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Paper Title: Changes In The Structure of Pedagogical Knowledge in Mathematics and Science Preservice Teachers
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Abstract: This study investigated changes in preservice mathematics and science teachers' knowledge structures related to effective teaching during the final year of their teacher preparation program. The research questions included: (1) How do student teachers' concepts of effective mathematics or science teaching change through time?; (2) What experiences and factors influence changes in the organization of students' concepts related to teaching?; and (3) Do student teachers radically reconstruct their knowledge? Ten seniors in middle grades teacher education participated in the study. Each student drew concept maps, completed card sorting tasks and participated in four structured interviews during the senior year. The findings of the study indicated that student teachers underwent a radical reconstruction of their knowledge related to teaching during the middle of student teaching.

Analysis of the concept maps and the multidimensional scaling revealed that most of the changes in knowledge structures occurred during the middle of student teaching and these changes were a result of the student teachers' experiences with students and other teachers.

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Changes In The Structure of Pedagogical Knowledge in Mathematics and Science Preservice Teachers

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The purpose of this study was to examine how the concepts related to "effective teaching" change during student teaching for middle grades preservice mathematics and science teachers. The student teaching experience has proven to be one of the most critical components of teacher preparation programs, but little is known about the impact of specific experiences on preservice teachers' pedagogical knowledge.

In this study we examine how student teachers structure their knowledge at several points in their teacher education program. We explore the questions Shulman identified in 1986: "What are the sources of teacher knowledge? What does a teacher know and when did he or she come to know it? How is new knowledge acquired, old knowledge retrieved, and both combined to form a new knowledge base?" (p. 8)

Specifically we examine changes in knowledge structures across the student teaching experience to determine if student teachers experience weak restructuring (such as accretion), or radical reconstruction of knowledge. Accretion, according to Rumelhart and Norman (1978), is a type of weak reconstruction of knowledge that typically involves the daily accumulation of knowledge. Radical reconstruction, on the other hand, involves changes in core concepts and a change in the organization of the cognitive structure. Radical restructuring has been associated with the expert/novice shift found in areas such as chess or physics (Vosniadou & Brewer, 1987).

In a previous study of student teacher-pupil interactions, we found that student teachers appear to experience a decrease in interactions with their pupils midway through their student teaching, and this decrease appears to be associated with a tendency to seek control of the variability of the classroom (Jones & Vesilind, 1993). The results of this previous study led us to speculate that the student teachers were attempting to find predictable patterns and sequences of behaviors that they could control. This decrease in interactions that occurred at the midpoint of student teaching, as well as reports by other researchers that student teachers often experience a crisis or paralysis of action in the middle of student teaching (Corcoran, 1981; Veenman, 1984), led us to question whether these behaviors coincide with student teachers' attempts to radically reconstruct their knowledge about teaching.

Concept mapping is a technique that has been shown to be an effective tool for examining how individuals structure their knowledge (Novak & Gowan, 1984; Markham, Mintzes, & Jones, 1993.) Cary (1986) suggested that "by comparing successive concept maps produced as the student gains mastery of the domain, the researcher can see how knowledge is restructured in the course of acquisition" (p. 1126).

In the present study concept maps and a sorting task were used to examine how preservice teachers' concepts change throughout student teaching. In addition, structured interviews were conducted to examine the impetus for student teachers' knowledge reorganization.

Research Questions

1. How do student teachers' concepts of effective teaching change through time?
2. What experiences and factors influence changes in the organization of students' concepts related to effective teaching?
3. Do student teachers radically reconstruct their pedagogical knowledge during student teaching?

METHODOLOGY

Subjects

The subjects in this study were 10 seniors who were enrolled in the middle grades teacher education program at a large university in North Carolina. The 10 cooperating teachers and the university supervisor who served as supervisors for the participating students also participated in a separate study (Jones & Vesilind, 1993).

