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AUTHOR	Kokoski, Teresa M.; Housner, Lynn Dale
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ABSTRACT

The present study was an exploratory study of the content-specific knowledge structures of three teacher educators (two in math and one in science). Pathfinder, a method for eliciting associative memory networks, was used to describe the knowledge structures of the teacher educators. Pathfinder was also used to determine changes in knowledge structures of students enrolled in a teaching methodology class taught by each educator. Finally, a measure of the correspondence between students' knowledge structures and those of the teacher educators was correlated with students' performances in the courses. For two teacher educators, students' knowledge structures corresponded more closely with that of the teacher educator after the course than before. For one teacher educator, students exhibited little change in knowledge structure correspondence. Also, students who corresponded most to teacher educators performed better in their respective courses. The findings point to the need for further study of the acquisition of knowledge in undergraduate students and the processes associated with the transmission of knowledge in math and science teacher-education programs. Contains 3 figures, and 19 references. (Author/SLD)

Pathfinder Analysis of Knowledge Structures: An Exploratory Investigation of Math and Science Teacher Educators

Teresa M. Kokoski, University of New Mexico
Division of Innovative Programs
College of Education
Albuquerque, NM 87131

Lynn Dale Housner, New Mexico State University
Department of Physical Education, Recreation, & Dance
Box 3M, Las Cruces, NM 88003

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Abstract

The present study was an exploratory study of the content-specific knowledge structures of three teacher educators in math ($\underline{n}=2$) and science ($\underline{n}=1$). Pathfinder, a method for eliciting associative memory networks, was used to describe the knowledge structures of the teacher educators. Pathfinder was also used to determine changes in students' knowledge structures enrolled in a teaching methodology taught by each teacher educator. Finally, a measure of the correspondence between students' knowledge structures and those of the teacher educators was correlated with students' performance in the courses. For two teacher educators, students' knowledge structures corresponded more closely with that of the teacher educator after the course than before. For one teacher educator, students exhibited little change in knowledge structure correspondence. Also, students who corresponded most to teacher educators performed better in their respective courses. The findings point to the need for further study of the acquisition of knowledge in undergraduate students and the processes associated with the transmission of knowledge in math and science teacher education programs.

KEY WORDS: Knowledge structures, math, prospective teachers, science, teacher educators.

Pathfinder Analysis of Knowledge Structures: An Exploratory Investigation of Math and Science Teacher Educators

Classroom research on the nature of knowledge representations that characterize experienced and inexperienced teachers indicates that experienced teachers have richer, more well-instantiated cognitive representations about subject matter, instructional strategies, classrooms, and the nature of children than do inexperienced teachers (Carter, 1990; Leinhardt & Smith, 1985; Leinhardt, 1989; Peterson & Comeaux, 1987). The breadth and depth of experienced teachers' knowledge structures enable them to provide instruction that is at once comprehensive and responsive to student needs. Experts are equipped with an array of alternate, field-tested management routines, methods for conveying subject matter to students, and other instructional strategies that permit flexible improvisation in response to unpredictable classroom events (Borko & Livingston, 1989; Livingston & Borko, 1989).

Recently Ennis, Mueller, and Zhu (1991) have extended this work using a cognitive mapping technique based on subject-generated, ordered knowledge structures. They studied the differences in knowledge structure organization between experts in physical education and prospective physical education teachers with varying levels of undergraduate experience. The findings point to the increasing sophistication and organization of knowledge that takes place as teachers move from undergraduate student through beginning teacher to expert teacher.

This line of inquiry may have important implications for teacher education. Ennis et al. (1991) argue that knowledge forms the basis for flexible and adaptive teaching and that the knowledge base underlying teaching expertise can be delineated and represented to prospective teachers. Housner et al. (in press) concur, stating that knowledge of the teacher education experiences that contribute most to the efficient storage and application of knowledge might contribute to the design of more effective teacher education programs. The assumption, from a cognitive psychological perspective, is that knowledge forms the basis for flexible and adaptive teaching and that the knowledge base that underlies expertise in teaching can be delineated and represented to prospective teachers.

Unfortunately, the teacher educator has been noticeably absent in studies of knowledge development in prospective teachers. Floden and Klinzing (1990) have argued, "Indeed, more studies are needed to tap the wisdom of practice possessed by teacher educators" (p.20). Research has not been conducted that attempts to assess the knowledge structure of teacher educators and how that knowledge is imparted to prospective teachers. In their recent review of research on education professors, Howey and Zimpher (1990) concluded, "If teaching is understandably a primary activity of the professorate, research into it is not" (p.356).

