoral students (participants C and D) completed elicitation questionnaires based on their respective concept labels (i.e., the concepts provided by their instructors).

1. Below are three concepts related to the process of "Research."

Theory	Data Analysis	Methodology

2. In terms of the "Research" process, how are two of these concepts similar and different from the third? (Please circle the two that are similar.)

3. In the following box (Box A), use a word or phrase to describe what makes these two concepts similar, and different from the third.

4. In the following box (Box B), use a word or phrase to describe what makes the third concept different from the other two.

A		B

5. Now, evaluate whether the term in box A or box B best describes each of the concepts below. If you decide that the term in box A best describes the concept, then place an "X" in the first of second block, depending on how well you think it describes the concept. If, however, you decide that the term in Box B best describes the concept, then place an "X" in the fourth of fifth block. If you are unsure, place an "X" in the center block. For each concept, place one "X" in the appropriate box.

	The term in Box A describes this concept VERY WELL.	The term in Box A describes this concept SOMEWHAT.	UNSURE	The term in Box B describes this concept SOMEWHAT.	The term in Box B describes this concept VERY WELL.
Alternative Explanation					
Causal Assertions					
Causal Comparative					
Conclusions					
Consideration of Observations					
Content Analysis					
Correlation					
Critical Analysis of Results					
Descriptive Statistics					
Empirical					
Ethics					
Ethnography					
Experiments					
External Validity					
Generalizability					
Historical					
Hypothesis					
Inferential Statistics					
Instrumentation					
Internal Validity					
Interpretation					
Interpretation					
Interview					
Literature Review					
Null Hypothesis					
Prediction					
Qualitative					
Qualitative Observations					
Quantitative					
Reliability					
Report					
Research Questions					
Results					
Samples					
Survey					
Synthesis					
Validity					
Variability					
Variables					

Figure B-1. Repertory grid elicitation questionnaire—Masters students.

1. Below are three concepts related to the process of "Research."

Theory	Data Analysis	Methodology

2. In terms of the "Research" process, how are two of these concepts similar and different from the third? (Please circle the two that are similar.)

3. In the following box (Box A), use a word or phrase to describe what makes these two concepts similar, and different from the third.

4. In the following box (Box B), use a word or phrase to describe what makes the third concept different from the other two.

A		B

5. Now, evaluate whether the term in box A or box B best describes each of the concepts below. If you decide that the term in box A best describes the concept, then place an "X" in the first of second block, depending on how well you think it describes the concept. If, however, you decide that the term in Box B best describes the concept, then place an "X" in the fourth of fifth block. If you are unsure, place an "X" in the center block. For each concept, place one "X" in the appropriate box.

	The term in Box A describes this concept VERY WELL.	The term in Box A describes this concept SOMEWHAT.	UNSURE	The term in Box B describes this concept SOMEWHAT.	The term in Box B describes this concept VERY WELL.
Accuracy					
Alternative Hypothesis					
Causal Comparative					
Causation					
Coding					
Conclusions					
Correlation					
Data					
Deductive Theory					
Empirical					
Ethics					
Ethnography					
Experiments					
External Validity					
Field Notes					
Guiding Questions					
Hypothesis					
Inductive Theory					
Instrumentation					
Internal Validity					
Interview					
Legal Issues					
Literature Review					
Methodology					
Naturalistic Inquiry					
Null Hypothesis					
Observations					
Prediction					
Qualitative					
Qualitative Data					
Quantitative					
Quantitative Data					
Quasi-Experimental					
Research Problem					
Results					
Samples					
Single Subject					
Statistics					
Survey					
Theory					
Understanding					
Validity					
Variability					
Variables					

Figure B-2. Repertory grid elicitation questionnaire—Doctoral students.

Appendix C—Repertory Grid Products

Data collected in the repertory grid elicitation questionnaire were analyzed using the University of Calgary's Web-Grid, which is accessible over the Worldwide Web (http://tiger.cpsc.ucalgary.ca/WebGrid). This tool records the results of the repertory grid elicitations and provides analysis in the form of repertory grid matrices and principal components analyses derived from each matrix.

The repertory grid matrices depict how each participant evaluated the concept labels (in terms of their own unique constructs). In the right-hand column of the matrix is a clustering of the concept labels and constructs, based on the percentage of matches within each cluster.

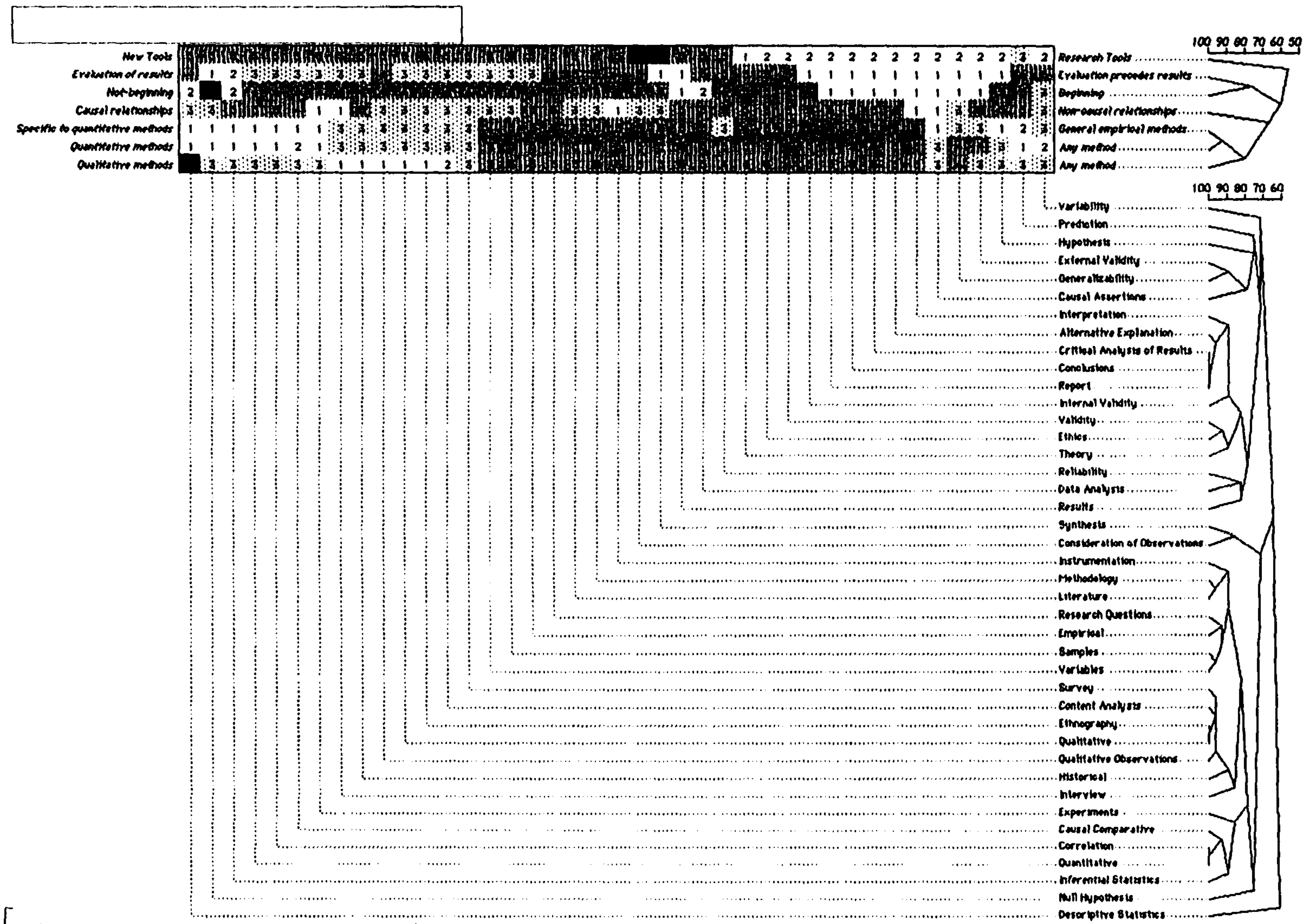

Figure C-1. Repertory grid for I1.