Procedure

The students were enrolled in a middle grades methods class (6 credit hours) during the fall semester. This class included instruction in teaching methods for two content areas (mathematics, language arts, social studies or science), middle school philosophy, and teaching reading and writing across the content areas. In addition, students were required to observe classes at their student teaching placement site for a minimum of 2 hours each week. During the spring semester, the students completed a semester of student teaching (16 weeks) and returned to the university for a weekly seminar. The seminar was designed to provide the students with opportunities to reflect on their student teaching and to receive support with solving problems encountered during student teaching. The seminar also included an examination of a number of topics including gender and multicultural issues in teaching, censorship in schools, and strategies for applying for jobs.

Students were given instruction on how to draw concept maps during August of their senior year. They were given time to practice drawing sample maps and were then asked to draw a concept map of effective teaching. Students were given one hour to complete their individual maps.

At the end of the semester (early January), at midterm of the spring semester (early March) and at the end of student teaching (May), the last map they had drawn was returned to the students, and they were asked to study the map and to decide if they would organize their knowledge differently. They were told to either draw a new map, modify their old map, or redraw the old map as it was. Each student was then interviewed individually and was asked to discuss his or her map and concepts related to teaching. Students were asked to describe what factors influenced them to change their maps. Interviews were audio recorded and later transcribed.

The cooperating teachers and middle grades university supervisors also drew concept maps at the beginning and end of the year. After the students, teachers and supervisors had drawn their first map, a frequency count was made of the concepts on the maps. The 20 most frequently used concepts were identified. These 20 concepts were placed on index cards and were given as a card sorting task to the students after the second, third and fourth concept map interviews. Students were instructed to look at the words on the cards and to sort the cards into piles according to how they thought the cards went together. They were told that they could have as many or as few piles of cards as they would like. The students were then left alone until they completed the task. Students were individually interviewed and asked to describe their sorting rationale for each card.

Analysis

The concept maps were coded and scored as described by Novak and Gowin (1984) and Markham, Mintzes and Jones (1993). In this process a total concept map score, as well as subscores are calculated from each map. The subscore categories included the number of concepts, examples, relationships, hierarchies, and crosslinks. Concepts are defined as a regularity in events or objects designated by some label. Examples are specific events or objects that are valid instances of those designated by the concept label. Relationships are defined as the connecting lines with linking word or words between two concepts or a concept and an example or between two examples. Hierarchies are coded when concepts and examples are connected from general to specific. Crosslinks are connections between one segment of a concept hierarchy and a segment of another hierarchy.

In order to determine if students radically reorganized their knowledge (beyond simply adding and deleting concepts), the frequencies of superordinate concepts were examined for each student across the four concept maps. Superordinate concepts were defined as concepts that are highest in a hierarchy and are directly connected to the title "effective teaching."

The results of the sorting task were analyzed with multidimensional scaling (Kruskal and Wish, 1978; Young, & Rheingans 1991). Multidimensional scaling is used to represent the semantic dimensions underlying a domain of concepts and provides information about the organization of the concepts in memory (Cooke, 1990). In this analysis process, a matrix was created that indicated how frequently a student placed one of the 20 concepts from the card sorting task with another concept. Multidimensional scaling algorithms then take pairwise proximity estimates for the set of concepts and generate multidimensional spatial layouts of these concepts. These dimensions reflect features along which the concepts vary, and psychological proximity is represented by the distances between the concepts (Cooke, 1990). Multidimensional scaling solutions have been shown to be psychologically meaningful (Cooke, 1990) for analogy completion (Rips, Shoben, & Smith, 1973), similarity judgment time (Hutchinson & Lockheed, 1977), categorical judgment time (Shoben, 1976), and judgments in an inductive reasoning task (Rips, 1975).

The interviews were analyzed for evidence of students' reasoning for changes in their concept maps. Each explanation was coded into a category that represented the source of change for the concept map. The categories that emerged from the responses were: the cooperating teacher, student teaching experiences (parents, other teachers, students and extracurricular activities), classes at the university, future jobs, peers, family, media, map design (changes related to how they viewed the structure of the map), conferences attended, and books or other readings. Two researchers independently coded the categories for an interrater reliability of .88. For those items in disagreement, the two researchers discussed the items and ultimately reached consensus.

RESULTS

Concept Maps

The results of the concept mapping indicate that student teachers' pedagogical knowledge became more complex and integrated across the last year of the teacher education program. The maps revealed that students used more concepts and crosslinks across the four maps. These results suggest that the knowledge structures of the students are dynamic and become more integrated and complex as the students complete their university classes and student teaching.