Additionally, there is little available research regarding the contributions of teacher education experiences to the acquisition of declarative knowledge in prospective teachers. research on the influence of teacher education courses and experiences on knowledge acquisition in prospective teachers has been rare (Rovegno, 1991). As Livingston and Borko (1990) point out, educational researchers "...need to investigate systematically the nature and sequence of teacher education experiences (both preservice and inservice) that help novices develop their knowledge structures in ways that enable them to evolve toward expertise" (p.386).

Purpose of the Study

The present study was an exploratory investigation designed to examine the structure of knowledge structures housed in the memory of teacher educators in math and science. Furthermore, the study sought to determine the influence of the teacher educator on the development of knowledge structures in education students enrolled in math and science teaching methodology courses.

The Pathfinder scaling algorithm (Schvaneveldt, Durso, & Dearholt, 1989), an associative networking technique, was used to map the knowledge structures of the teacher educators and undergraduate students enrolled in their math and science methodology courses. Of particular relevance to the present investigation are recent studies Goldsmith, Johnson, and Acton (1991) and Housner, et al. (in press). Goldsmith et al. (1991) employed Pathfinder to investigate the relationship between student knowledge structures and academic performance in a college course on psychological research methods. Their findings indicated that students' representations of key concepts in the domain corresponded more closely with that of the instructor's following the course. More importantly, measures of correspondence were significantly related (r=.61 to .74) to the final number of academic performance points accrued in the course.

More recently, Housner, Gomez, and Griffey (in press) conducted an investigation of the structure of pedagogical knowledge housed in the memory of an experienced teacher educator and the influence of this knowledge on the knowledge structures of education majors enrolled in the teacher educator's teaching methodology course. The study also sought to examine the correlation between the correspondence of students' knowledge structures to the instructor's and course performance.

Pathfinder analysis indicated that students' knowledge of key pedagogical concepts corresponded more closely to the instructor's following the course. Also, student measures of correspondence following the class were significantly related to academic performance ($.58 < r < .82$), teaching performance ($.65 < r < .74$) and final course grade ($.71 < r < .85$).

Based on these findings, it was expected that students' knowledge representations would correspond more closely with that of the instructor following the course of instruction. Also, it was hypothesized that students with knowledge representations that most closely corresponded to the instructors would exhibit higher academic performance evaluations than students low in correspondence.

Method

Subjects

The teacher educators. Three teacher educators (one male, two female) in math ($n = 2$) and science ($n = 1$) from three different university level teacher education programs were recruited to participate in the study. All of the teacher educators had obtained a Doctorate degree in teacher education. Each teacher educator had received their Ph.D. degree from institutions that are highly respected for their programs in teacher education. Also, each teacher educator had experience instructing teaching methodology courses and supervising prospective teachers in student teaching or clinicalexperiences.

Course performance variables

For each course, data regarding student performance on knowledge tests were collected from the teacher educators at the end of the course. These data were used to investigate the relationship between the correspondence of the students' knowledge structures with the teacher educator who taught the course and performance in the course.

Instrumentation

Pathfinder network scaling algorithm. Knowledge was assessed using the Pathfinder network scaling algorithm (Schvaneveldt, Durso, and Dearholt, 1989). Pathfinder has been used successfully as a knowledge representation technique in memory studies, (Cooke, Durso, & Schvaneveldt, 1986), capturing the cognitive structures underlying expertise, (Schvaneveldt, et al., 1985), extracting semantic information from text, (McDonald, Plate, & Schvaneveldt, 1990), and in the assessment of students' representations of academic subjects (Goldsmith, Johnson, & Acton, 1991).

The first step in the procedure is to generate a list of concepts that represents the criterion domain of knowledge. Then, relatedness data are obtained by having subjects rate every possible pair of concepts on a scale ranging from highly related (a rating of 1) to completely unrelated (a rating of 9). The rating procedure is conducted using and IBM compatible personal computer and the Pathfinder software package.

The Pathfinder scaling algorithm is then used to transform the relatedness data into associative network representations. In Pathfinder networks, each concept is represented by a node and relations between concepts are represented by links between nodes. Pathfinder regards the degree of relatedness as an estimate of psychological distance. Thus, highly related concepts are separated by fewer links and less related concepts are separated by more links or may be entirely unconnected. The algorithm operates by computing all paths between two nodes and includes a link between those nodes only if the link represents the most related, (or minimum-length), path between the two concepts. Pathfinder reduces proximity data to the most salient relationships among concepts.

In the present study, a single measure of correspondence provided by Pathfinder was used to compare network representations; Information. Information is based on the probability that two networks would share X or more links in common. Chance probability, computed on the hypergeometric distribution, takes the number of links in common, the number of links in network 1, the number of links in network 2, and the number of the nodes in the two networks as input, and produces the probability that two networks with these characteristics would share X or more shared links becomes smaller as the number of shared links increases. In other words, the likelihood that two networks will share one or more links is much greater than the likelihood of sharing 10 or more links. Alternately, chance probability can be expressed in informational terms. That is, Information = log2 (1/p). Thus, the Information measure is based on the information metric and is interpreted as a measure of the amount on information in the instructor's network that is captured by the student's network.