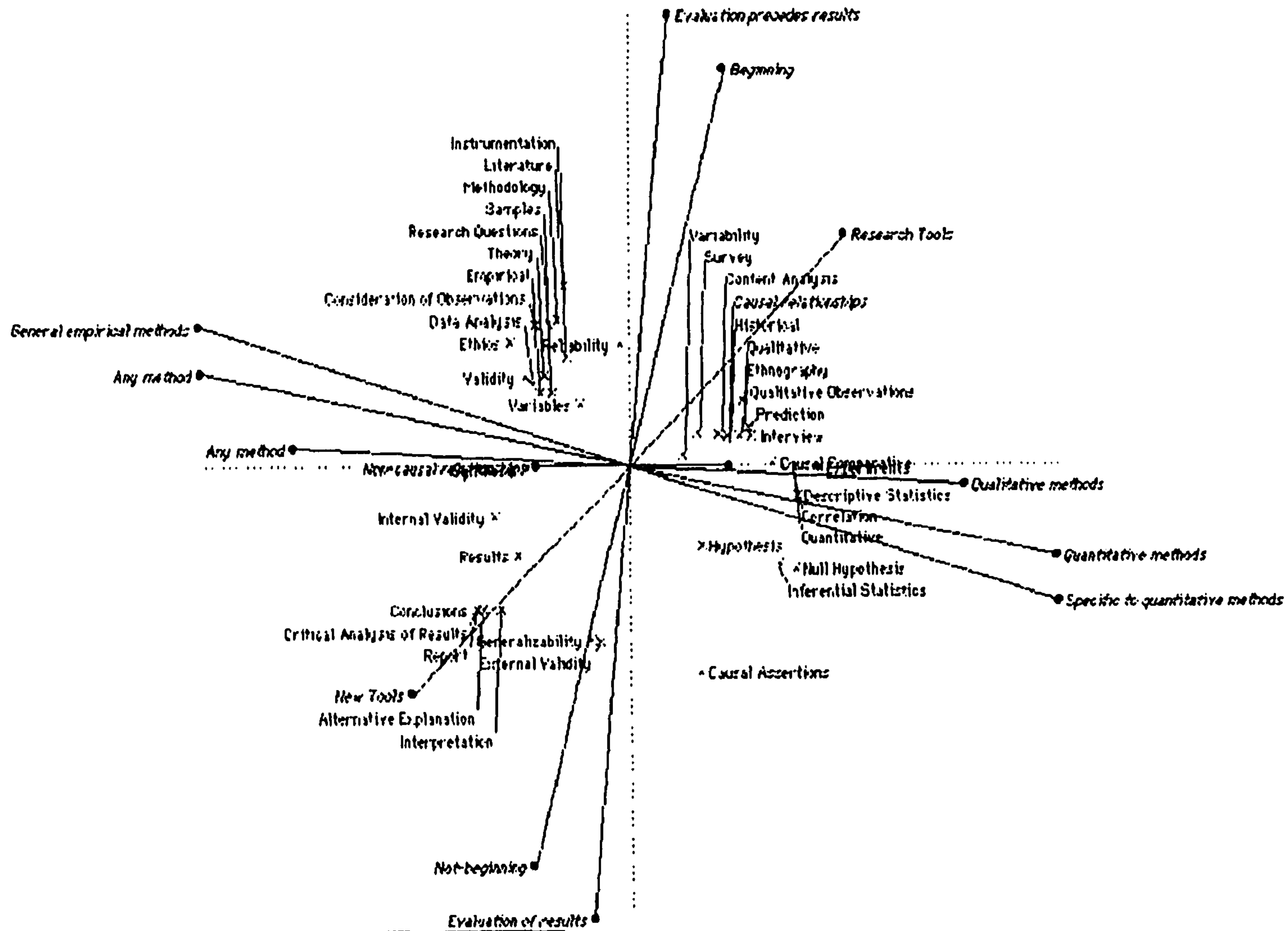

Figure C-2. Principal components analysis for I1.

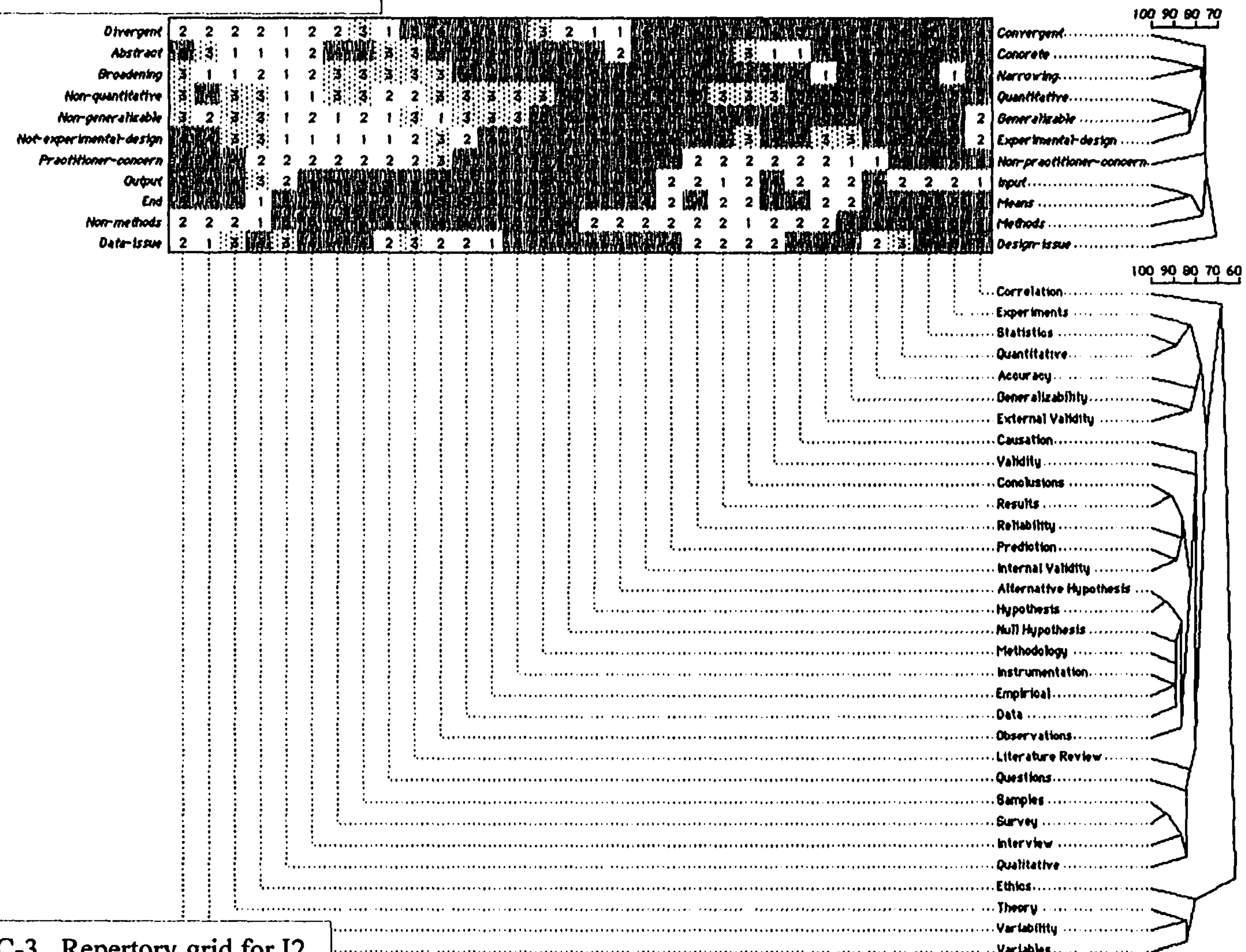

Figure C-3. Repertory grid for I2.

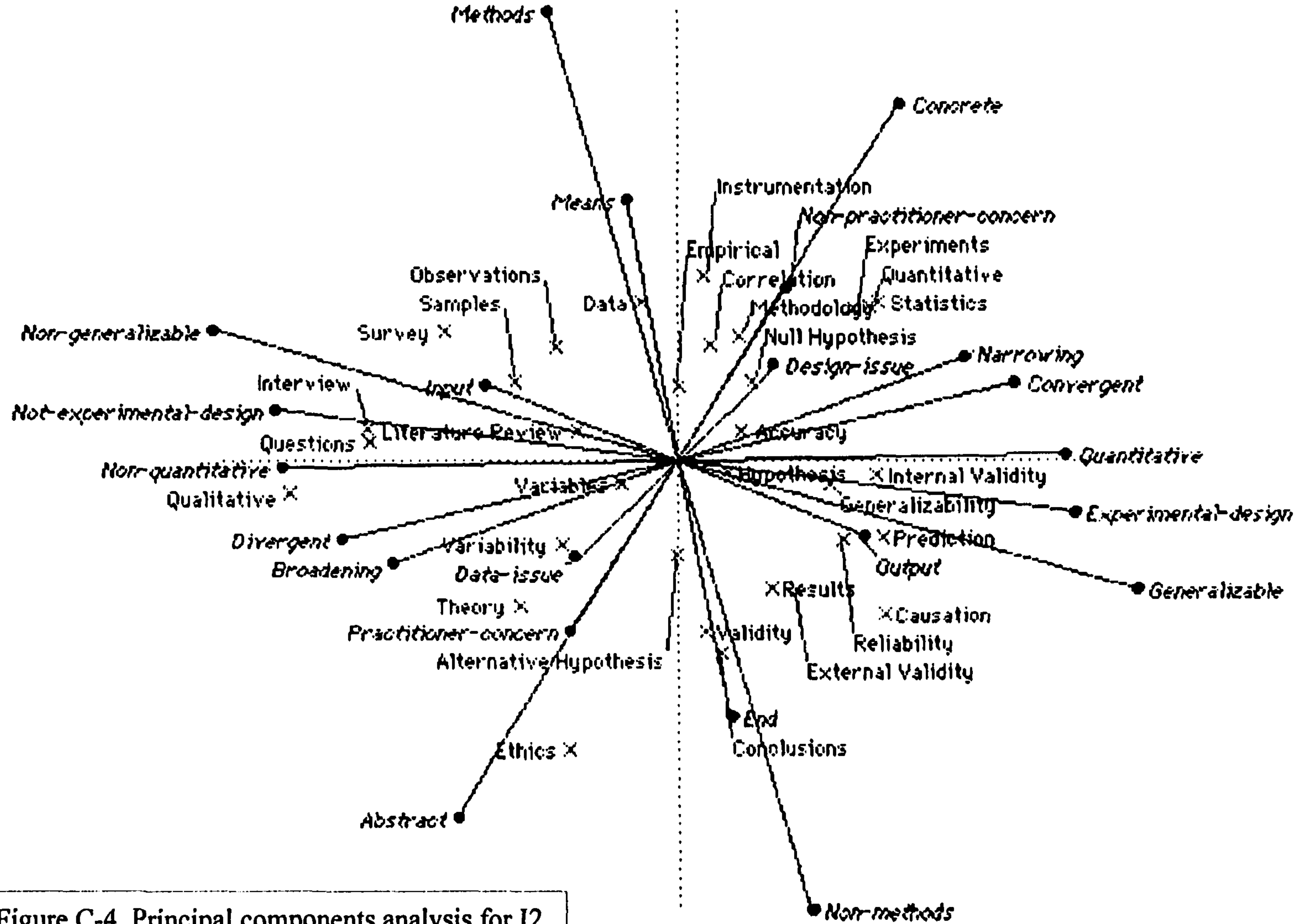

Figure C-4. Principal components analysis for I2.