Figures 1-4 show concept maps drawn by Shelley, a student teacher. These maps show that Shelley's knowledge became more complex as she gained teaching experience. A sharp increase in the number of crosslinks and concepts is seen in map 3, which was drawn during the middle of student teaching when Shelley was teaching a full load of classes. The concept map scores for 10 science and mathematics student teachers are shown in (Table 1).

Table 1
<u>Concept Mapping Scores.</u>

Category	Mean			
	Map 1 (August)	Map 2 (January)	Map 3 (March)	Map 4 (May)
Examples	17.0	17.7	10.0	11.4
Relationships	60.1	65.9	67.0	64.8
Hierarchies	28.0	24.5	26.0	27.0
Crosslinks	39.0	57.0	86.0	74.0

Note. X^2 (9, N= 10) = 17.6, p< .05

The number of examples decreased as the students completed student teaching. Several students indicated during the map 3 and 4 interviews that they focused more on the overall organization of their map and omitted specific examples of some concepts. For example, Katie said, "I think that I have narrowed it down. I have a lot of things out there, but I've realized what's the most important." In the first map, students used more examples but used fewer crosslinks between hierarchies. The first maps showed that the students held detailed knowledge of selected concept hierarchies, but they lacked integration between hierarchies and concepts.

The analysis of the superordinate concepts showed that the total number of superordinate concepts increased for each sequential concept map (Table 2). However, when the mean number of superordinate concepts that were added or deleted was determined, the greatest number of changes appeared in the third map. The changes in the superordinate, or organizing concepts provide evidence that radical reconstruction of knowledge is taking place when the student teacher is most actively involved in student teaching.

Table 2
Changes in Superordinate Concepts

Mean	Map 1 (August)	Map 2 (January)	Map 3 (March)	Map 4 (May)
Superordinate Concepts	5.3	5.7	6.0	6.7
Superordinate Concepts Lost		-1.2	-1.7	-.7
Superordinate Concepts Gained		+1.6	+2.0	+1.4
Total Number of Changes		2.8	3.7	2.1

Note. Concepts lost or gained reflect changes from the previous map.
Note. N=10

During the interviews with students about their second map, 43% of the reasons they cited for the changes from map 1 were related to experiences that they had at their field placement (Table 3). Their university classes were listed as the second most frequent (23%) influence on the changes in the second map.

The interviews about map 3 took place when the student was in the middle of their student teaching, and the university classes were no longer cited as a reason for changes made in the concept map. Students attributed the changes in their concept map primarily to their student teaching experiences (67%). Attendance at the state middle school conference was also given by 12% of the students as a factor that influenced the organization of their third map. For map 4, the changes were attributed predominantly to the experiences the student teachers had during their student teaching, although other factors such as getting a future teaching job and peers were also cited.

Particularly noticeable on the student concept maps was the absence of concepts related to subject matter knowledge and pedagogical content knowledge (Shulman & Sykes, 1986). The lack of pedagogical content knowledge held by novice teachers has also been reported by Clermont, Krajcik, and Borko, (1993). Although all student teachers in the present study had completed methods coursework in two content areas (mathematics, language arts, science or social studies) in the fall of the senior year, there was little evidence of content-related concepts on the maps. One possibility is that the format of the concept map task failed to elicit content and pedagogical content knowledge. Students were instructed to think about concepts related to "effective teaching," and possibly student teachers considered only general concepts to be pertinent. Another interpretation is that because the student teachers in middle grades receive preparation in two content areas, they are unable to differentiate within their cognitive framework those concepts related to their content areas and the more general pedagogical concepts. Further research comparing teacher preparation in one and two subject areas can provide insight into the development of pedagogical content knowledge.

Multidimensional Scaling Results

The multidimensional scalings (MDS) for the card sorting tasks also provided evidence that students changed their knowledge organization across their student teaching experience (Figures 1-3). When the second multidimensional scaling is compared to the first, the concept "knowledge" moves from being closely associated with "teaching methods" and "teaching experiences" to being closer to the concepts "understanding" and "learning." "Flexibility" moves from a class management concept cluster on MDS-1 to a cluster that includes "instruction" on MDS-2, and then is not tightly clustered with any other concepts in MDS-3, but is situated near "materials" and "preparation," as well as the concepts "teaching methods" and "instruction."