In addition to Information, Pathfinder software provides a measure of coherence that can be used to describe the internal consistency of the subject's knowledge representations. Therefore, it can be used only as an indirect measure for comparing knowledge organization of two networks. Coherence is a within-subject correlation performed on relatedness ratings. Coherence is based on the assumption that concepts related to each other should be related to other concepts in common. For example, if concept A is highly related to concept B, then they should share relationships with other concepts. Since coherence can not be used to directly compare knowledge structures, measures of coherence were used only to assess the internal consistency of the ratings of the teacher educators.

Procedure

Delineating the knowledge base. The initial step in the study was to delineate the pedagogical knowledge structure of the teacher educators. This procedure was completed before the teaching methods courses began. The researchers conducted several interviews with the course instructor focusing on his perceptions of effective teaching and the knowledge that he expected students to take away from the methods courses. As the teacher educator described the key concepts that represented important components of his teaching methodology class, each concept was written on a 3 by 5 index card.

After the teacher educator was finished generating concepts, she/he was provided with the final set of cards and asked to sort the cards into meaningful categories. At this point the teacher educator was encouraged to create new concept cards that he/she might think of while sorting cards. Also, he/she was allowed to make copies of cards, if a particular concept belonged to more than one category.

Since Pathfinder requires subjects to rate the relatedness of all possible pairs of concepts, including all concepts in the analysis would have been inordinately time consuming. Therefore, the course instructor was asked to identify 40 or fewer key concepts that represented the most important pedagogical knowledge contained within the course. The complete set of concepts and the concepts identified as most important are presented in Tables 1-3.

Table 1 Concepts generated by math educator #1

A.1 Math as a concept* A.2 Place value* A.3 Grouping A.4 Balancing equations A.5 Adding* A.6 Subtracting* A.7 Multiplying* A.8 Dividing* A.9 Conceptual meaning* A.10 Formal thought* A.11 Deductive logic*	B.1 Effective teaching* B.2 Internalize set of rules* B.3 Progressions in math* B.4 Simple to complex* B.5 Concrete to abstract* B.6 Instances versus noninstances* B.7 Experiences numbers* B.8 Errors as useful*	C.1 Math as a skill* C.2 Rules* C.3 Provides temporary help* C.4 Important early*
D.1 Manipulatives* D.2 Concrete* D.3 Alternate representational form*	E.1 Reasons for math* E.2 Math as empowerment* E.3 Limitations of numbers* E.4 Utility of math*	

*INDICATES A CONCEPT DESIGNATED AS MOST IMPORTANT

Table 2 Concepts generated by math educator #2		
A.1 Decimals A.2 Cognitive Theory* A.3 Concrete* A.4 Pictorial* A.5 Abstract* A.6 Concrete Operations A.7 Semi-Concrete	B.1 Current Issues in Math Education B.2 Minorities B.3 NCTM Standards B.4 Females B.5 Mathematics Anxiety B.6 Equity	C.1 Geometry* C.2 Spatial Relations* C.3 Plane Figures* C.4 Rectangle C.5 Square C.6 Circle
D.1 Fractions* D.2 Renaming* D.3 Bars D.4 Common Denominator D.5 Reducing	E.1 Place Value* E.2 Non-Proportional* E.3 Diene's Blocks* E.4 One-to-Many correspondence* E.5 Proportional E.6 Pocket Charts E.7 Bundles E.8 Sticks E.9 Unifix Cubes E.10 Expanded Notation	F.1 Beginning Counting* F.2 One-to-one Correspondence* F.3 Cardinal Principle F.4 Number Sense F.5 Ordinal Uses of Numbers F.6 Unifix Cubes* F.7 Ticking-Off F.8 Cuisenaire Rods F.9 Number Line F.10 Zero Concept F.11 Count-On
G.1 Decimals & Percents G.2 Decimal Squares* G.3 Percents*	H.1 Bloom's Taxonomy H.2 Performance Objectives H.3 Modeling H.4 Effective Teaching H.5 Criteria H.6 Conditions H.7 Performance	I.1 Algorithm* I.2 Regrouping* I.3 Basic Facts* I.4 Measurement Division* I.5 Whole Number Operations I.6 Unifix Cubes I.7 Repeated Addition I.8 Cuisenaire Rods I.9 Part-Time Division I.10 Repeated Subtraction I.11 Arrays I.12 Flash Cards I.13 Vertical Rotation
J.1 Prenumeration* J.2 Continuous* J.3 Discrete* J.4 Classification* J.5 Attribute Blocks* J.6 Patterns J.7 Comparison J.8 Matching	K.1 Measure* K.2 Volume* K.3 Capacity K.4 Perimeter K.5 Area K.6 Linear	