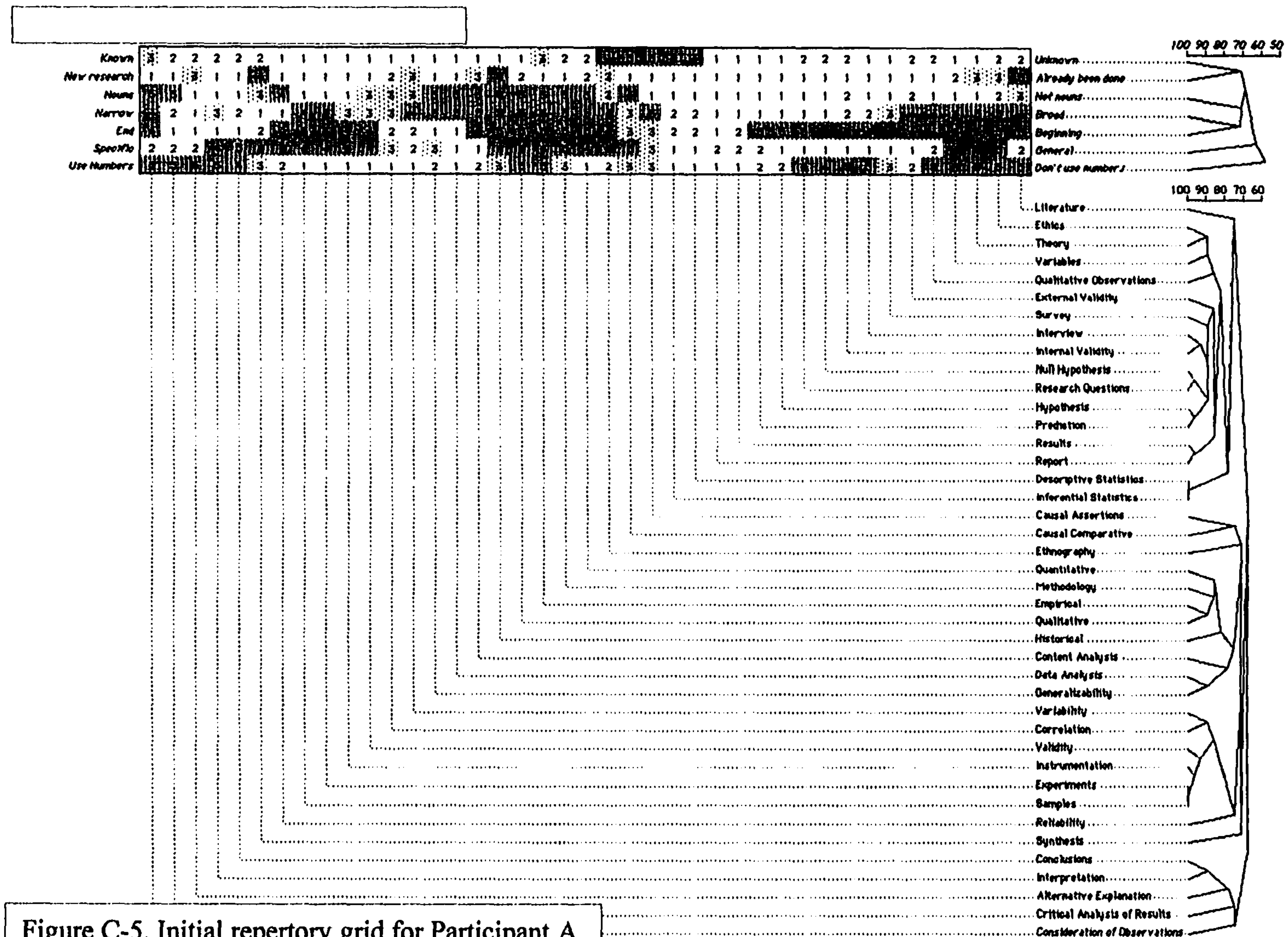

Figure C-5. Initial repertory grid for Participant A.

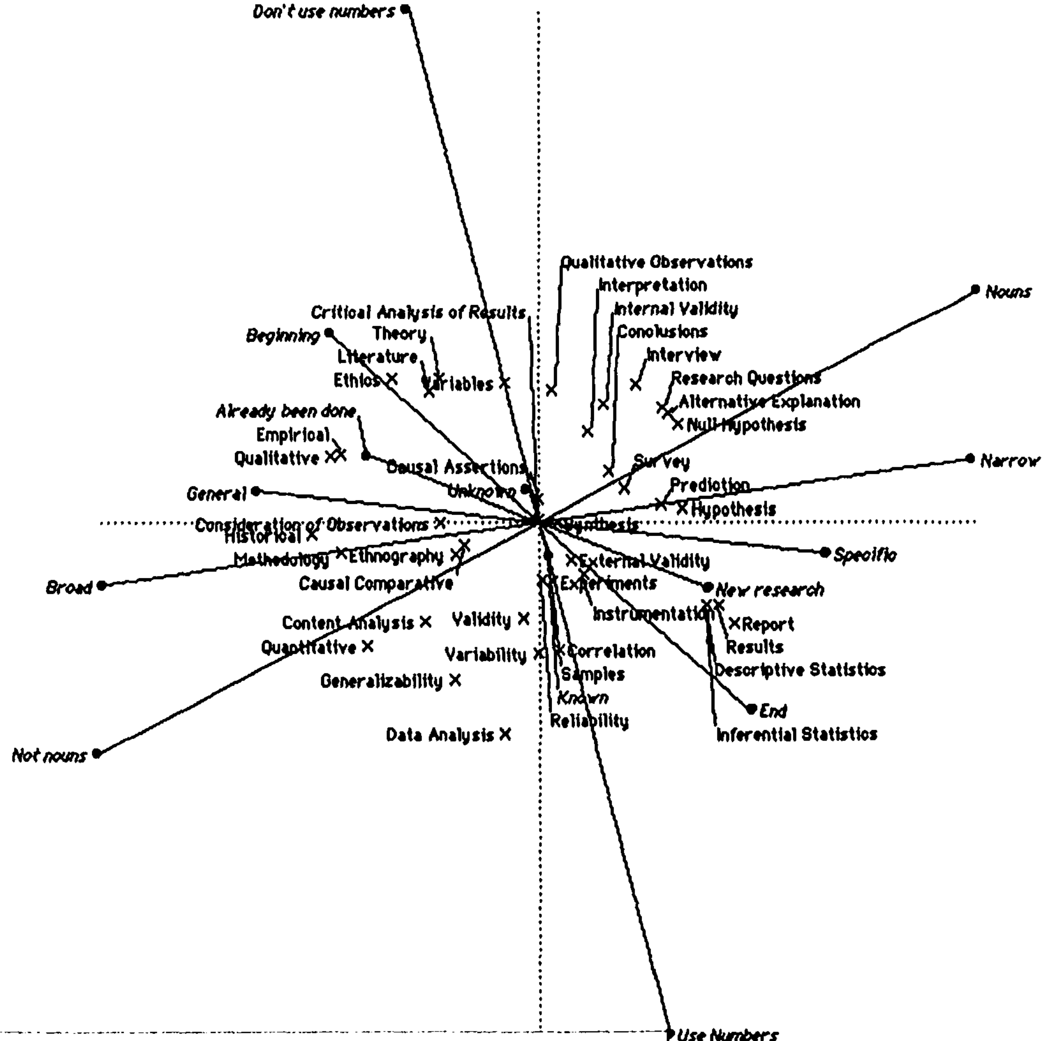

Figure C-6. Initial principal components analysis for Participant A.

