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ABSTRACT

This exploratory study examined the structure of declarative knowledge about pedagogy housed in the memory of an experienced teacher educator, and it sought to determine the teacher educator's influence on the development of declarative knowledge structures in undergraduate students enrolled in three sections of a physical education teaching methods course. The Pathfinder scaling algorithm, an associative networking technique, was used to map the pedagogical knowledge structures of the teacher educator and undergraduate students before and following participation in the course. Comparison of students' knowledge of key pedagogical concepts with the instructor's indicated that students' knowledge was more coherent and corresponded more closely to the instructor's following the courses; final measures of correspondence and coherence were significantly associated with course performance. Also, university grade point average (GPA) was highly related to course performance variables while American College Test (ACT) scores were not. A follow-up of a subset of students indicated that key pedagogical concepts were retained over a six-month period of time. However, performance on a semantic classification task of pedagogical concepts provided little evidence that students most highly correspondent with the instructor organized knowledge at a more semantic level than students who were less correspondent. (Contains 58 references.) (LL)

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Pedagogical Knowledge Structures in Prospective Teachers

Paper presented at the 38th Annual Meeting of the Southwest Psychological Asociation. Austin, TX, April 16-18, 1992

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Abstract

The Pathfinder network scaling algorithm was used to analyze the structure of prospective teachers' pedagogical knowledge before and following participation in three sections of a physical education teaching methods class. Comparison of students' knowledge of key pedagogical concepts with the instructor's indicated that students' knowledge was more coherent and corresponded more closely to the instructor's following the courses. Also, final measures of correspondence and coherence were significantly associated with course performance. Additionally, university grade point average (GPA) was highly related to course performance variables while American College Test (ACT) scores were not. A follow-up of a subset of students indicated that key pedagogical concepts were retained over a six month period of time. However, performance on a semantic classification task of pedagogical concepts provided little evidence that students most highly correspondent with the instructor organized knowledge at a more semantic level than students who were less correspondent. Future directions for the study of knowledge acquisition in physical education teachers and teacher educators are discussed.

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Pedagogical Knowledge Structures in Prospective Teachers

Educational researchers have begun to describe the nature of knowledge representations that underly the cognitive processes and teaching behaviors employed by experienced and inexperienced teachers. Results of this line of research provide initial support to the notion 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. Moreover, knowledge that teachers bring to classrooms seems to have a powerful influence on the way that teaching is perceived and practiced (Berliner, 1987; Carter, 1990; Leinhardt, & Smith, 1985, Leinhardt, 1989; Peterson, & Comeaux, 1987; Shulman, 1986).

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, 1990).

Recently, researchers have investigated the ways that knowledge develops as teachers progress from being undergraduate students through induction to becoming experienced teachers. Shulman (1986) and his associates (Grossman, 1989; Gudmundsdottir & Shulman, 1987; Richert, Wilson & Marks, 1986; Wilson, Shulman & Richert, 1987) have focused on the influence of disciplinary perspectives, content knowledge, orientations toward subject matter, personal beliefs about teaching, and teacher education experiences on the development of prospective teachers' pedagogical content knowledge. The emerging findings indicate that each of these factors can influence the way that teachers establish educational goals, organize curricular structures, communicate values and beliefs about content, and select instructional techniques for transforming and conveying subject matter to students.

In physical education, Ennis, Mueller, and Zhu (1991) and Lynn, French, Rink, Lee, and Solomon (1990) have extended this work using a cognitive mapping technique based on subject-generated, ordered 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. In both studies, 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 has potentially important implications for teacher education. Ennis et al. (1991) suggests, "Teacher preparation and staff development experiences that encourage teachers to assimilate new knowledge into continually evolving networks may facilitate the formation of complex structures associated with expertise" (p.317). 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.

According to cognitive psychologists (Anderson, 1983; Chi 1981), an important component of the knowledge base is declarative knowledge. Declarative knowledge is the domain-specific, factual content residing in long-term memory. Declarative knowledge is often represented in semantic networks consisting of concepts or nodes, relations describing the nature of each node, and links representing meaningful connections between concepts (Anderson, 1983).

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).

Additionally, 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).

Purpose of the Study

The present study was an exploratory investigation designed to examine the structure of declarative knowledge about pedagogy housed in the memory of an experienced teacher educator. Furthermore, the study sought to determine the influence of the teacher educator on the development of declarative knowledge structures in undergraduate education students enrolled in three sections of a generic teaching methodology course. The Pathfinder scaling algorithm, an associative networking technique, was employed to map the pedagogical knowledge structures of the teacher educator and undergraduate students.

Of particular relevance to the present investigation is a recent study by Goldsmith, Johnson, and Acton (1991). They 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.

Based on the findings of Goldsmith et al. (1991), 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 and teaching performance evaluations than students low in correspondence.

The researchers also were interested in examining the relationship between measures used as criteria for entrance into teacher education programs and students' ability to internalize, organize, and utilize pedagogical concepts. Therefore, students' university GPA and ACT scores were collected.

Finally, measures were taken to find out whether students were able to maintain the structural integrity of knowledge representations over time. We also investigated the relationship between measures of correspondence to students' ability to semantically classify the relations connecting concept pairs. A follow-up investigation was conducted using students from one of the sections of the teaching methods class. These students returned six months after completing the class. At this time a more detailed analysis of students' ability to internalize, organize, and retain pedagogical knowledge was conducted.

Pathfinder network scaling algorithm

A variety of knowledge elicitation and representation techniques can be used in the production of empirically-based structural representations of knowledge. In the present study knowledge was assessed using the Pathfinder scaling algorithm (Schvaneveldt, Durso, and Dearholt, 1989). The procedure for assessing knowledge organization through the use of Pathfinder requires several steps. Initially, a list of concepts representing the domain under investigation is generated. Concepts that comprise knowledge of the domain are delineated according to some criterion; in this case an experienced teacher educator. 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 6).

Knowledge measures. Two measures derived directly from the relatedness ratings were used to compare students' pedagogical knowledge to that of the teacher educator. Proximity is a commonly used measure of correspondence calculated by performing a correlation between the entire set of relatedness ratings for the teacher educator and each student. Coherence is a measure of the internal consistency of a student's relatedness ratings. Therefore, it can be used only as an indirect measure for comparing knowledge organization between a student and the teacher educator. Coherence is based on the assumption that concepts that are related to individual concepts should be highly related to each other. For example, if concept A is highly related to concept B, then they should share relationships with many other concepts.

The Pathfinder scaling algorithm is used to transform the relatedness data into associative network representations. In Pathfinder networks, each concept is represented by a node and the 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. 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. The advantage of a Pathfinder network over the original proximity data is that it results in a reduction to the most salient relationships among concepts, and provides a visual summary of those relationships.

Pathfinder provides two measures of correspondence that were be used to compare student and teacher educator network representations; similarity and graph-theoretic distance. Similarity is a set-theoretic method for evaluating the similarity of two Pathfinder networks. Similarity measures the degree two networks share the same neighborhoods (i.e., connections to items one link away). In computing similarity, the neighborhoods for a particular node (concept) in both networks is obtained. Then, the ratio of the intersection to the union of the neighborhoods is computed for each of the nodes. The final similarity measure is the resulting average of the ratio of the intersection to the union for all nodes in both networks. An example of the procedure for calculating similarity is presented in Table 1.

TABLE 1 ABOUT HERE

Graph-theoretic distance (GTD) is another measure of correspondence computed by correlating the graph-theoretic distance, or minimum number of links, between every pair of nodes in two Pathfinder networks. An illustration of the procedure for calculating GTD is provided in Table 2.

TABLE 2 ABOUT HERE

Interpreting knowledge measures. In determining the meaning of metrics such as these it is important to keep in mind that psychological validity of a metric has no meaning unless it is related in some way to behavior. For all of the knowledge measures higher values are associated with increased levels of correspondence and coherence. However, a knowledge measure, such as a similarity score of .36, conveys very little information in isolation. Rather, metrics such as these only have meaning when they can be used to predict behavior (Olson, & Biolsi, 1991).

Pathfinder has been used successfully as a knowledge representation technique in a number of domains. The knowledge representations generated by Pathfinder have been used as predictors of knowledge organization in memory studies (Cooke, Durso, & Schvaneveldt, 1986; Branaghan, 1989). Pathfinder has also been used for extracting semantic information from text (McDonald, Plate & Schvaneveldt, 1990), capturing the cognitive structures underlying human expertise (Cooke, & Schvaneveldt, 1988; Gammack, 1989; Schvaneveldt, et al., 1985) and in the assessment of students' mental models for academic subject areas (Goldsmith & Johnson, 1989).