*INDICATES A CONCEPT DESIGNATED AS MOST IMPORTANT

Table 3 Concepts generated by science teacher		
A.1 Instructional Strategies A.2 Teaching Models* A.3 Learning Cycle* A.4 Batteries & Bulbs * A.5 Learning Centers * A.6 Discrepant Events* A.7 Model Activities* A.8 Investigative* A.9 Inquiry-Based Learning* A.10 Cooperative Learning A.11 Exploration A.12 Concept Introduction A.13 Concept Application	B.1 Science Concepts* B.2 Pendulums* B.3 Reaction Time* B.4 Sound - Humazoos B.5 Happy Balls B.6 Explain Reasons for Discrepant events	C.1 Evaluation* C.2 Performance Based
D.1 Integration with Other Content* D.2 Science & P.E.* D.3 Science & Language Arts* D.4 Writing Across the Curriculum D.5 Math and Science	E.1 Lifelong Skills* E.2 Science Process Skills E.3 Observation* E.4 Hypothesizing* E.5 Manipulative Variable* E.6 Inference* E.7 Classification* E.8 Designing Investigations E.9 Communication E.10 Measurement E.11 Prediction E.12 Data Collection & Organization* E.13 Defining Operationally E.14 Analyzing Data E.15 Responding Variable	F.1 Management of Science Activities* F.2 Management of Children* F.3 Planning F.4 Distribute & Retrieve Equipment*
G.1 Science on a low budget G.2 Managing Science Materials G.3 Straws, Strings & Paper Clips	H.1 Nature of Science* H.2 Developing Positive Science Attitudes* H.3 Skepticism H.4 Philosophy of Science H.5 Curiosity H.6 Motivation H.7 Non-absolutism	I.1 Science & Joe's Six Pack* I.2 Relevance I.3 Usefulness I.4 Ownership
J.1 Supplemental Curriculum* J.2 Project Wild* J.3 AIMS J.4 Lung Volume	K.1 Professionalism K.2 Professional Journals K.3 Science and Children K.4 Ranger Rick K.5 NSTA K.6 NMSTA	L.1 Constructivism L.2 Prior Knowledge
M.1 Preferred Processing Mode M.2 Sensory Experience M.3 Auditory Mode M.4 Visual Mode M.5 Hands on Mode M.6 Concrete Experience		

*INDICATES A CONCEPT DESIGNATED AS MOST IMPORTANT

Eliciting student knowledge. During the initial week of each class, students rated all possible pairs key concepts identified by the course instructor. Concept pairs were rated using a scale ranging from highly related (1) to completely unrelated (9). Students repeated this procedure during the final week of each class. The rating procedure took approximately one hour. The Pathfinder software package was then used to transform proximity data into a network representing the students' knowledge structures of the domain of concepts. Pathfinder networks were used to compare students' knowledge structures of the domain of concepts. Pathfinder networks were used to compare students' pedagogical knowledge structures at the beginning and end of the semester to the knowledge structures of the course instructor, the three experienced teacher educators, and a composite knowledge structure of all three teacher educators.

Eliciting teacher educators' knowledge. The three teacher educators rated all possible pairs of the critical concepts only once. Otherwise, the rating procedures was identical to that performed by the students. The Pathfinder software package was used to transform proximity data into networks representing the teacher educators' knowledge structures of the domain of concepts.

Results

Teacher educator knowledge

Pathfinder analysis revealed that coherence measures for the three teacher educators were .43, .48, and .51. The magnitude of the coherence measures indicates that within-subject correlations of teacher educators' ratings of concept pairs were reasonably consistent. The Pathfinder networks for each of the teacher educators is presented in Figures 1-3 in

Appendix A.

Student knowledge

Mean information measures comparing students' initial and final Pathfinder networks to that of the teacher educators are presented in Table 4. Dependent t tests were conducted to determine if students became significantly more like the teacher educator teaching their course during the semester of instruction.

The t tests (see Table 4) indicated that for two teacher educators, students corresponded to the teacher educators significantly more at the end of the semester than at the beginning. For the other teacher educator, students did not change significantly across the semester.

Table 4. Means, standard deviations, and t-test comparing initial and final Information measures for each teacher educator.