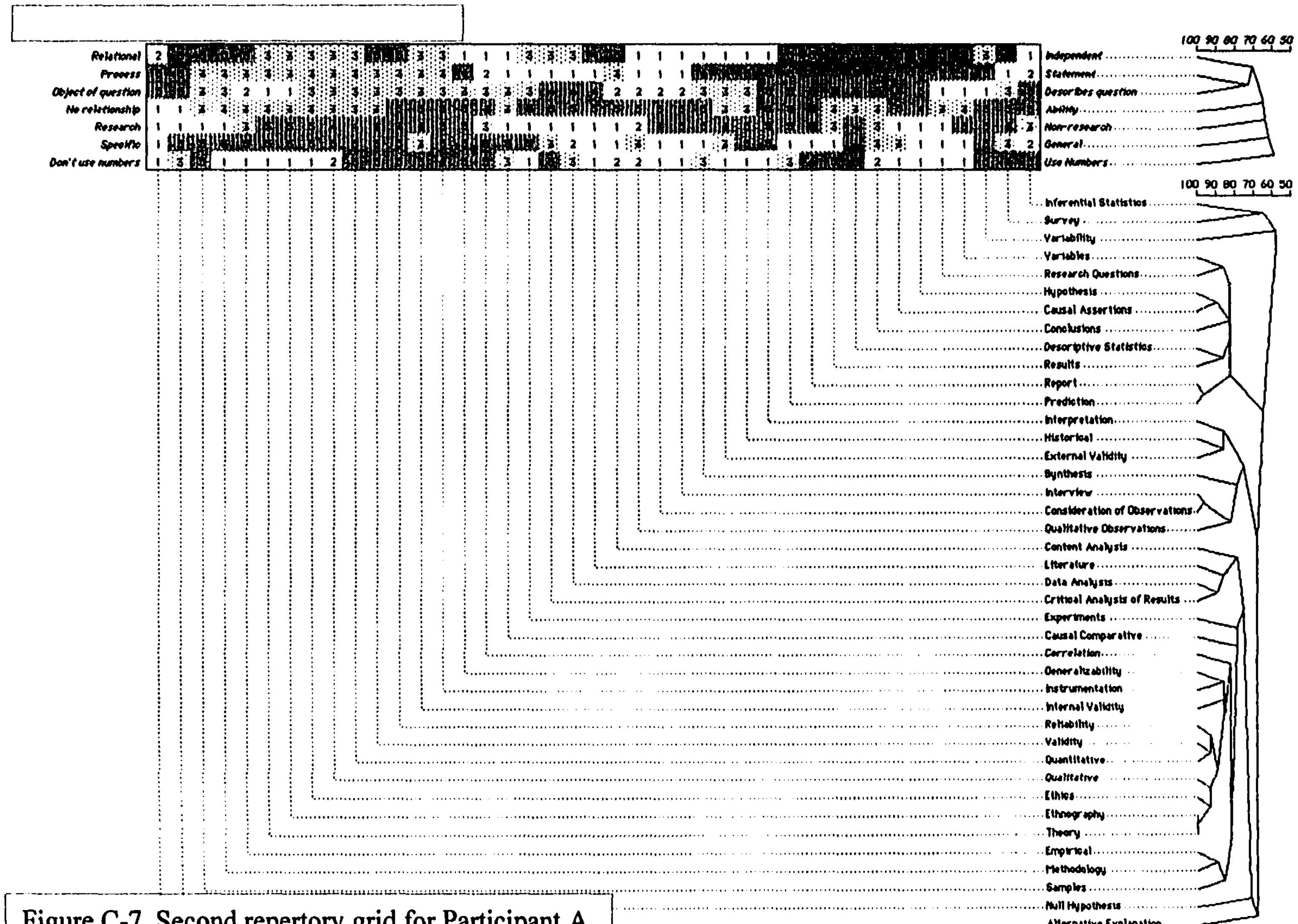

Figure C-7. Second repertory grid for Participant A.

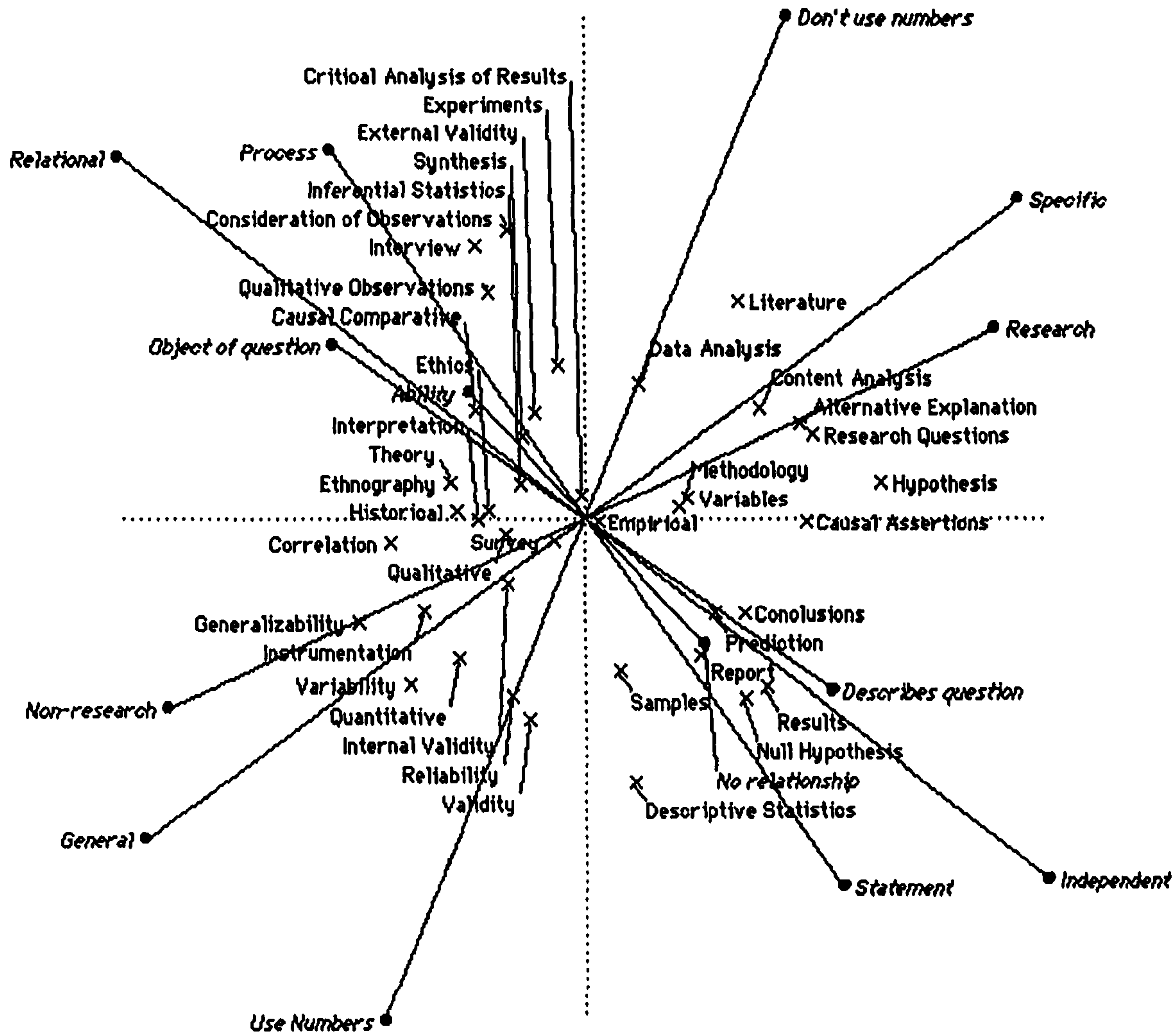

Figure C-1. Second principal components analysis for Participant A.