Pathfinder is only one of many knowledge representation scaling techniques, such as Multidimensional Scaling (Kruskal, 1964), Hierarchical Cluster Analysis (Johnson, 1967), or Ordered Trees Structures (Reitman & Rueter, 1980). Olson and Biolsi (1991) suggest that it is important to use scaling methods that best fit the organization of the underlying representation of knowledge under study. Pathfinder is well suited for situations where an ordered and hierarchical structure of knowledge is not presumed.

Classic work in network models of semantic memory suggests that memory can be organized in terms of an associative structure with many local connections, rather than in terms of a strictly hierarchical structure (Anderson, 1983; Collins & Loftus, 1975; Rumelhart & McClelland, 1986). During the initial interviews (see methods section) it appeared that the teacher educator's pedagogical knowledge was comprised of interrelated and interdependent sets of concepts. Unlike many hierarchical techniques, Pathfinder fits nicely with this type of representation. Pathfinder does not require that concepts be nested hierarchically and it can reveal any number of links connecting concepts, thus showing elaborate semantic relations. Therefore, for the domain of knowledge under investigation in the present study Pathfinder was considered preferable to techniques that require concepts be represented in hierarchical format.

Assumptions regarding teacher education

Pathfinder was used in the present study because it is capable of assessing the correspondence between the knowledge structure of students and some criterion structure; in this case, that of an experienced teacher educator. A major assumption of the present study is that a fundamental task of teacher educators is to share what they know with students. Although we know little about the nature of teacher educator knowledge, it seems reasonable to argue that substantial knowledge about teaching has been accumulated during the course of a professional career. It is our position that it is incumbent for teacher educators to transmit their knowledge about effective teaching to students in a manner that is readily comprehensible.

A liability of the Pathfinder technique is that prospective teachers are assessed on their ability to build and use knowledge in a way similar to the instructor. A teacher educator who is committed to a particular model of instruction may be intolerant of the creative, idiosyncratic, yet functional representations of teaching that might be adopted by prospective teachers.

However, this does not suggest that prospective teachers are necessarily indoctrinated to think as their professors do. Although this may occur in some teacher education courses and experiences, the philosophy espoused by the teacher educator in the present study during initial interview sessions was, "prospective teachers should be equipped, empowered if you will, with current knowledge regarding the assets and liabilities of research on teaching." He argued that without such knowledge about pedagogy little reflectivity is possible. Students need to be provided with knowledge to reflect upon. If prospective teachers are indoctrinated at all, it would be with the expectation that they would be able to flexibly and reflectively employ knowledge during clinical experiences, student teaching, and induction.

Explicitly, or by example, teacher educators convey their perspectives about the nature of effective teaching to students. The key is to make explicit the beliefs, values, and knowledge that form the foundation of educational practice in teacher education.

Method

Subjects

The teacher educator. The teacher educator who participated in the investigation was also a collaborator in the research project. There were several reasons why this teacher educator was selected as a subject. First, he had extensive experience as a teacher educator. He had worked for 11 years at the university level as a teacher of prospective educators. During this time his primary responsibilities included teaching courses on pedagogical methods and supervising students during clinical field experiences and student teaching.

Second, several converging lines of evidence indicated that he was an effective teacher educator. In his 1991 departmental performance evaluation the department head summarized his teaching ability by stating, "students and peers recognize his ability as an effective teacher educator." Also, evaluations of his teaching by students have been consistent and exemplary. In 1990, based on standardized, university-wide student evaluations he was rated in the top 10% of all university professors in teaching effectiveness. Finally, he was a finalist for both the Westhafer and Burlington Northern awards for teaching excellence in 1990 and 1991, respectively.

Finally, the teacher educator was interested in analyzing his own teaching. By participating in the study he saw the opportunity to assess the structure of his own pedagogical knowledge and the influence of his teaching on students' ability to internalize and organize knowledge. Based upon these criteria, the researchers felt that the teacher educator had adequate teaching expertise to warrant inclusion in the study.

The undergraduate students. The students were 28 undergraduate education majors (17 females & 11 males) attending a medium-sized university in the United States. Students were enrolled in one of three sections of a course on generic teaching methods in physical education taught by the teacher educator. The courses were conducted during the spring semester of 1990 (5 females & 3 males), the fall semester of 1990 (8 females & 2 males) and the spring semester of 1991 (4 females and 6 males). Participants were treated in accordance with the ethical standards described in Principle 9 of the American Psychological Association.

Students from three different classes were included in the study because of the low number of students enrolled in each class. Despite the disadvantages of using aggregated data, examining the structural characteristics of students' pedagogical knowledge across three courses taught at different times would be a more rigorous test of the usefulness of Pathfinder in the study of teaching. Furthermore, one way ANOVAs performed on GPAs, ACT scores, academic performance, teaching performance, and pre-post changes in similarity, graph-theoretic distance, proximity, and coherence indicated that differences between classes did not approach significance (p >.05) for any of these variables.

The teaching methodology course

Course description. The focus of each of the courses was on generic teaching in physical education. The courses consisted primarily of assigned readings, lectures, class discussions, and modeled teaching demonstrations pertaining to research on teaching effectiveness (Housner, 1990; Rosenshine & Stevens, 1986). Assets and liabilities associated with pedagogical concepts about teaching effectiveness were emphasized. According to the teacher educator an important tenet of the class was that, "teaching is highly contextualized. There is no one best way to teach. Rather particular teaching techniques vary in their effectiveness depending on a myriad of critical variables associated with teaching goals, student characteristics, subject matter, etc."

Although it is expected that minor adjustments are made in the same courses taught during different semesters, the structure and content of the courses in the present study were kept as similar as possible. The same packet of reading materials, lecture notes, modeled teaches, examinations, and evaluation criteria were used in each of the classes. Therefore, the pedagogical principles espoused in all of the classes were highly similar.

A component of each course was a clinical teaching experience. Students had an opportunity to apply pedagogical concepts while teaching two, five lesson units to groups of approximately 10 children ranging in age from seven to 11. This laboratory experience was conducted at the university and has been a part of the teaching methodology courses for over five years.

Course performance variables. The influence of knowledge organization on class performance was examined by correlating the three measures of knowledge correspondence and the single coherence measure with naturally-occurring academic and teaching performance measures. Academic performance was the average of the combined percent correct responses achieved by students on a midterm and a comprehensive final examination. Both examinations were typical combinations of objective and subjective items. Teaching performance consisted of the instructor's qualitative assessments of the students' ability to apply key pedagogical concepts during the clinical component of the course. The final teaching performance rating was a percent score out of a possible 100% and represented the instructor's overall impression of a student's ability to plan and implement lessons that included the designated pedagogical concepts.

A final grade was determined for each student by calculating the average of academic (midterm + final) and teaching performance. This average score represented the final grade in the course. Thus, each component represented 33 percent of the final grade. The investigation was conducted using aggregate data from three different classes. Although ANOVAs on course performance variables indicated that the three classes did not differ significantly, within-class z transformations were performed on all course performance variables to further minimalize between-class differences.

Procedures

Assessing teacher educator knowledge. The initial step in the study was to delineate the pedagogical knowledge structure of the teacher educator. This process began during the fall semester of 1989. Researchers conducted several interviews with the teacher educator 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 pedagogical concepts that represented important components of his teaching methodology classes, each concept was written on a 3 by 5 index card.

After the teacher educator was finished generating concepts, 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 might think of while sorting cards. Also, he was allowed to make copies of cards, if a particular concept belonged to more than one category. The interview and card sorting procedures resulted in a list of 92 concepts.

Since Pathfinder requires subjects to rate the relatedness of all possible pairs (n x n-1 /2) of concepts, including all 92 concepts in the analysis would have been inordinately time consuming. Therefore, the instructor was asked to identify 40 or fewer key concepts that represented the most important pedagogical knowledge contained within the courses. The teacher identified 36 key pedagogical concepts. All possible pairs (N=630) of the 36 key pedagogical concepts were randomly presented and the instructor was asked to rate the relatedness between each concept pair. Concept pairs were rated using a scale ranging from highly related (1) to completely unrelated (6). The rating procedure was conducted using a personal computer and a data collection software package. The rating procedure took approximately one hour.