The shifting concepts clustered with "class management" suggest that inthe middle period of student teaching "class management" is defined by mostly by "rules." By the end of student teaching, however, classmanagement is seen as integrated with preparation, planning, materials, and organization, as well as with rules.

Table 3

Students' Explanations for Changing the Concept Map

Category	Map 2 (January)	Map 3 (March)	Map 4 (May)
Cooperating Teacher	3	3	1
Student Teaching Experiences		10	6
1. Experiences With Students		2	7
2. Experiences With Other Teachers	2	6	
3. Parents		4	4
4. Extracurricular Activities		1	1
Other		2	
Classes at the University	7		2
Observations at the Student Teaching Site	10	1	2
Future	2	3	3
Metacognition	2		
Peers	3		1
Family	1		
Media	2	1	
Map Design	2		1
Conferences Attended		4	1
Readings		1	
Total	30	33	37

DISCUSSION

These results provide support for the supposition that the knowledge organization of student teachers is fluid and without stable pedagogical schemas. The concept maps and the multidimensional scalings provide support for the hypothesis that this conceptual reorganization is not the result of simply adding new information (weak reconstruction) but involves a radical reconstruction of knowledge.

Leinhardt (1988) suggested that expert teachers' schemas contribute to their ability as experts to work with speed and fluidity. Carter, et al. (1987) also associate well defined pedagogical schemas with teaching expertise:

> Expert teachers, like other experts, appear to bring rich schema to the interpretation of phenomena, and these schemata appear to provide them with a framework for meaningfully interpreting information. Experts' schemata allow them to weight information so that its saliency and utility are determined quite quickly. In teaching, such skill in processing information is necessary because of the complex, dynamic, information-rich world of the classroom. It is likely that a necessary though not sufficient condition for the development of these skills is experience. (p. 156)

The constantly changing superordinate concepts of the student teachers provides evidence that these "novice" teachers lack the stable pedagogical schemas they need to make rapid decisions as they interact with large numbers of pupils. Furthermore, the large number of changes that the student teachers made in their concept maps in the middle of their student teaching indicates that this is a time of cognitive reorganization. During this period, the student teacher has assumed the full teaching load and is assuming a greater responsibility for planning, teaching and student evaluation. This increase in responsibilities coincides with the observed changes in the reorganization of knowledge structures. This is also a time in which student teachers have been described as in "reality shock" (Veenman, 1984), or as "paralyzed" (Corcoran, 1981). It appears as if the student teacher is unable to react to the intense demands of their student teaching due to their lack of a stable pedagogical knowledge framework. This lack of stability is illustrated by the shifting clusters of concepts in the card-sorting task.

The students reported that the concept maps were a valuable tool for them to use in thinking about their beliefs related to teaching. The concept maps not only highlighted schemas that were firmly held by student teachers, but they also served as a tool to help the student teachers articulate their thoughts about areas in which they were unsure. The sequence of concept maps provided a trail for us to follow the student teachers as they moved through their student teaching experience. Further research can delineate which of these specific sources of change are the most effective in promoting cognitive growth in preservice teachers.

Many of the students also indicated that they valued having the opportunity to draw and then discuss their concept maps with an interviewer. They expressed fascination (and sometimes frustration) at the effectiveness of the concept map in helping them to reflect on their teaching.

SUMMARY

Both the concept maps and the card-sorting tasks revealed a lack of stable knowledge structures in preservice teachers' concepts about effective teaching. The middle period of student teaching appears to be a time of radical reconstruction of knowledge as student teachers attempt to incorporate their clinical experiences with their prior knowledge.