	Teacher Educators		
INFORMATION	MATH #1	MATH #2	SCIENCE
INITIAL			
N	43	18	41
M	4.86	4.27	3.66
SD	3.4	3.98	3.71
RANGE	54-13.8	.32-17.4	.04-16.2
FINAL			
N	43	18	41
M	3.97	8.10	6.72
SD	3.72	9.63	6.72
RANGE	.11-17.1	.34-32.4	.05-35.1
	t=1.40	t=2.14	t=3.14
	p<.16	p<.05	p<.003

Information value of 4.54 = p<.05, 6.64 = p<.01, 9.97 = p<.001

Student knowledge and course performance

Pearson product-moment correlations between student course performance scores and initial and final Information measures comparing students' networks with the networks of the teacher educators are presented in Table 5.

Table 5 Pearson product-moment correlations between course performance variable and initial and final student Information measures for each teacher

INITIAL INFORMATION

	MATH #1	MATH #2	SCIENCE
Midterm Exam #1	.08	.32	.27
Midterm Exam #2	.17	.31	____
Midterm Exam #3	.34*	____	____
Final Exam	.17	.28	.09

FINAL INFORMATION

	MATH #1	MATH #2	SCIENCE
Midterm Exam #1	.31*	.48*	.26
Midterm Exam #2	.28	.55*	____
Midterm Exam #3	.41**	____	____
Final Exam	.34*	.59*	.37*

*$p < .05$, **$p < .01$

Correlations between initial student Information measures and course performance scores were generally low to moderate with only one reaching significance. In contrast, correlations between final Information measures and student performance scores were generally moderate to high with most reaching significance. This indicates that by the end of the courses students whose knowledge structures corresponded most with that of the teacher educator tended to perform better in the teaching of methodology course.

Discussion

Pathfinder appears to be an effective methodology for describing the knowledge structures of teacher educators and capturing changes in knowledge structures of prospective teachers. The findings replicated those provided by Goldsmith et al. (1991) and Housner et al. (in press). However, the magnitude of the changes in correspondence and the relationships between students' correspondence to the teacher educators and course performance were lower than those uncovered by Goldsmith et al. (1991) and Housner et al. (in press).

Unfortunately, Pathfinder provides only a glimpse at the process of transmitting knowledge in teacher education program. There is no available data that would permit one to explain the apparent differences between the findings in this study and earlier research. Clearly, research is needed that attempts to describe the actual instructional strategies that are employed by teacher educators. While there has been much discussion regarding the importance of pedagogical content knowledge to effective teaching, this concept needs to be extended to the study of effective teacher education. Research needs to describe the types of analogies, metaphors, simulations, examples, etc. that teacher educator use to mathematical and science concepts to prospective teachers (Schulman, 1987).

However, one can speculate about some of the reasons why correspondence levels might be easier to obtain in some courses than in others. The courses involved in this study were content specific. Typically students enroll in these courses as part of their academic programs. Unlike the Physical Education courses used in the Housner study where students elected into the PE class, these students had no choice. Therefore the setting of elective versus required courses may impart attitudinal implications. Another consideration is the academic disposition toward the courses. Evidence from research shows that many students do not feel comfortable with their knowledge in science and mathematics. Therefore, confidence level of preservice teachers toward these topics should be a component of future studies in this area. Other factors may have come to play in this specific study which were not significant in other studies and should be further investigated. This would include student status (graduate vs. undergraduate), broad vs. narrow knowledge course content, and the depth of knowledge in content areas.

Our analyses indicated that students were beginning the difficult process of internalizing and organizing knowledge. Pathfinder, however, provides only a glimpse of the organizational characteristics of declarative knowledge. It does not adequately address issues regarding the semantic nature of the relations connecting concepts or whether learning takes place by adding new links, strengthening old links or removing erroneous links and how different knowledge acquisition strategies are related to the development of particular types of conceptual relations (Rumelhart, & Norman, 1978).

Researchers (Ericsson & Oliver, 1988; Olson & Biolsi, 1991) have argued that quantitative cognitive mapping techniques alone do not provide sufficiently detailed data regarding the substance or meaning of knowledge representation. They argue that a combination of methodologies must be employed to extract the type of fine-grained, descriptive information needed to adequately address questions regarding how knowledge is acquired and applied in the solution of domain specific problems. For example, Ericsson and Oliver (1988) argue that process-oriented methodologies such as interviews, observations, think-aloud sessions, and stimulated recall should be combined with product-oriented methodologies, such as Pathfinder, to generate detailed data that would facilitate the meaningful interpretation of knowledge structure research.

An important question that bears directly on the role of knowledge in teaching is, how declarative knowledge about pedagogy is transformed into procedural knowledge that can be applied in teaching settings. Procedural knowledge is often represented in the form of productions or if-then statements that contain situations (if) and the actions (then)that can be carried out in response to situations. Anderson (1982) has argued that declarative knowledge provides the substance from which procedural knowledge is developed. What is not known is how the knowledge reorganization process unfolds for teachers as they move from teacher education programs, through student teaching and into induction.