The Pathfinder network scaling algorithm was then used to transform proximity data (a matrix of relatedness ratings) into a network representing the instructor's knowledge structure of the domain of concepts. Pathfinder permits the subject to manipulate the spatial organization of the network so that it more closely resembles the subject's perceived internal representation of the domain. Nodes (concepts) may be moved to any spatial location within the network. However, links between nodes can neither be added or deleted.

The resulting spatial organization of the concepts conveys only subjective information regarding the subjects' perceptions of the organization of knowledge over and above the objective information conveyed by the links connecting concepts. The teacher educator was asked to view his network and manipulate it in any way that he would like so that it closely resembled his perception of the organization of the domain.

Assessing students' knowledge. During the initial week of each of the teaching methodology classes, students rated all possible pairs of the key pedagogical concepts. Students repeated this procedure during the final week of each class. Pathfinder networks were then generated and used to compare the correspondence and coherence of students' pedagogical knowledge structures to that of the instructor. These measures were used to determine the changes in pedagogical knowledge organization that occurred during the teaching methodology course and the correlation of these changes to course performance.

In addition to knowledge measures, university GPA and ACT scores were collected for students. GPAs were available for all students and ACT scores were available for 20 students. Correlations were used to examine the relationships between these variables and course performance. The researchers were careful not to inform the teacher educator of the knowledge measures, GPAs, or ACT scores of individual students until after the courses were completed.

Results

Teacher educator's knowledge

The final set of 36 key pedagogical concepts that reflected the instructor's perception of the most important concepts related to effective teaching were grouped by the instructor into six categories; 1) direct instruction concepts included review, anticipatory set, state objectives, comprehension monitoring, questioning, choral response, guided practice, independent practice, closure, and precue; 2) management concepts included obtaining attention, withitness, rules/routines/procedures, smooth transitions, teacher circulation, and management time; 3) task structure concepts included task analysis, hierarchical sequencing, non-exclusion, task parameters, inherent feedback, varied task contexts, and safe space; 4) feedback concepts included teacher feedback, evaluation, diagnose, prescribe, corrective, praise, and manual guidance; 5) pedagogical content knowledge included focus attention, instructional cues, demonstration, manual guidance and analogies/metaphors; and 6) student growth concepts included student success and student engagement.

FIGURE 1 ABOUT HERE

The teacher educator's Pathfinder network is presented in figure 1. When asked to describe the structure of the Pathfinder network, the teacher educator said that it was apparent from the network that he viewed student engagement and success as two important and overarching pedagogical concepts. These concepts pervaded the network and were linked to a number of concepts in several categories. Interestingly, these concepts were frequently duplicated during the card sorting task and placed in more than one pedagogical category. This conformed to his belief that the most important component of effective teaching was facilitating student affective, cognitive, and psychomotor learning. He also pointed out that the associative structure of the network fit his view of the interdependence and interrelatedness of pedagogical concepts.

However, he also observed that when manipulating the spatial organization of the network that he tended to place the concepts into meaningful categories or chunks. For example, inspection of the network shows that the management concepts (obtaining attention, withitness, management time, smooth transitions, rules/routines/procedures, and teacher circulation) are all placed together in the lower right hand corner of the network.

Careful examination of the network indicates that the concepts representing the other pedagogical categories are similarly placed in close proximity to one another. Therefore, although Pathfinder is based on the assumption of a non-hierarchical organization of human memory, the teacher educator in the present study felt more comfortable with concepts grouped together in highly interactive categories.

Students' knowledge

Analysis indicated that students exhibited changes in knowledge organization across the course of the semester. Mean initial measures for similarity, graph-theoretical distance, proximity and coherence were .13 (SD=.05), .07 (SD=.09), .12 (SD=.09), and .53 (SD=11), respectively. Final means for these measures were .24 (SD=.07), .26 (SD=.14), .37 (SD=.16), and .60 (SD=.12), respectively.

A Hotelling's t-squared $(4,27) = 140.8$, $p<.001$, performed on differences between initial and final correspondence and coherence measures indicated that students' knowledge structures changed significantly and approximated the structure of the instructor more so at the end of the class than at the beginning. Dependent t-tests indicated that similarity; $t(27)=10.45$, $p<.001$, graph-theoretic distance; $t(27)=10.90$, $p<.001$, proximity; $t(27)=9.82$, $p<.001$, and coherence; $t(27)=3.52$, $p<.001$ were significantly higher at the end of the semester.

Graphic representations of knowledge structures provided additional evidence indicating that students' knowledge structures not only approximated the instructor's more closely at the end of the course but their structures also displayed increased organization and differentiation of pedagogical concepts. Figures 2 and 3 represent the intersection of the Pathfinder network of a typical student with that of the instructor's at the beginning and end of class, respectively. The student's final correspondence measures and the magnitude of changes from initial to final assessments were close to the final overall mean levels and mean changes achieved for all students. The correspondence measures for the student at the beginning of the class were; similarity .11, graph theoretical distance .12 and proximity .06. By the end of the class, correspondence measures for the student were; similarity .23, graph theoretic distance .25, and proximity .31. The links between concepts indicate those links that were shared in common with the instructor's Pathfinder network (see Figure 1).

FIGURES 2 & 3 ABOUT HERE

Inspection of the networks indicates that at the end of class the student had more links connecting concepts (N=51) that were in common with the instructor than at the beginning of the class (N=13). At the end of the class the student possessed a network where the salient relationships between concepts were beginning to emerge. However, even at the end of class the student had substantially fewer links connecting concepts than the instructor (N=84). Thirty-nine percent of the most salient links were not included in the student's network following instruction.

Student knowledge and course performance

Correlations. Descriptive statistics for students' course performance scores and GPA and ACT scores are presented in Table 3. Correlations between within-class z transformations of student performance scores and initial and final knowledge measures are presented in Table 4. Because of the number of correlations computed and the relatively small sample size, the confidence level for significance was set at $p<.01$.

TABLES 3 & 4 ABOUT HERE

Correlations between initial knowledge measures and student course performance scores were generally moderate with only two of the relationships reaching significance; those between similarity, graph-theoretic distance and performance on the midterm. This makes intuitive sense. Since initial measures of correspondence represent pedagogical knowledge that students brought with them to the courses, it would be expected that these measures might relate to course performance requirements completed earliest in the semester; such as the midterm.

In contrast to initial measures, correlations between final knowledge measures and student performance scores were generally moderate to high ($r(26)=.46$ to.85) with all but one, that between coherence and teaching rating, reaching significance. University GPA was also highly related to all academic course performance variables ($r(26)=.69$ to.77).

TABLE 5 ABOUT HERE

Correlations between GPA, ACT scores and course performance variables and final measures are presented in table 5. GPA was found to be significantly related to all knowledge measures and all course performance variables. However, GPA was found to relate only moderately to teaching performance; $r(26)=.48$. Unlike GPA, all correlations between ACT scores, measures of correspondence and coherence, and course performance failed to reach significance.

Step wise regression analyses. To more fully explore the relationship between students' knowledge structure and GPA and course performance, stepwise regression analyses were performed on academic and teaching performance measures. A stepwise regression analysis was conducted for academic and teaching performance. Initial and final knowledge measures and GPA were included in the analyses as predictor variables. ACT scores were not included because of low correlations with both academic and teaching performance variables and the unavailability of scores for eight students. Since there were nine predictor variables and 28 subjects in the analysis, the degrees of freedom for the F to enter was calculated as (N-K)-1 or 18. At a confidence level of $p<.05$, the F (1,18) to enter was set at 4.41.

The ANOVA for the full stepwise regression model for academic performance was significant, $F(2,25)= 48.63$, $p <.001$. Final proximity entered the equation first and accounted for 66.1% (adjusted r-squared) of the variance. GPA entered the equation next and added 11.8% to the explanatory power of the regression equation. The final regression model accounted for 77.9% of the variance in academic performance. As anticipated, initial measures were not included in the model.

The ANOVA for the full stepwise regression equation for teaching performance was also significant, $F(1,26)= 31.40$, $p<.001$. In contrast to academic performance, GPA was not included in the regression equation. Final proximity was the only variable to enter the regression equation and accounted for 52.9% (adjusted r-squared) of teaching performance variance. Although more modest than academic performance, by the end of the semester correspondence of knowledge representations was the best predictor of teaching performance.