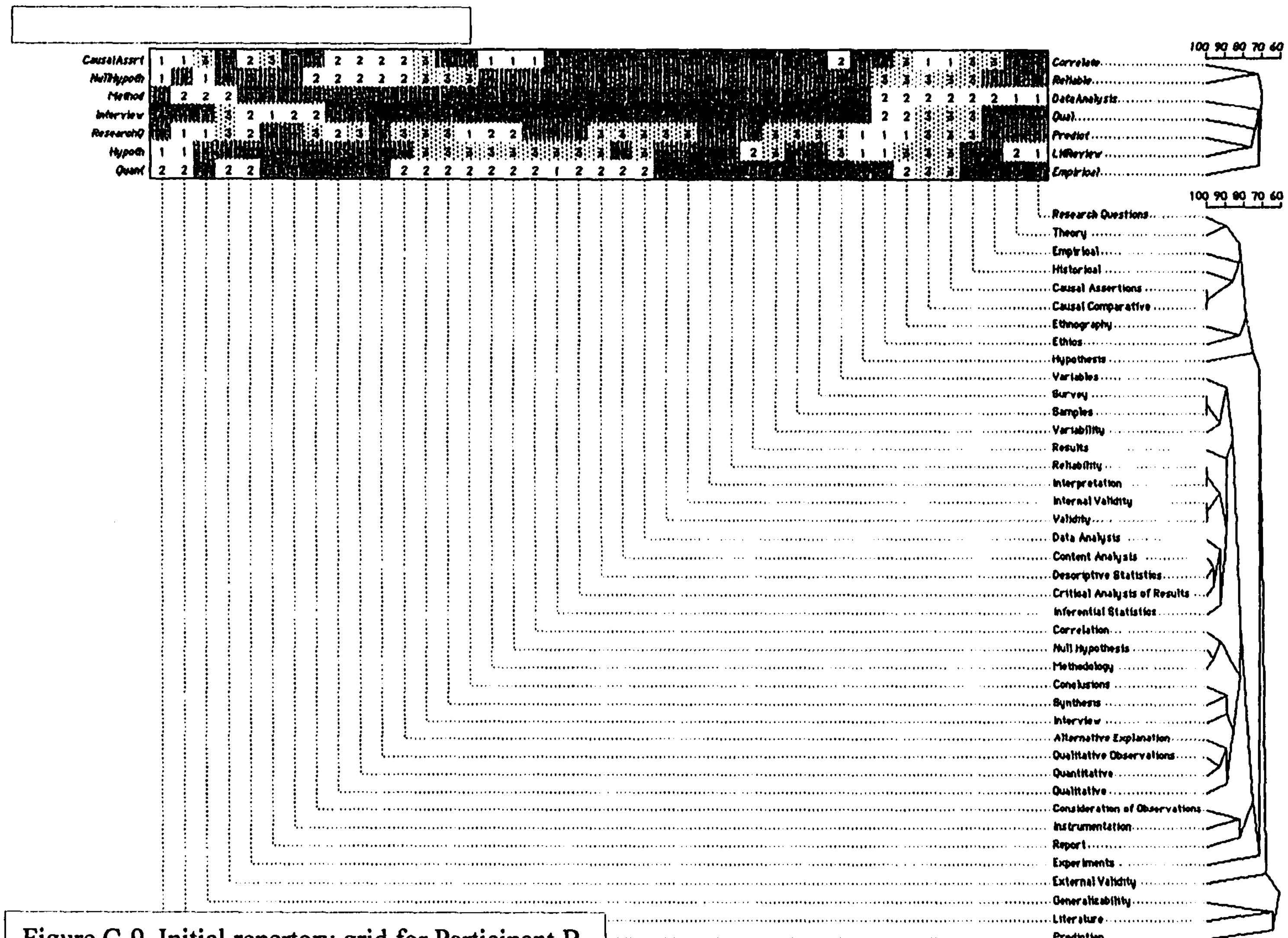

Figure C-9. Initial repertory grid for Participant B.

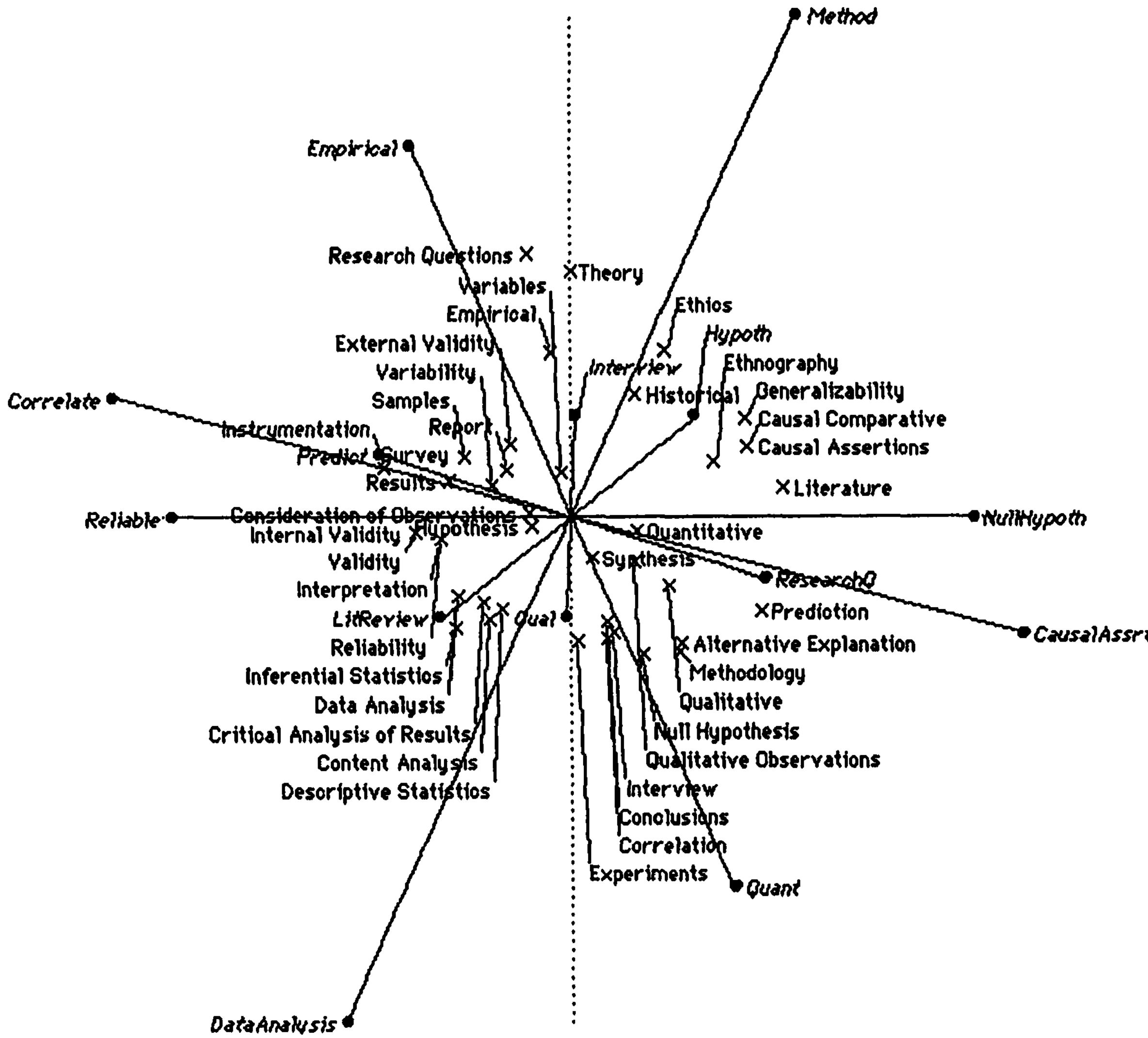

Figure C-10. Initial principal components analysis for Participant B.

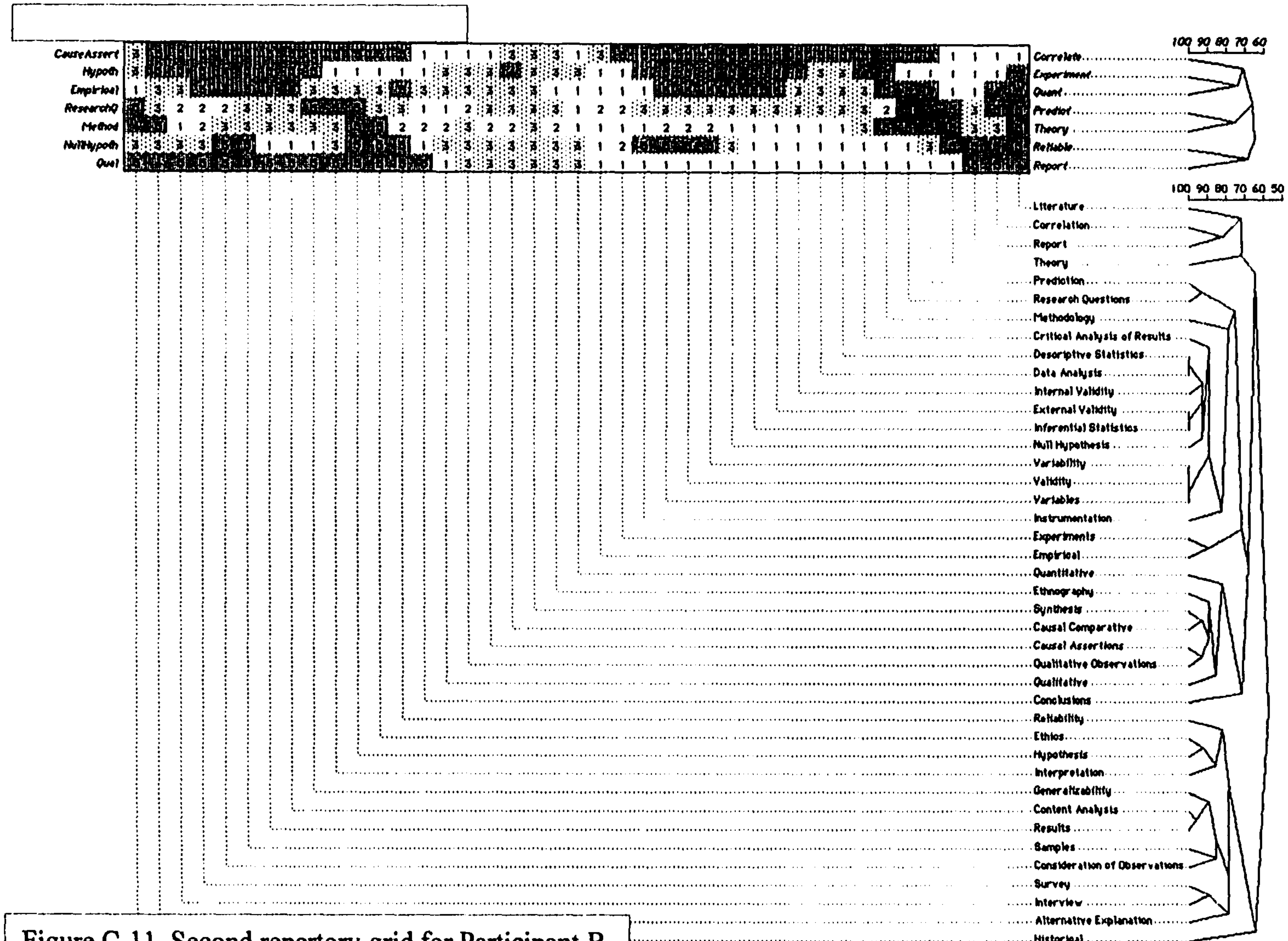

Figure C-11. Second repertory grid for Participant B.