An important part of the study of knowledge growth in beginning teachers is to obtain behavioral indicators of procedural knowledge. Research needs to be pursued that attempts to describe the acquisition of knowledge by prospective teachers and how that knowledge influences behavior, cognitive skill, and reflectivity associated with becoming a successful teacher. Fine-grained analyses of what it is that teachers actually know, think, and do as they plan, implement, and evaluate lessons, units, and larger curricular structures need to be conducted. Furthermore, it is important that future studies employ systematic observations of actuai teaching behavior and instruments that focus on the planning, interactive decision making, and self-evaluation of teachers. In this way it would be possible to determine the influence of procedural knowledge on teaching as thought is translated into action.

Research on the socialization processes evident in education (Lortie, suggests that the knowledge obtained in teacher education programs may be modified to a considerable degree by teaching experience. As teachers gain experience, it may be that a craft knowledge about teaching develops that includes only portions of the theoretical knowledge is present in the memory of experienced physical educators, but in an inert or inactive form, because this knowledge is perceived to have marginal practical utility. The context within which the beginning teacher works will probably be critical in determining the extent to which theoretical knowledge is retained, modified, or forgotten.

Since analysis of the knowledge structures of experienced math and science education teachers was not included, no data were available pertaining to how knowledge is reorganized as teaching experience accrues and what types of knowledge are retained or submerged in memory. Future studies need to delineate the nature of pedagogical knowledge that underpins teaching math and science and modifications of knowledge that take place as a function of teaching experience. We need to know more about the socialization of teachers not only from the sociological perspective but, from a cognitive perspective as well. Combining qualitative approaches borrowed from anthropology or sociology that are currently being employed in the study of teaching with quantitative cognitive mapping techniques could provide a rich methodology ideal for developing fin-grained descriptions regarding the acquisition, organization, and application of knowledge by teachers.

In summary, application of Pathfinder to the study of teaching appears to have potential for unveiling the knowledge structures of teacher educators and prospective teachers. An important feature of Pathfinder is that it can be applied to individual students, thus providing a means for quantifying the changes in knowledge organization of a student over time. The Information measure or graphic representations of knowledge structures that can be generated using Pathfinder (see Housner et al. in press) can be used to describe how students internalize and represent well-delineated bodies of knowledge. Mapping the knowledge structures of teacher educators and prospective teachers provides insight into the complexities associated with organizing and applying a vast body of knowledge and may have the potential to contribute significantly to the improvement of teaching and teacher education. There are still, however, many unanswered questions that must be addressed before the results of studies of knowledge organization can be applied to teacher education.

References

Anderson, J.R. (1982). Acquisition of cognitive skill. Psychological Review, 89, 369-406.

rko, H., & Livingston, C. (1989). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. American Educational Research Journal, 26, 473-498.

Carter, K. (1990). Teachers' knowledge and learning to teach. In W.R. Houston (Ed.), Handbook of research on Teacher Education (pp. 291-310) New York: MacMillan.

Cooke, N.M., Durso, F.T., & Schvaneveldt, R.W. (1986). Recall and measures of memory organization. Journal of Experimental Psychology: Learninng, Memory, and Cognition, 12, 538-549.

Ennis, C.D., Mueller, L.K., & Zhu, W. (1991). Description of knowledge structures within a concept-based curriculum framework. Research Quarterly for Exercise and Sport, 62, 309-318.

Ericsson, K.A., & Oliver, W.L. (1988). Methodology for laboratory research on thinking: Task analysis, collection of observations, and data analysis. In R.J. Sternberg & E.E. Smith (Eds.), The psychology of human thought (pp. 392-428). Cambrige: Cambrige University Press.

Goldsmith, T.E., Johnson, P.J. & Acton, W.H. (1991). Assessing structural knowledge. Journal of Educatonal Psychology, 83, 88-89.

Housner, L.D. (1990). Selecting master teachers: Evidence from process-product research. Journal of Teaching in Physical Education, 9, 201-226.

Leinhardt, G. (1989). Math lessons: A contrast of novice and expert competence. Journal for Research in Mathematics Education, 20, 52-75.

Leinhardt, G., & Smith, D. (1985). Expertise in mathematics instruction: Subject matter knowledge. Journal of Educational Psychology, 77, 247-271.

Livingston, C., & Borko, H. (1989). Expert-novice differences in teaching: A cognitgive analysis and implications for teacher education. Journal of Teacher Education, 40, 36-42.

McDonald, J.E., Plate, T.A., & Schvaneveldt, R.W. (1990). Using Pathfinder to extract semantic information from text. In R.W. Schvaneveldt (Ed.), Pathfinder associative networks: Studies in knowledge organization (pp149-164). New Jersey: Ablex.