Discussion

The findings suggest that the knowledge measures used in the present study are potentially valuable for direct, structural assessments of pedagogical knowledge organization in prospective teachers. Students internalized and used the key pedagogical concepts that comprised a major focus of the course. The results indicate that correspondence between student and teacher knowledge structures was not only predictive of classroom academic performance, but also related, though to a lesser extent, to instructor-rated teaching performance.

Although all final knowledge measures were found to correlate significantly with course performance, proximity was found to be the best predictor of both academic and teaching performance. Since proximity is based on the actual relatedness ratings rather than Pathfinder transformations of ratings, it might be argued that using Pathfinder to generate similarity and graph-theoretic metrics provides little explanatory power above that provided by proximity data alone.

This may be due to the incipient nature of beginning teachers' knowledge. Nisbett, Fong, Lehman & Cheng (1987) and Voss, Blais, Means, Green & Ahwesh (1986) suggest that novices need several experiences in relevant coursework before expert-like strategic thought begins to emerge. After only a single course it would not be surprising to find students in the present study still contending with the difficult task of semantically organizing pedagogical knowledge. Perhaps students represented knowledge at surface rather than deep levels which may be best captured by simple relatedness ratings.

When considering the relative value of relatedness ratings and Pathfinder transformations care should be taken not to completely dismiss the contribution of Pathfinder. Network representations cannot be derived from proximity measures. Pathfinder transformation of the original relatedness ratings is required for graphic representations of knowledge to be generated. Moreover, reduction of data to representations depicts the most salient relations within a domain of knowledge and provides a means for comparing the semantic organization of networks.

Also, it should be kept in mind that measures of similarity and graph-theoretic distance were highly correlated with course performance measures. Forcing similarity and GTD into the stepwise regression analyses ahead of proximity for academic and teaching performance accounted 53% and 43.7% of the variance, respectively. This would indicate that Pathfinder measures contribute substantially to course performance. However, this contribution is masked by proximity which captures most of the variance in course performance. Therefore, it can be argued that Pathfinder measures may be potentially important indicators of knowledge organization and performance. However, it is clear that more research needs to assess the relative contributions of Pathfinder measures and knowledge measures based on relatedness ratings alone.

Several converging sources of data provide support to the notion that knowledge representation and comparison techniques can be used as a valid measures of classroom learning. First, whereas initial knowledge measures were unrelated to academic or teaching performance, final measures contributed significantly to course performance. Therefore, students who were best able, by the end of the course, to assimilate and utilize the pedagogical knowledge in ways that were both coherent and consistent with the criterion structure performed better.

Secondly, stepwise regression analyses indicated that GPA was significantly related to academic performance. Not surprisingly, university GPAs were highly related to all <u>academic</u> course performance variables. It would be expected that students with an established record of academic success in other courses would also perform better on examinations of conceptual material in the teaching methodology course. However, GPA was only modestly correlated with <u>teaching</u> performance. Furthermore, regression analysis indicated that GPA did not significantly contribute to the explained variance in teaching performance. This is consistent with past research. Although most teacher education programs require a minimal GPA for admission (Darling-Hammond, 1990), there is little available evidence that GPA is related in any substantive way with teaching effectiveness (Doyle, 1990). Apparently, applying pedagogical knowledge on tests and in actual teaching practice is similar but requires the use of knowledge in different ways.

Unlike GPA, all relationships between ACT scores and course performance variables failed to reach significance. This is not surprising when one considers that ACT performance is a more distant measure, both conceptually and temporally, of overall ability than current GPA.

Taken together, the results of the present study suggest that the teacher educator, course, and students under study exhibited reasonably authentic performance characteristics. It would appear that the knowledge representation and comparison techniques used in the present study represent a viable method for assessing the structural knowledge changes that occur in prospective teachers as a result of participation in a teaching methodology course.

The analysis of the Pathfinder networks for the average student before and after completing the course provided evidence that the student had some prior knowledge of the pedagogical concepts at the beginning of the class. It was also apparent that at the end of the semester the student still had not fully organized knowledge to include the most salient relationships between concepts. Of course, this would seem a reasonable outcome for a single undergraduate course.

Although it is impossible to know for sure from the available data, perhaps this student was experiencing knowledge structure change through a process of accretion, or restructuring relative to previously held beliefs about effective teaching (Rumelhart & Norman, 1978). New knowledge is often added and refined in a slow and deliberate way. It would appear that even at the end of the semester this student was still in the process of gradual knowledge acquisition.

Analysis of the student's network representations indicate that changes in network organization are consistent with changes in measures of correspondence. As measures of correspondence increased across the semester so did the number of salient links shared in common with the instructor. According to associative network theorists, learning can be conceptualized in this manner (Anderson, 1983; Schwartz & Reisberg, 1991). Of course, another scenario could be used that describes existing links between concepts being reinforced or strengthened over time. Or, links present before instruction may be removed as students reexamine their understanding of the relationships among concepts. Previously held beliefs about a domain of knowledge may be challenged by new knowledge and result in the removal of links representing misconceptions. Finally, learning can be conceptualized as the establishment of new semantic relations representing new meanings associated with existing links.

Correlations between knowledge measures and course performance variables indicate that certain students were better able than others to assimilate and organize knowledge into structures similar to the instructor. However, the findings provide little insight into how students internalize and organize information. Pathfinder analysis does not provide information regarding how links are added, strengthened, or removed as knowledge is organized. It also provides no information about the nature of the semantic relations connecting concepts. Does increased correspondence suggest a deep, semantic representation of the key pedagogical concepts incorporated into the class or are the changes superficial and transitory, representing only a temporary change in knowledge structure?

To address these issues, a follow-up investigation was conducted six months after course completion with students of the spring 1990 section of the teaching methods course serving as subjects. Past research using Pathfinder has demonstrated that experts can easily identify the semantic relations of the links connecting concepts (Schvaneveldt, et al., 1985). Therefore, students were assessed on their retention of pedagogical concepts and their ability to correctly identify the semantic relationship of the links connecting highly related concept pairs.

Follow-up Investigation Methods

Subjects

Students from the spring 1990 semester methods class (N=8) participated as subjects in the follow-up investigation. In December, 1990, six months after the completion the teaching methods course all eight students were paid $10.00/ hour to participate in a three hour follow-up session. Only the students from the spring 1990 class were included in the follow-up investigation because the other classes had not yet finished their respective sections of the course. Students were treated in accordance with the ethical standards stipulated in Principle 9 of the American Psychological Association.

Procedures

Retention of concepts. During the first phase of the follow-up session, students rated the relatedness of all possible pairs of the key pedagogical concepts in a manner identical to that employed in the initial investigation. This procedure was used to assess the stability and structural integrity of students' representations of pedagogical concepts over a six month period of delay.

Classifying semantic relations. In the second phase of the session students were required to identify the semantic nature of the linkages connecting pairs of concepts using a classification system developed by the investigators and class instructor. All concept pairs (N=157) previously rated by the instructor as highly related (ratings of 1 or 2) were analyzed to determine the semantic relation linking each pair.

The instructor was shown related concept pairs and asked to "think-aloud" describing the relationship defining the link or connection between each pair. The verbal protocols were recorded and subsequently transcribed for analysis. A taxonomy for defining the nature of relations between concepts developed by Chaffin and Hermann (1984) was used to analyze each concept-concept link and delineate the types of semantic relationships present in the domain. Five types of semantic relations were found; 1) ordinate-subordinate, 2) causal, 3) co-occurrence, 4) shared class, and 5) procedural.

Ordinate-subordinate relations are those where one concept **is a type of** another concept. For example, analogy/metaphor is a type of instructional cue. Causal relations are present when one concept **is caused or facilitated by** another concept. An example would be student success is caused or facilitated by hierarchical sequencing. Proximity relations indicate that two concepts **occur in the same segment of a lesson**. For instance, review occurs in the same segment of the lesson (i.e., the introduction) as the anticipatory set. Shared class relations are those in which the pair of concepts both belong **to the same class or group of concepts**. For example, praise and corrective both belong to the same class or group of concepts; called teacher feedback. Procedural relations occur when one concept represents an action **performed on or about** another concept. An example is questioning is performed on or about instructional cues.

A classification test was designed that required subjects to select the semantic relation that correctly represented the relationship between concept pairs. Sixty concept pairs were selected that were distributed across each of the five types of relations in the following manner; 10 ordinate-subordinate, 14 causal, 12 co-occurrence, 14 shared class, and 10 procedural. Additionally, 28 non-related pairs (instructor rating of 6) were randomly interspersed among the related pairs to serve as distractors. The final test was comprised of 88 concept pairs. Students' classifications of the related and non-related concept pairs were analyzed to determine the percent of concept pairs classified in a fashion corresponding to the ways the instructor had previously classified them.