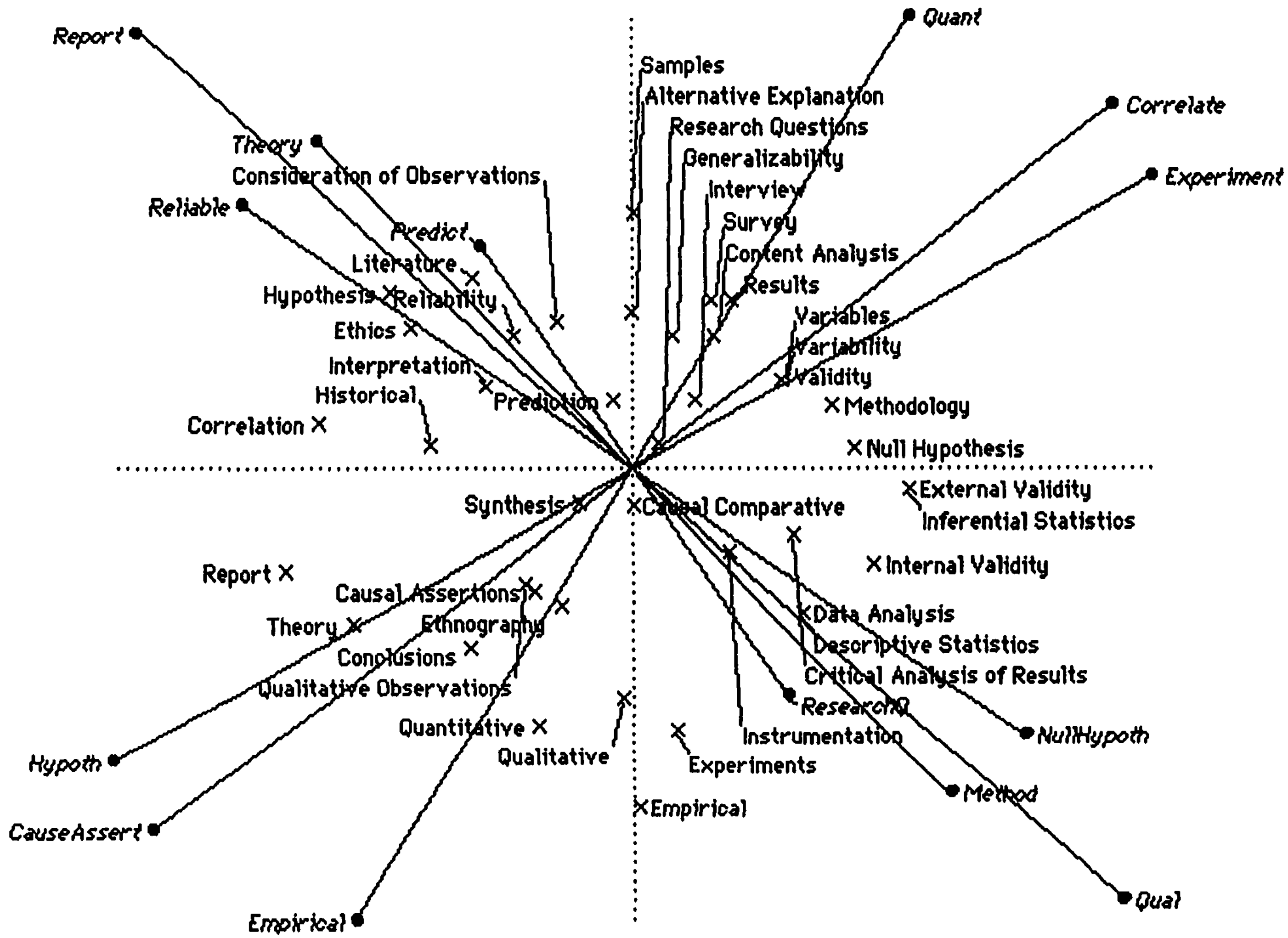

Figure C-12. Second principal components analysis for Participant B.

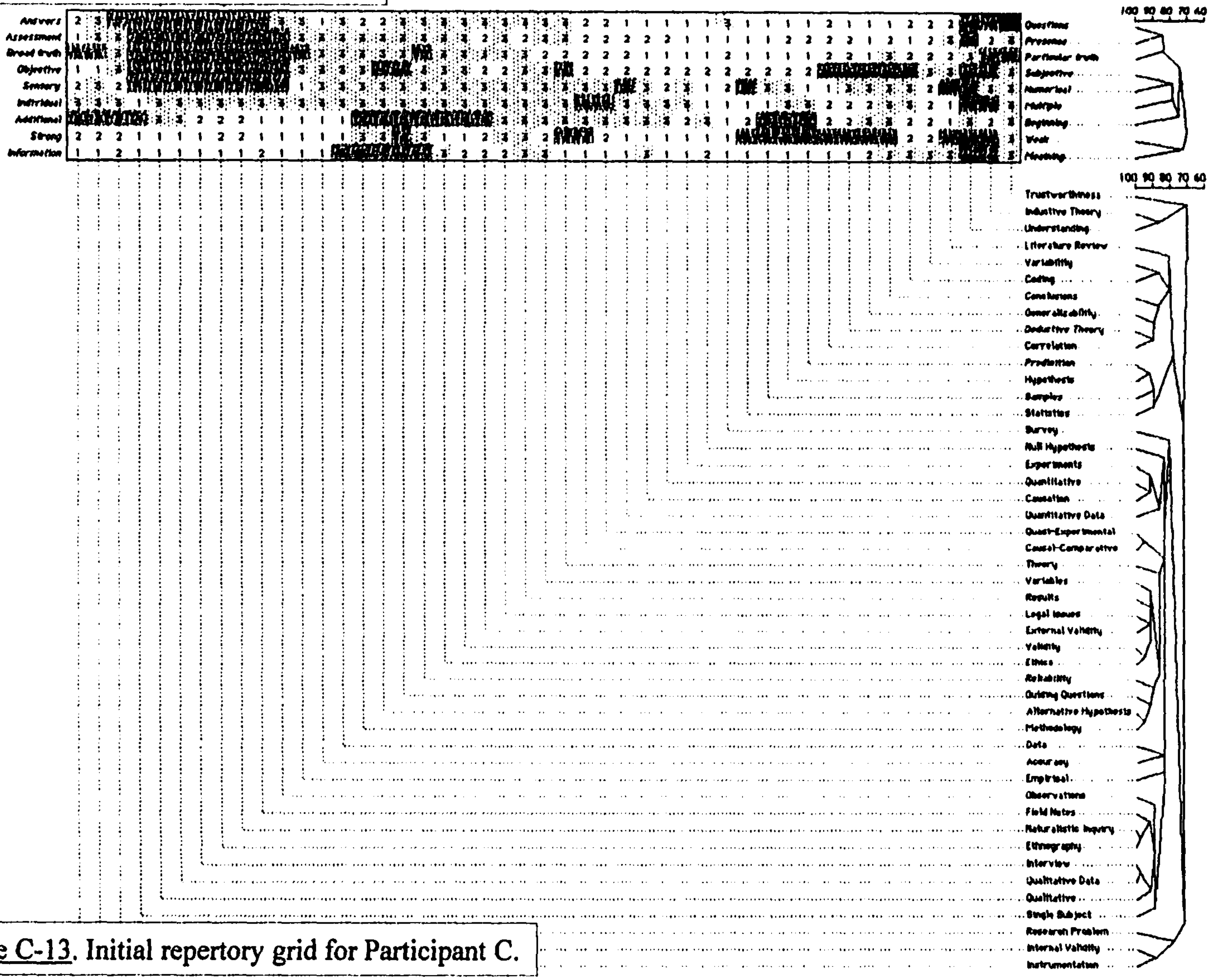

Figure C-13. Initial repertory grid for Participant C.