Olson, J.R., & Biolsi, K.J. (1991). Techniques for representing expert knowledge. In K.A. Ericsson & J. Smith (Eds.), Toward a general theory of expertise (pp.240-285). Cambridge: Cambridge University Press.

Peterson, P., & Comeaux, M. (1987). Teachers' schemata for classroom events: The mental scaffolding of teachers' thinking during classroom instruction. Teaching and Teacher Education, 3, 319-331.

Rovegno, I. (1991). A participant-observation study of knowledge restructuring in a field-based elementary physical education methods course. Research Quarterly for Exercise and Sport, 62, 205-212.

Rumelhart, D.E., & Norman, D.A. (1978). Accretion, tuning, and restructuring: Three modes of learning. In J.W. Cotton & R. Klatzky (Ed.), Semantic factors in cognition (pp.37-60). Hillsdale, NJ: Lawrence Erlbaum.

Schvaneveldt, R.W., Durso, F.T., Goldsmith, T.E., Breen, T.J., Cooke, N.M., Tucker, R.g., & DeMaio, J.C. (1985). Measuring the sturcture of expertise. International Journal of Man-Machine Studies, 23, 699-728.

Schvaneveldt, R.W., Durso, F.T., & Dearholt (1989). Network structures in proximity data. In G.H.Bower (Ed.), The psychology of learning and motivation (pp.249-284). New York: Academic Press.

Shulman, L. (1987). Knowledge and teaching: Fondations of the new reform. Harvard Educational Review, 57, 1-22.

Figure 1. Pathfinder network of math teacher educator #1.