The reliability of the instrument was examined through a test-retest procedure. The teacher educator completed the classification task six months after initial construction of the instrument. Comparison of classifications on the retest with initial classifications yielded a coefficient of agreement of .96. Thus, the test appeared to be a stable measure of the teacher educator's perceptions of the semantic relations connecting concepts.

Results

Retention of concepts

Mean similarity, graph theoretic distance, proximity and coherence for initial, final, and delayed assessments are presented in Table 6. The data show a slight deterioration in similarity over a six month period of time. Four repeated one-way ANOVAs were performed to determine the differences between initial, final, and delayed measures of correspondence and coherence. A MANOVA was not employed because of the small sample size. The confidence level was adjusted ($p<.05/4 = .0125$) to reduce the likelihood of TYPE I error.

TABLE 6. ABOUT HERE

Repeated measures ANOVAs performed on similarity; $F(2,14)= 10.15$, $p<.009$, graph theoretic distance; $F(2,14)= 26.66$, $p<.001$, and proximity; $F(2,14)= 10.26$, $p<.008$ measures followed by Sheffe' multiple range post-hoc tests indicated that the reduction in correspondence was not significant between final and delayed assessments for all correspondence measures. Furthermore, delayed graph theoretic distance and delayed proximity measures were significantly higher than initial measures.

The ANOVA performed on measures of coherence failed to reach significance; $F(2,14)= 2.91$, $p<.12$. The trend in the data, however, was similar to that of correspondence scores with an increase taking place from initial to final assessment and a maintenance of this level from final to delayed assessment.

Classifying semantic relations

The overall mean per cent of related and non-related concept pairs classified correctly was 44.5% (SD=14.46, range= 20.4 to 73.7). Although the level of performance was low, an estimation t-test indicated that it was significantly higher than chance (16.67%); $t(7)=5.87$, $p<.0006$.

A one way ANOVA conducted on the mean performance for type of relation was significant; $F(5,42)= 5.331$, $p<.001$. Sheffe' multiple range post hoc tests indicated that the mean percent of concept pairs identified correctly was significantly higher for ordinate-subordinate (51.3%), causal (53.6%), co-occurrence (61.5%), and non-related (55.8%) concept pairs than shared class (19.6%) relations. Also, co-occurrence and non-related pairs were identified correctly at a significantly higher rate than procedural (25.0%) relations. No other comparisons were significant.

In order to examine the relationship between knowledge representation and the ability to discern the meanings of the links connecting concepts, correlations were performed between delayed correspondence and coherence measures and per cent of correctly identified semantic relations for each of the six types of concept pairs. Because of the small sample size and the number of correlations computed, the confidence level for significance was set at $p<.01$.

Significant correlations were found between delayed proximity and students' ability to correctly classify co-occurrence; $r(6)=.92$, $p<.001$ and non-related concept relations; $r(6)=.97$, $p<.001$. Delayed similarity was also related significantly to classifying non-related concepts $r(6)=.85$, $p<.01$). Finally, a significant correlation between graph theoretic distance and identifying procedural concept pairs $r(6)=.86$, $p<.01$ was also uncovered. No other correlations reached significance.

Discussion

The findings indicated that students maintained the structural integrity of their knowledge representations over a six month period of time. There were some additional data available that pointed to the role of correspondence in the retention of the key pedagogical concepts. During the follow-up session students were asked to describe effective teaching according to the philosophy espoused in the teaching methodology class. Analysis of the responses indicated that the number of key pedagogical concepts generated was significantly related to delayed similarity; $r(6)=.84$, $p<.01$ and delayed graph-theoretic distance; $r(6)=.91$, $p<.01$.

The findings for the classification task provides only marginal support for the notion that students with knowledge similar to that of the instructor represented knowledge at a deeper, more semantic level than students with less similar knowledge. Regardless of level of correspondence, all students had difficulty identifying the semantic relations linking concepts. The average performance across all six categories of relation types was only 44.5%. In fact, identification of shared class and procedural concept pairs was not significantly greater than that of chance (16.67%); $t(7)=.73$, $p<.48$ and $t(7)=.84$, $p<.42$, respectively.

Only co-occurrence relations seemed relatively easy for students to classify (61.5%). Identifying co-occurrence relations was also significantly related to proximity. However, relations representing the co-occurrence of pedagogical concepts in the same segment of a lesson (i.e., both precue and review occur during the closure of a lesson) were rather simple and straightforward. Co-occurrence concept pairs were well-practiced and actively employed to structure lessons during the clinical component of the course. The fact that the mean per cent for correct identification was highest for this type of semantic relation suggests that overlearning rather than depth of representation may have been the reason why students found this type of relation easiest to identify.

Procedural relations were found to be correlated with graph-theoretic distance. However, this type of relation was also difficult (25.0%) to classify; suggesting that correspondence did not provide a substantial advantage in recognizing this type of semantic relation. Interestingly, identification of non-related concept pairs was related to both similarity and proximity. This suggests that the advantage of representing knowledge in a way resembling the instructor is that students know which concepts do not go together.

Nonsignificant correlations between correspondence measures and identification of ordinate-subordinate, causal, and shared class relationships also suggest that the students' depth of semantic understanding of the domain was limited. Students found it relatively easier to correctly identify ordinate-subordinate relations (51.3%), and causal relations (53.6%) than shared class relations (19.6%). This may be because in ordinate-subordinate concept pair one of the concepts is simply a type of the other concept (i.e., praise <u>is a type of</u> teacher feedback). Similarly, in a causal relationship, one concept simply causes or facilitates another concept (i.e., student success is <u>caused or facilitated by</u> teacher feedback). In both cases all of the information necessary for making the judgement is contained within the concept pair.

Shared class relations, on the other hand, represent a relationship in which each of the presented concepts is related to and subsumed under a higher-order concept that is unavailable for scrutiny. For example, the concept pair choral response-questioning are both types of the over-arching concept comprehension monitoring, which is not present. In a sense, identifying causal and ordinate-subordinate relations require analysis of two concepts along a single linear dimension, while shared class relations require a more abstract analysis in two, orthogonal dimensions.

Identifying shared class concept pairs, perhaps more than any other type of relation, would require a deep, semantic representation of the pedagogical domain. Identifying shared class relations was the most difficult for students (19.6%) and unrelated to measures of correspondence. Taken together, although there were several significant relations between measures of correspondence and classifying semantic relations, it seems doubtful that students with high correspondence possess significantly deeper, more semantic representations than students lower in correspondence.

Conclusion

The findings of the initial and follow-up investigations indicate that the measures of knowledge derived from the relatedness ratings and Pathfinder transformations may be potentially valuable for examining the knowledge structure of teacher educators and the influence of teacher education experiences on pedagogical knowledge changes in prospective teachers. Unfortunately, the results of the present study provide little information pertaining to the ways that pedagogical knowledge is imparted by teacher educators or how prospective teachers organize and apply knowledge.

The present investigation uncovered one important antecedent variable that was related to students organization of pedagogical knowledge and class performance; university GPA. Results of the study indicated that students with a history of academic success were best able to organize the pedagogical concepts in memory and use this organized body of knowledge to successfully complete the requirements of the course.

The pervasive influence of GPA may reflect the different dispositions of students toward learning. According to Prawat (1989) students who adopt a mastery orientation toward academic tasks are intent on acquiring competence, highly metacognitive when performing academic tasks and receptive to abstract representation of knowledge. In contrast, students who adopt a performance orientation attempt to use learning as an expeditious way of completing academic requirements, "....as quickly and painlessly as possible" (pg.33). Though speculative at this point, it is possible to hypothesize that successful students in the present study had an orientation toward mastery while less successful students had an orientation toward performance.

Of course, it is equally plausible to argue that students with high GPAs have well developed studentship strategies that enable them to clearly "read" the instructor's intentions and respond accordingly on both exams and during teaching (Graber, 1989). The available data make it impossible to determine which explanation is correct. It seems reasonable to suggest that both orientation and studentship either separately or in combination might contribute to the relationship between GPA and course performance at various points in a student's teacher education career.

It is clear that more research is needed to uncover the reasons why certain students were better or more inclined than others at building representations of pedagogical knowledge. The findings suggest a number of theoretical and practical questions that need to be addressed in future research.