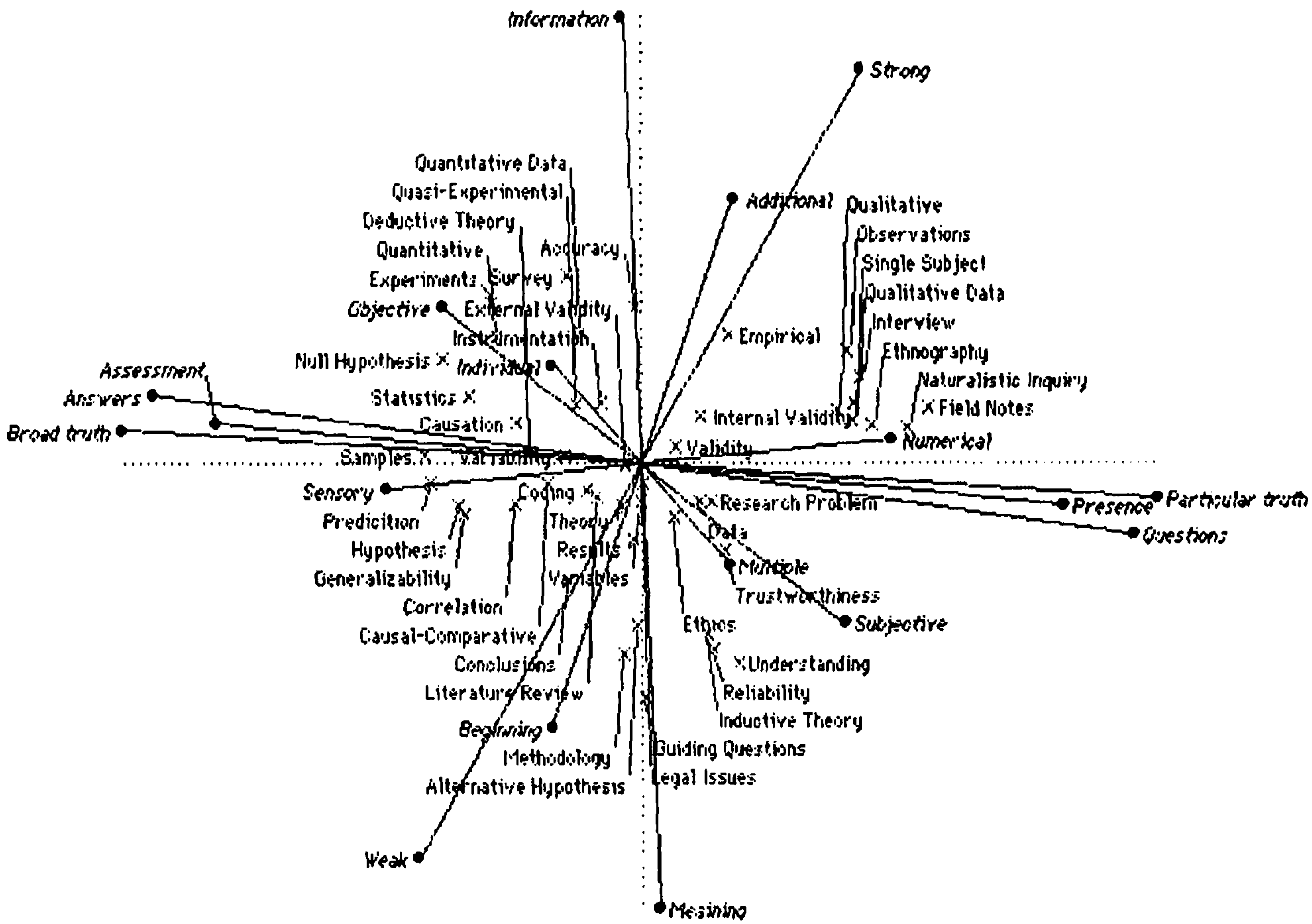

Figure C-14. Initial principal components analysis for Participant C.

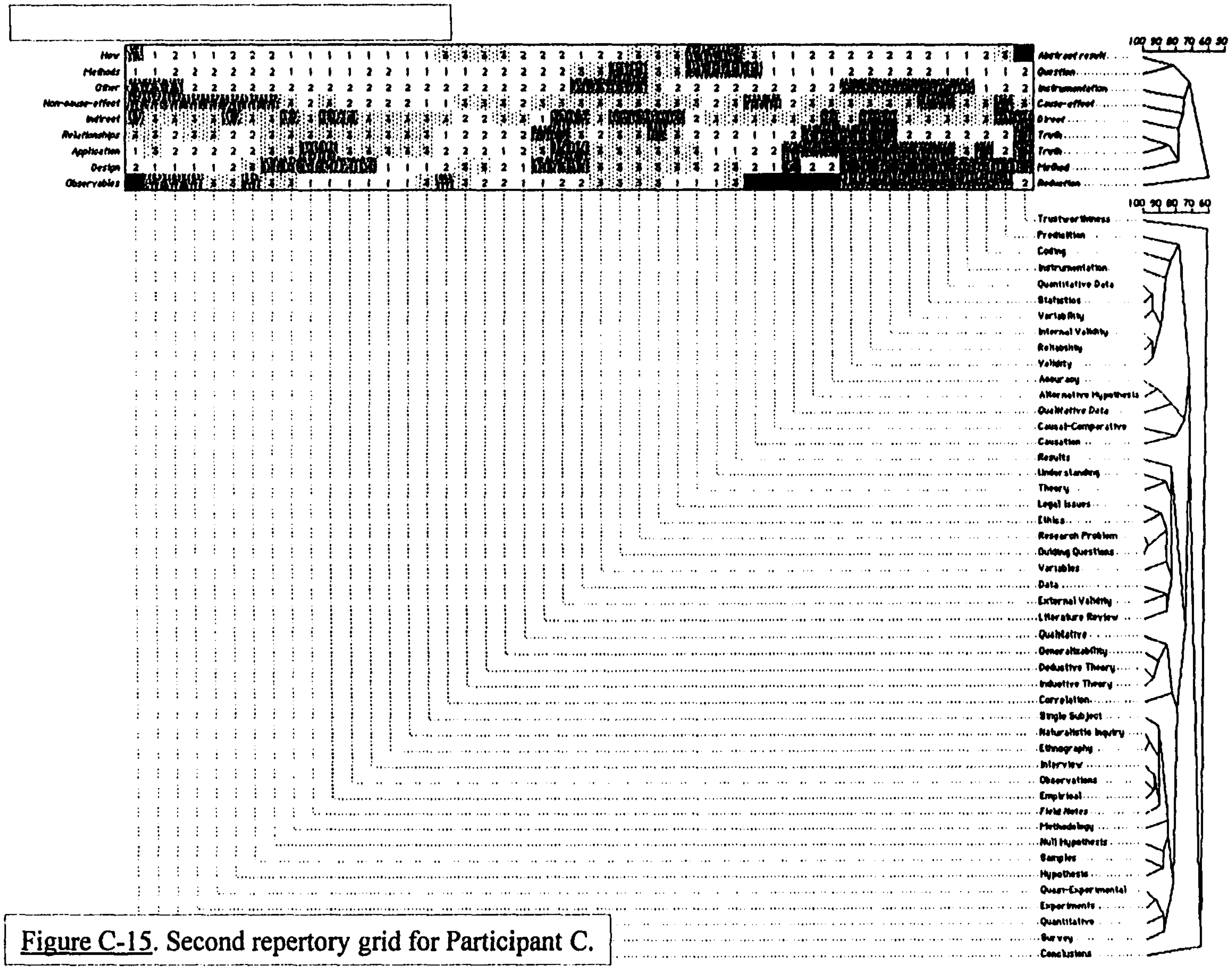

Figure C-15. Second repertory grid for Participant C.