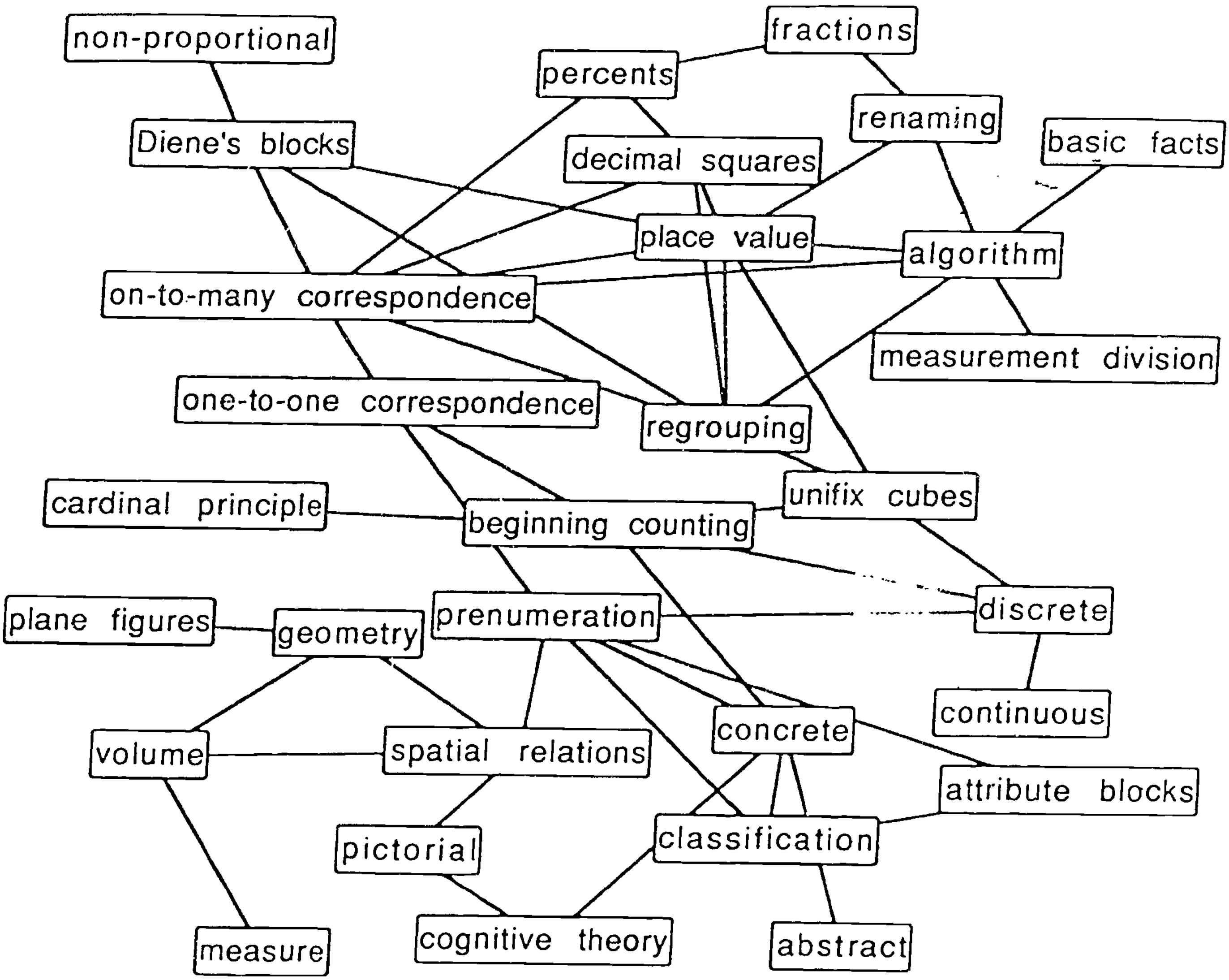

Figure 2. Pathfinder networks for math teacher educator# 2.

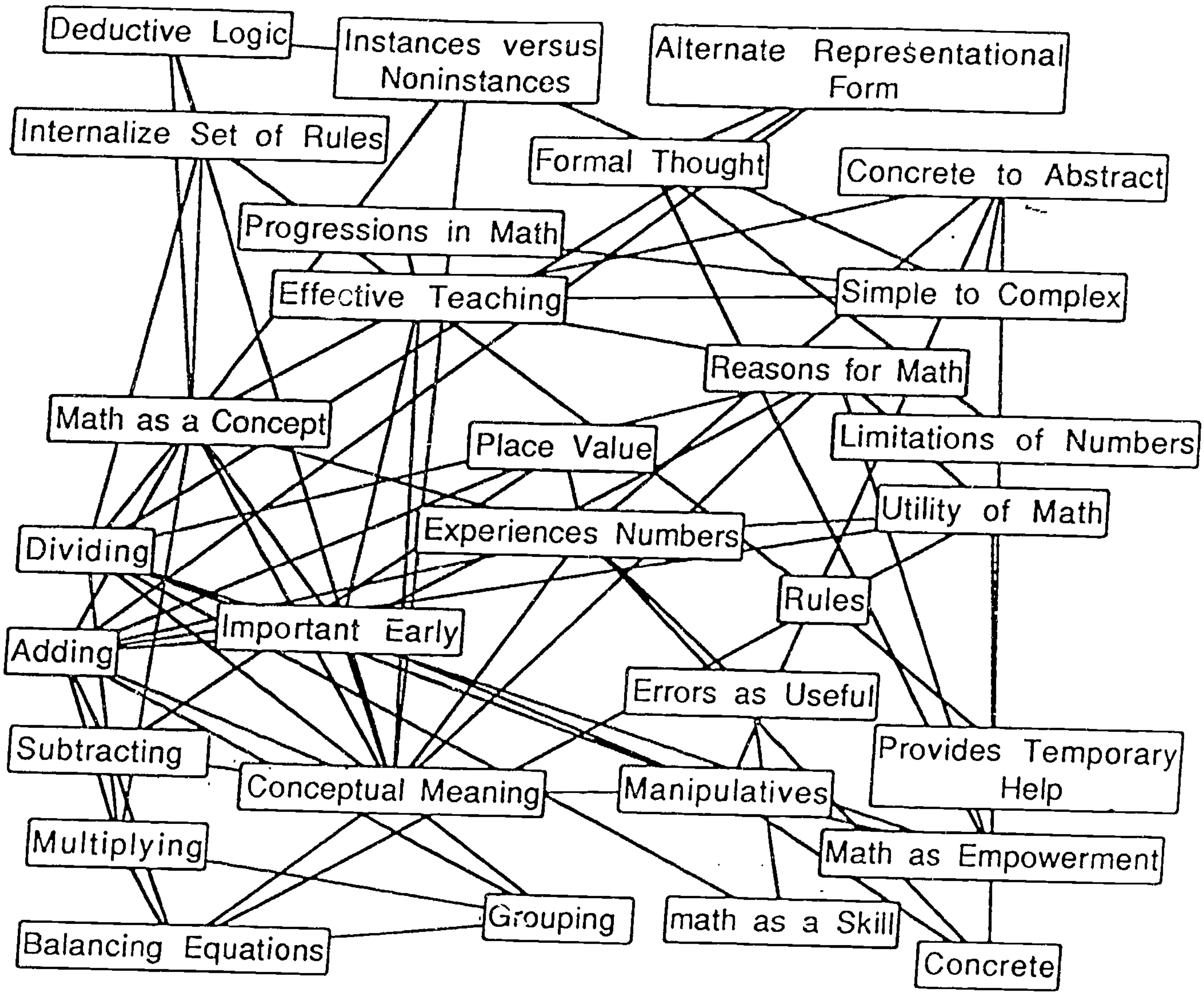

Figure 3. Pathfinder network for science teacher educator.