A particularly important line of research that needs to be pursued concerns the acquisition of knowledge by prospective teachers and how that knowledge influences behavior, cognitive skill, and reflectivity associated with becoming an effective teacher. Studies need to be designed that attempt to unpack and delineate the subject matter, pedagogical, and pedagogical content knowledge that characterize knowledge growth in teachers.

An important component of this research is the fine-grained analysis of what it is that teachers actually know, think and do as they plan, implement, and evaluate lessons, units, and larger curricular structures. Think-aloud planning sessions, stimulated recall, and methods for eliciting knowledge structures, such as Pathfinder, should be used to assess the knowledge and cognitive skill that characterize teaching. Furthermore, it is important that future studies employ systematic observations of actual teaching behavior and instruments that focus on the planning, interactive decision making, and self-evaluation of teachers.

Combining qualitative approaches currently employed in other studies of knowledge growth with the quantitative approach used in the present study could provide a rich methodology ideal for developing fine-grained intellectual and behavioral descriptions of successful and unsuccessful prospective, beginning, and inservice teachers. In this way it would be possible to determine the influence of knowledge on teaching as thought is translated into action.

Recently, educational researchers have shown an increased interest in subject matter knowledge and the instructional processes that teachers employ to represent this knowledge to learners. This concept has become known as pedagogical content knowledge. According to Shulman (1987), pedagogical content knowledge is, " the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful yet adaptive to the variations in ability and background presented by the students" (p.15).

Since the introduction of the concept of pedagogical content knowledge, educational researchers have embarked on programs of research in a variety of subject matter areas (e.g., mathematics, english, social studies, etc.). The thrust of investigations has been to describe the development of pedagogical content knowledge in prospective teachers (Ball, 1990; Ball, & Mcdiarmid, 1988; Graeber, Tirosh, & Glover, 1989; Grossman, 1989; Tirosh, & Graeber, 1990; Wilson, Shulman, & Richert, 1987) and the nature of pedagogical content knowledge employed by experienced teachers (Borko, & Livingston, 1989; Carpenter, Fennema, Peterson, & Carey, 1988; Leinhardt, 1989; Leinhardt & Smith, 1986; Livingston, & Borko, 1989, 1990; Wood, Cobb, Yackel, 1991).

The findings of this line of research indicate that beginning teachers may have adequate content knowledge. However, when confronted with student comprehension problems they have difficulty generating alternate methods for conveying content knowledge. Experienced teachers, on the other hand, demonstrate an ability to respond effectively to a diverse set of student learning problems. This appears to be accomplished through flexible and improvisational application of robust, field-tested instructional routines and heuristics built up in memory as a function of extensive teaching experience.

Currently, we are beginning a program of research designed to map the pedagogical content knowledge structure of prospective teachers as a function of participation in a variety of teacher education courses and how this knowledge is assimilated and organized into a coherent representation of the domain of human movement. Additionally, we are following prospective teachers into student teaching and induction in order to determine the long term effects of pedagogical content knowledge obtained in teacher education programs and the influence of teaching in ecologically valid settings on the application of and changes in this knowledge.

From a theoretical perspective more research needs to be conducted to determine what prospective teachers learn in teacher education programs and how this knowledge is organized in semantically meaningful ways in memory. The findings of the present study provided equivocal findings regarding the ability of students to classify the nature of the semantic relations connecting concepts. Generally, their performance was poor with correspondence related to performance for only several types of semantic relations. Future research needs to delineate the types of learning that take place as a prospective teacher progresses from beginning student through student teaching and into induction. Research needs to uncover whether learning takes place by adding new links, strengthening old links and removing erroneous links and how these different knowledge acquisition strategies are related to the development of semantic understanding of particular types of conceptual relations.

A particularly important line of inquiry, that has received little attention in physical education, concerns the knowledge of teacher educators and the ways that teacher educators attempt to impart knowledge to prospective teachers. Studies need to be designed that attempt to unpack and illustrate the subject matter, pedagogical, and pedagogical content knowledge of teacher educators. Teacher educators representing all of the academic disciplines that contribute knowledge to prospective teachers should be brought under study. We know little about the structure of knowledge of teacher educators in pedagogy, motor learning, exercise physiology, biomechanics, sport psychology, basic instruction, etc.

Moreover, there is virtually no research on the instructional techniques employed by teacher educators as they attempt to effectively transform and convey subject matter knowledge to prospective teachers. Similar to studies of teaching, research on teacher education needs to investigate the planning, decision making, instructional behaviors, and self-evaluation processes exhibited by effective teacher educators as they attempt to nurture knowledge growth in prospective teachers. While there is much discussion about pedagogical content knowledge of teachers, the pedagogical content knowledge of teacher educators has been largely ignored.

For example, research has begun to accumulate indicating that the use of cognitive mapping as an instructional method may facilitate student motivation and learning. Utilizing concept maps, whether derived from experts (Alvermann, 1986; Rewey, Dansereau, Skaggs, Hall, & Pitre, 1989), generated by instructors (Hirumi, & Bowers, 1991), or constructed by students (McCagg, & Dansereau, 1991; Schmid, & Telaro, 1990), can supplement text-based information and improve learner attention, motivation, recall, and test performance.

Apparently, concept maps assist students in "seeing" the structure of a subject matter domain; the subordinate and superordinate concepts and the interrelationships among these concepts. The pictorial representations serve as an advanced organizer that graphically displays the structure and organization of a content area. Perhaps the graphic representations available through the application of Pathfinder could be used as an instructional tool in teacher education.

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Network representations might also be used as a tool for the analysis of curricular experiences in teacher education programs. End-of-semester networks could be used to determine which associations among concepts are under developed. It is conceivable that such an analysis could highlight the types of associations that are most difficult for students to accommodate in memory. It might also point to portions of the curriculum that are important, but are under represented; or, content that is emphasized, but not conveyed as clearly as the instructor had originally thought.

In summary, application of Pathfinder to the study of teaching appears to have potential for uncovering and delineating the structure of knowledge that characterizes effective teacher educators and how that knowledge is imparted to prospective teachers. In addition, mapping knowledge structure changes in beginning teachers as they move from teacher education programs, through student teaching, and into induction provides insight into the complexities of organizing and applying a vast body of knowledge. Research on the processes associated with effective teaching and learning of subject matter, pedagogical, and pedagogical content knowledge has the potential to contribute significantly to the improvement of teaching and teacher education.

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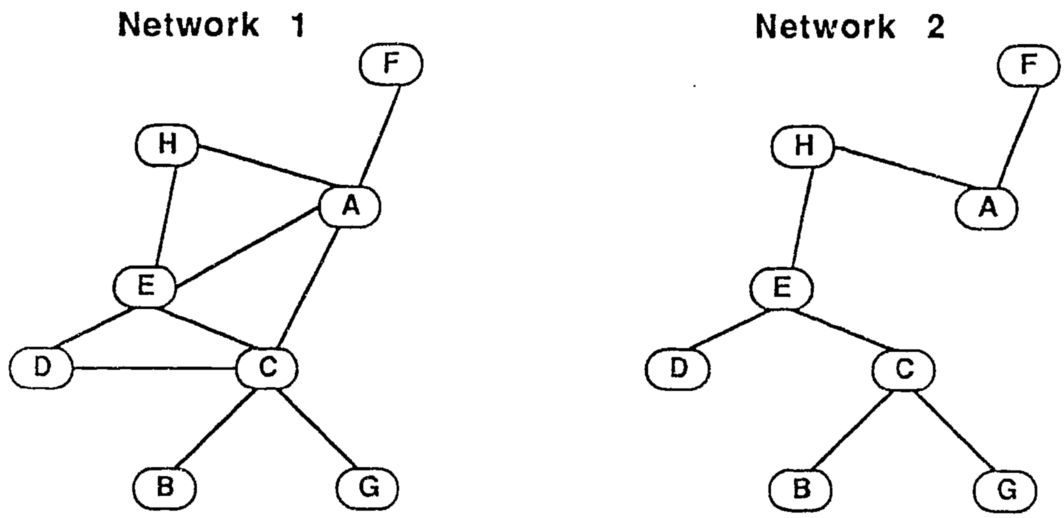


Similarity

1. Obtain the neighborhood for a node (concept) in Network 1 and Network 2.

A neighborhood about node A includes all nodes within one link of node A.