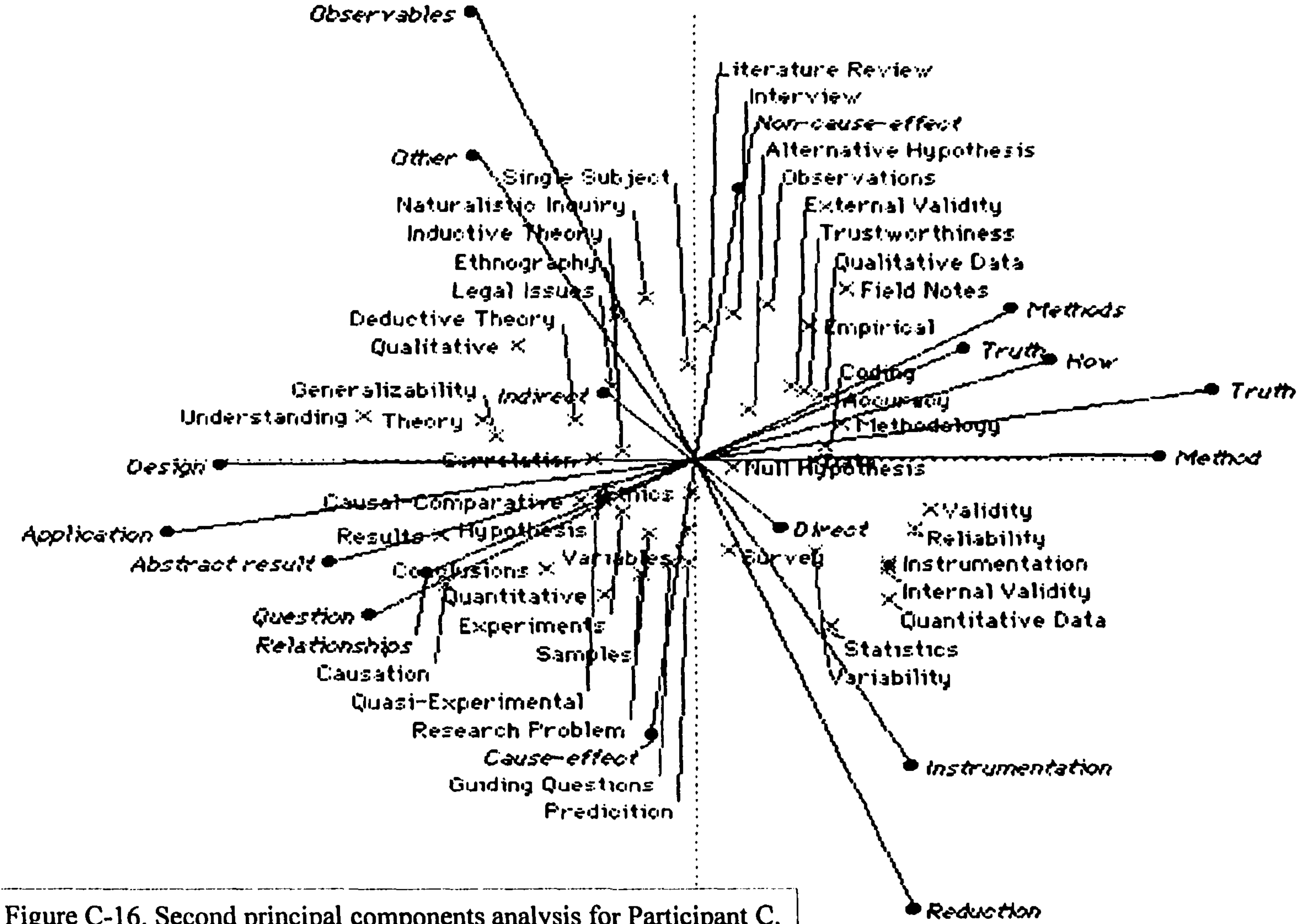

Figure C-16. Second principal components analysis for Participant C.

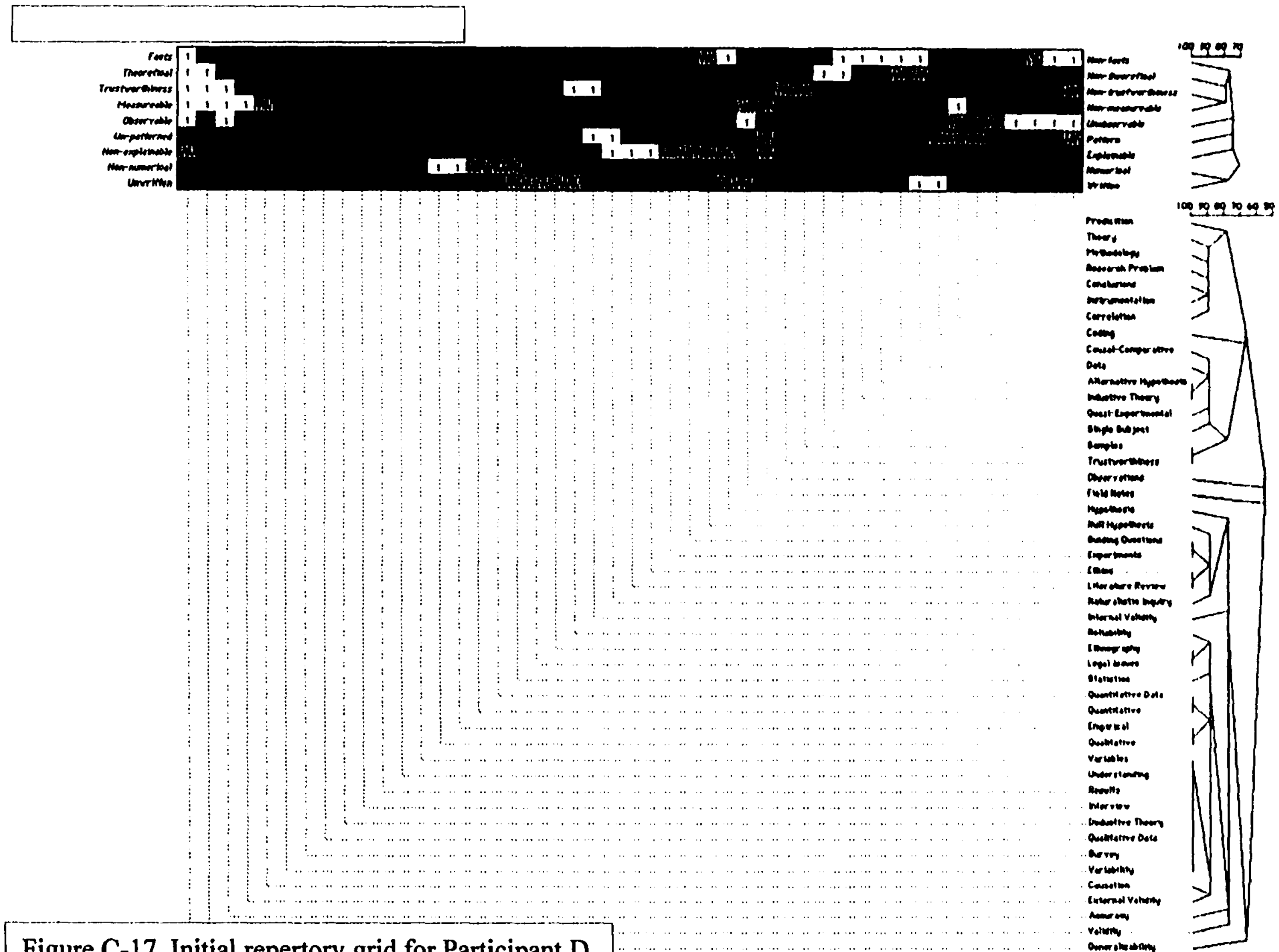

Figure C-17. Initial repertory grid for Participant D.

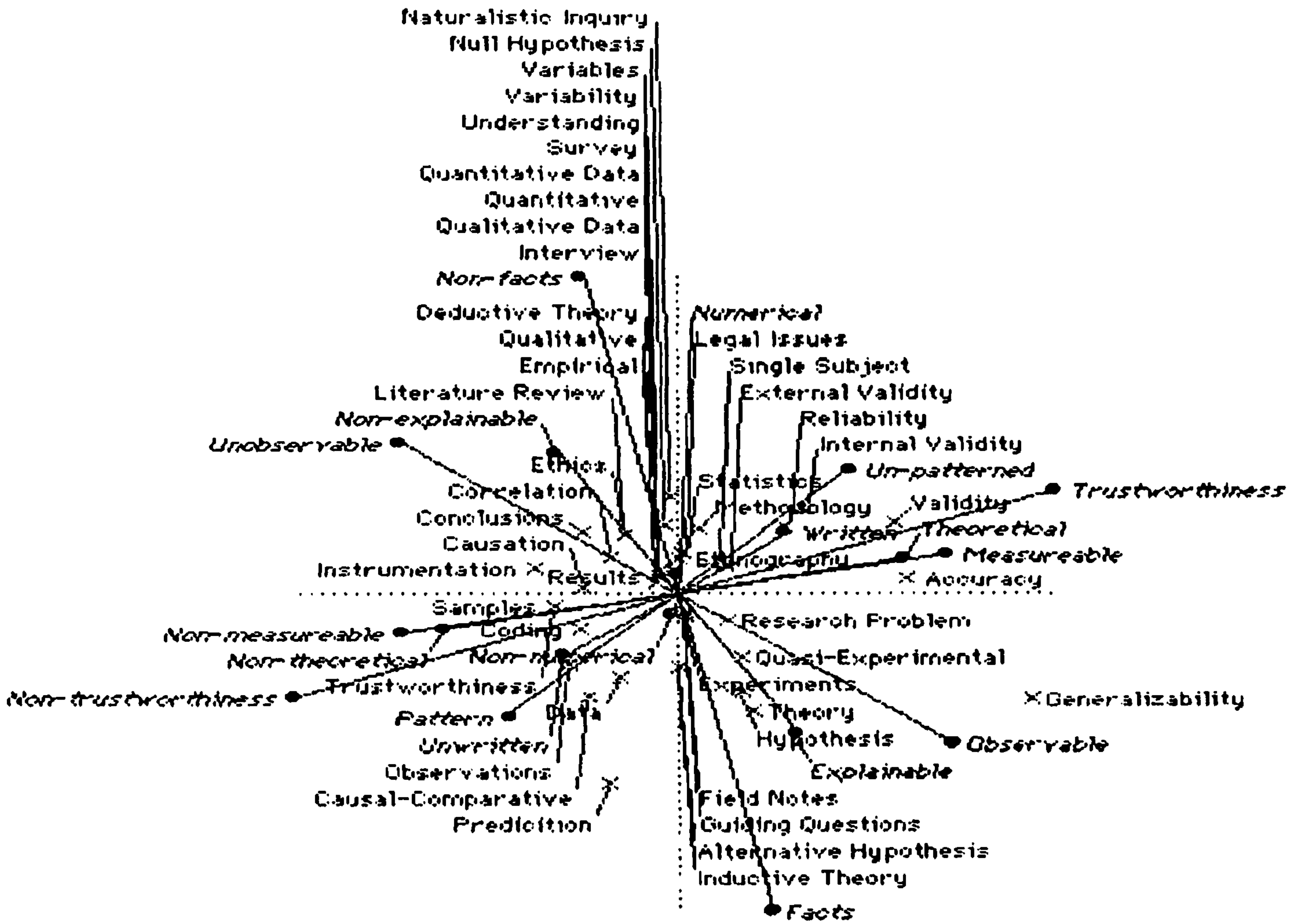

Figure C-18. Initial principal components analysis for Participant D.

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

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