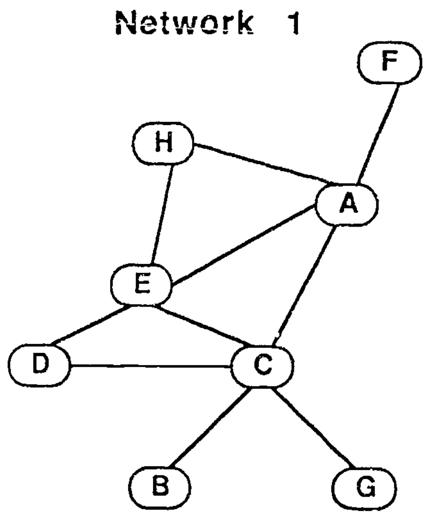
Neighborhood for Node A in Network 1: E, H, F, C
Neighborhood for Node A in Network 2: A, H

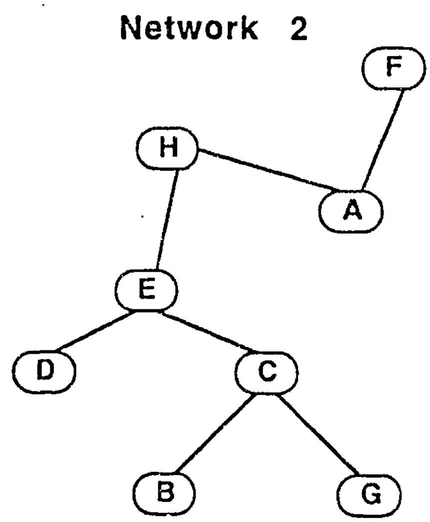
2. Compute the ratio of the intersection to the union of neighborhoods for the node in the two networks.

$$\frac{\text{Intersection A}}{\text{Union A}} = \frac{2}{4} = .5$$

3. Similarity is the average of the ratio of the intersection to the union for each node in the networks.

Table 1. Pathfinder transformation procedure for calculating similarity.





Distance

Correlation of the minimum distance between every pair of nodes (concepts) in Network 1 and Network 2.

Link Pair	Distance in Network 1	Distance in Network 2
A - C	1	3
A - D	2	3
A - G	2	4

Table 2. Pathfinder transformation procedure for calculating graph-theoretic distance (GTD).

	Midterm Exam %	Final Exam %	Teaching Rating %	Final Grade %	GPA	ACT
Means	84.9	76.7	80.8	80.9	3.26	20.75
SD	10.1	14.3	12.5	10.51	.44	4.5
Range	57-98	51-100	50-96	60-97	2.3-4.0	14-30

Table 3. Means, standard deviations (SD), and ranges for midterm, final, teaching, and final grade performance scores, university GPA and ACT scores (N=28).

Course Performance Variables	Initial Knowledge Measures Similarity	GTD	Proximity	Coherence
Midterm	.49*	.49*	.38	.35
Final Exam	.30	.33	.33	.32
Teaching	.37	.38	.30	.23
Final Grade	.46	.43	.40	.35

	Final Knowledge Measures Similarity	GTD	Proximity	Coherence
Midterm	.60*	.58*	.68**	.54*
Final Exam	.75**	.64*	.82**	.63*
Teaching	.70**	.65**	.74**	.46
Final Grade	.78**	.71**	.85**	.65**

Table 4. Correlations between *z* transformations of course performance scores, initial and final knowledge measures, GPA and ACT scores (N=28).
* p<.01, ** p<.001

	Course Performance Variables			
	Midterm	Final Exam	Teaching	Final Grade
GPA	.77**	.69**	.48*	.76**
Act	.37	.15	-.01	.19

	Final Knowledge Measures			
	Similarity	GTD	Proximity	Coherence
GPA	.64**	.63**	.68**	.73**
Act	.17	.39	.22	.33

Table 5. Correlations between university GPA and ACT scores and course performance variables and final knowledge measures (N=28). * p<.01, ** p<.001

	Initial Assessment	Final Assessment	Delayed Assessment
Similarity	M=.16 (SD=.05)	M=.28 (SD=.06)	M=.24 (SD=.07)
GTD	M=.13 (SD=.06)	M=.33 (SD=.09)	M=.25 (SD=.13)
Proximity	M=.19 (SD=.10)	M=.41 (SD=.09)	M=.38 (SD=.13)
Coherence	M=.56 (SD=.10)	M=.65 (SD=.10)	M=.67 (SD=.08)

Table 6. Mean similarity, graph theoretic distance, proximity, and coherence measures for initial (first week of the course), final (last week of the course), and delayed (six months after the course) assessments (N=8).

ERIC

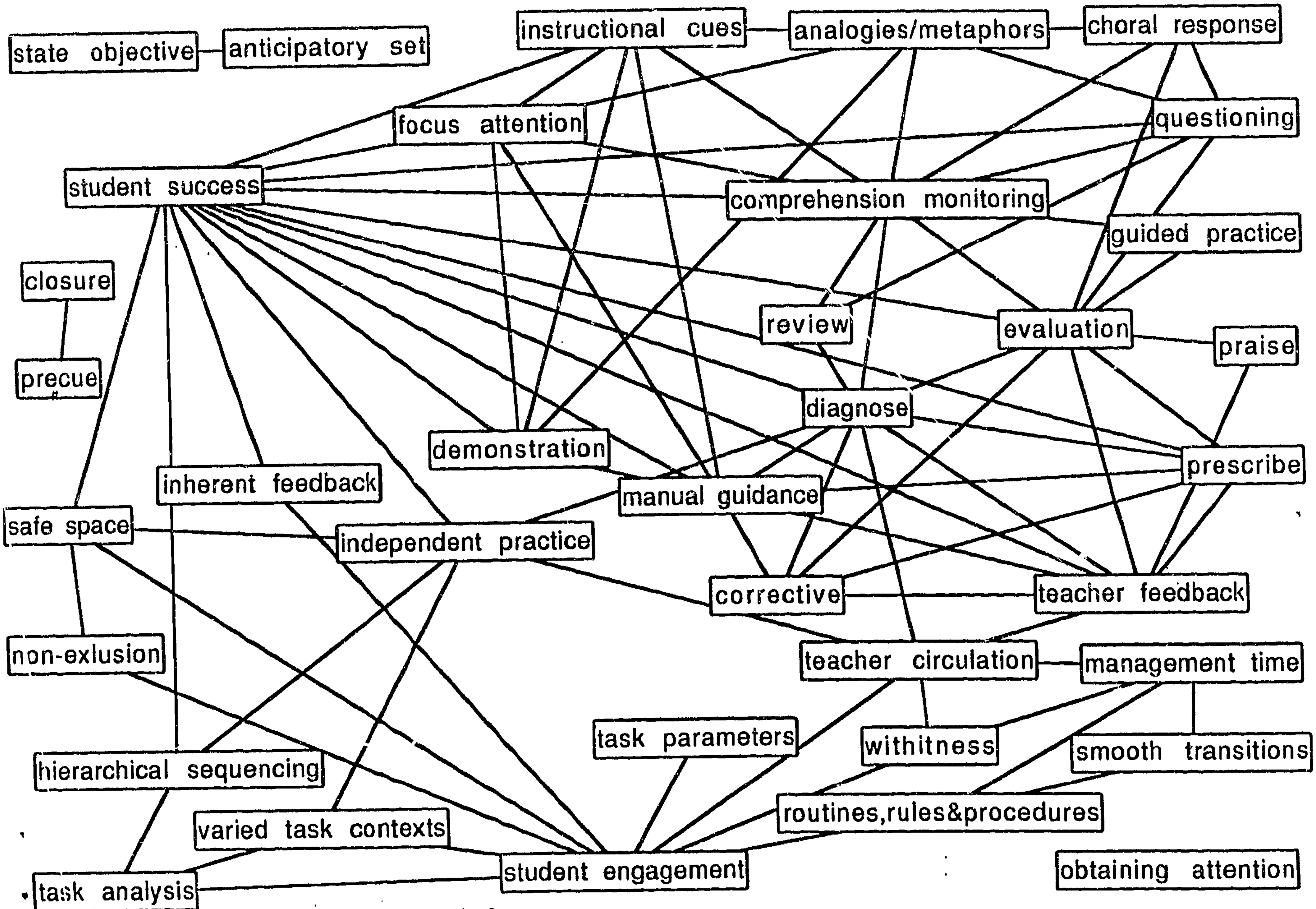
FIGURE CAPTIONS

Figure 1. Instructor's Pathfinder network (most related links).

Figure 2. Intersection of student's Pathfinder network with the instructor's Pathfinder network (links in common) in the beginning of the semester.

Figure 3. Intersection of student's Pathfinder network with the instructor's Pathfinder network (links in common) at the end of the semester.

FIGURE 1



state objective
anticipatory set
instructional cues
analogies/metaphors
choral response
focus attention
questioning
student success
comprehension monitoring
guided practice
closure
review
evaluation
praise
precue
diagnose
demonstration
prescribe
inherent feedback
manual guidance
safe space
independent practice
corrective
teacher feedback
non-exlusion
teacher circulation
management time
task parameters
withitness
smooth transitions
hierarchical sequencing
routines,rules&procedures
varied task contexts
student engagement
obtaining attention
task analysis

FIGURE 2

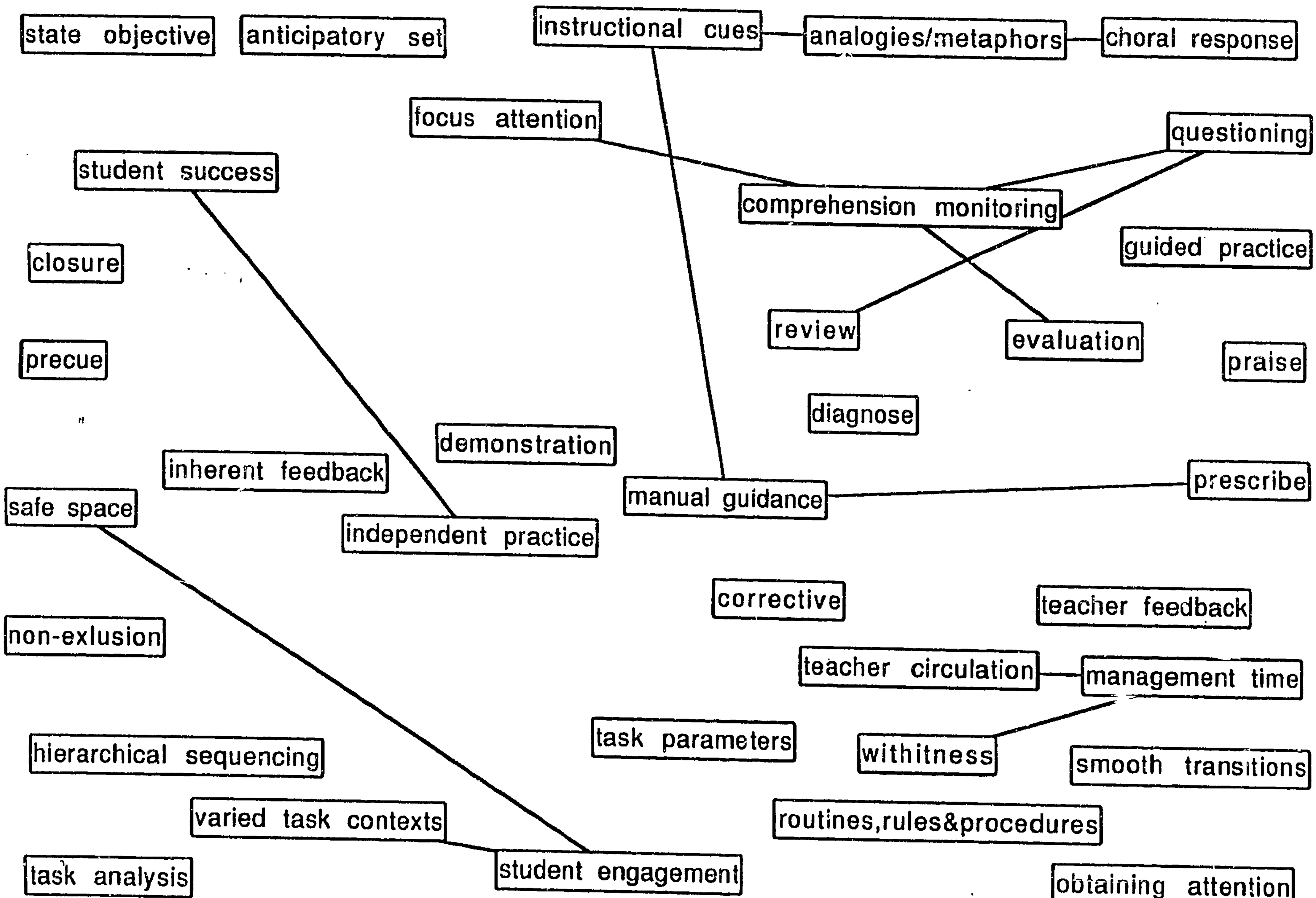


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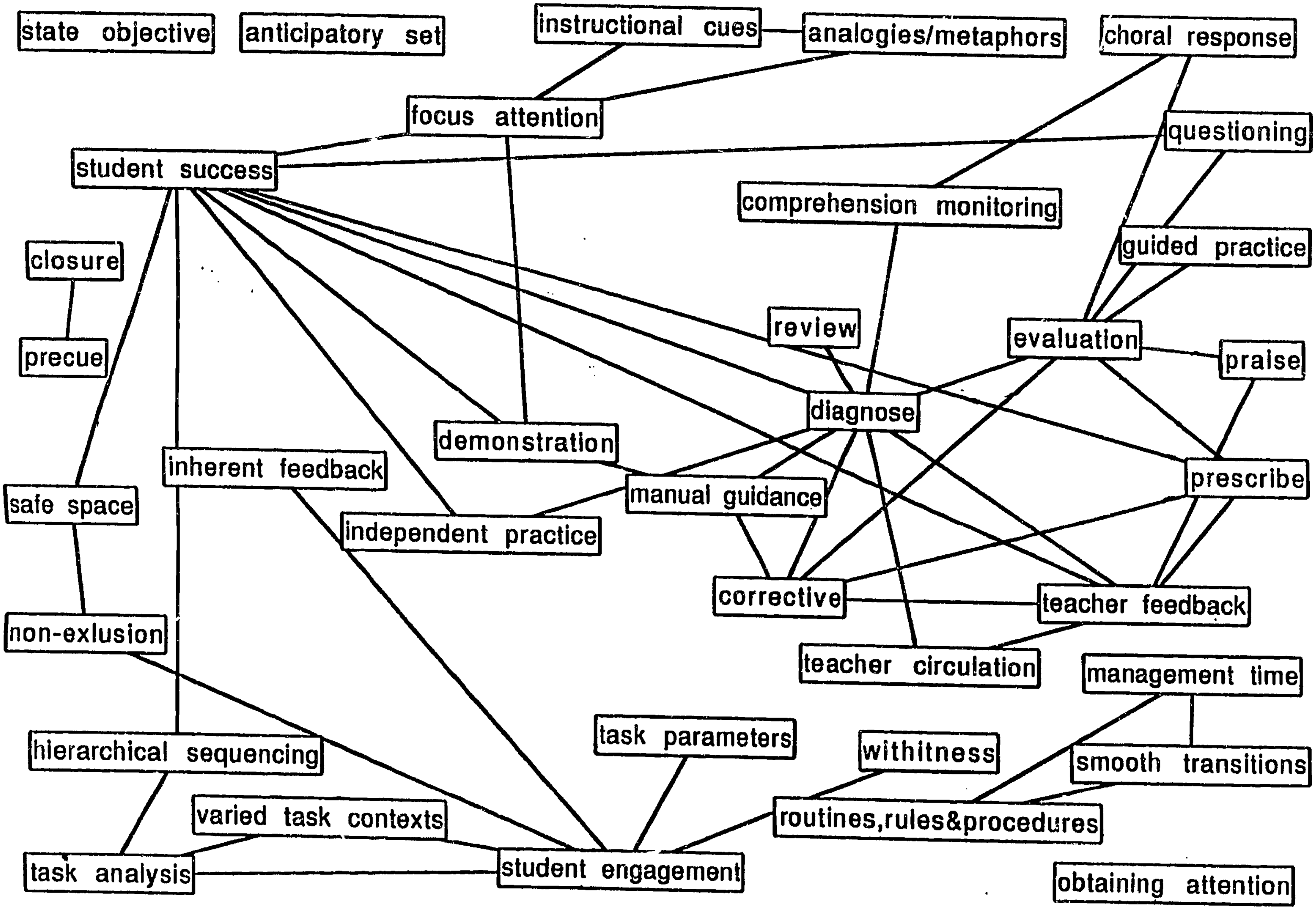
FIGURE 3



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