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THE FIGURES

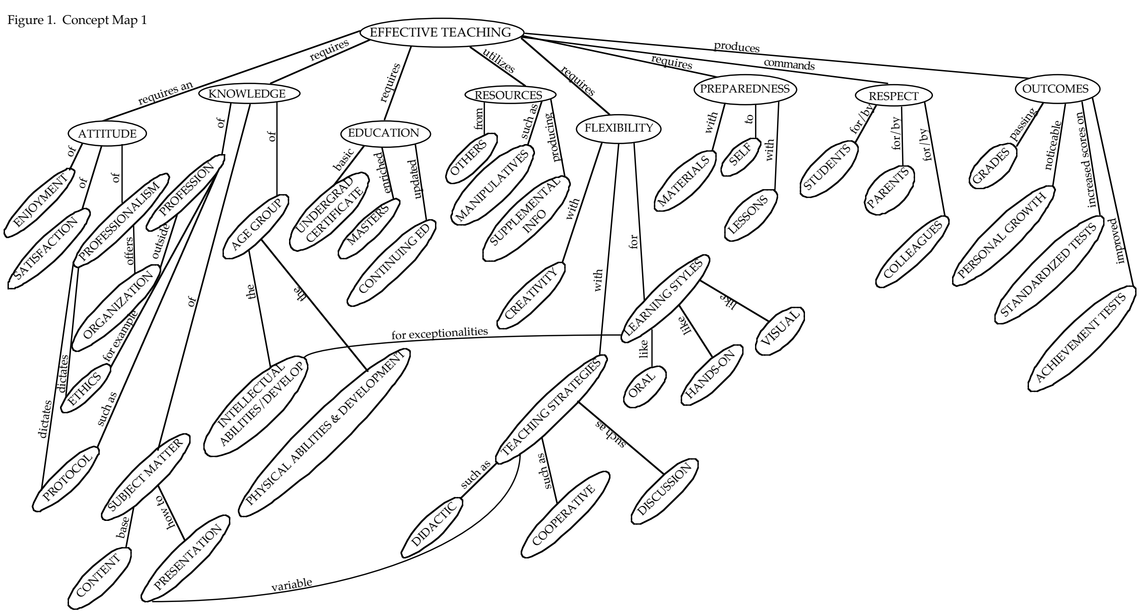

Figure 1. Concept Map 1.

Figure 2. Concept Map 2

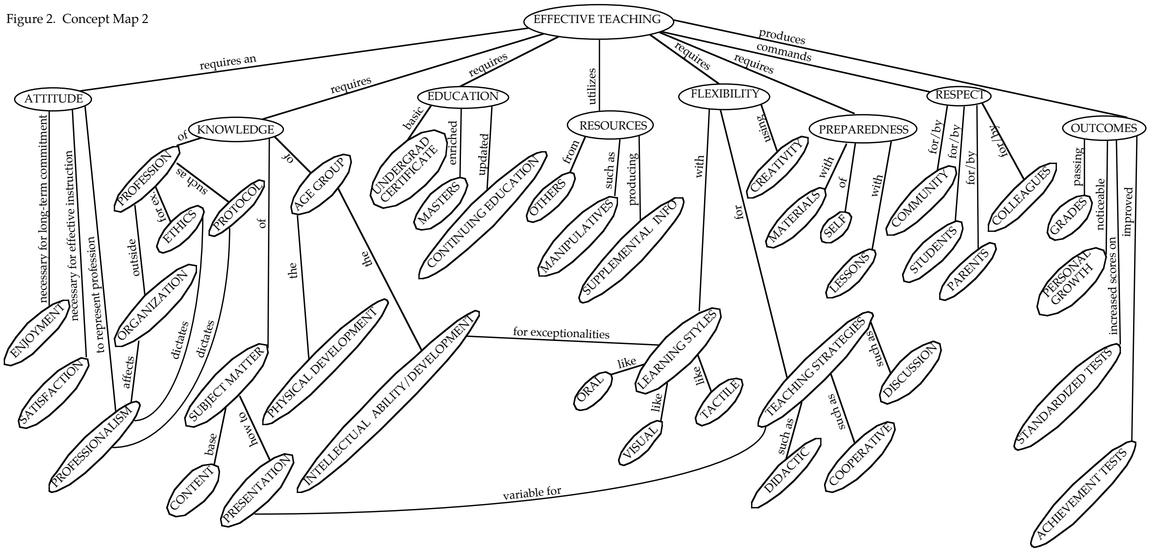

Figure 2. Concept Map 2.

Figure 3. Concept Map 3

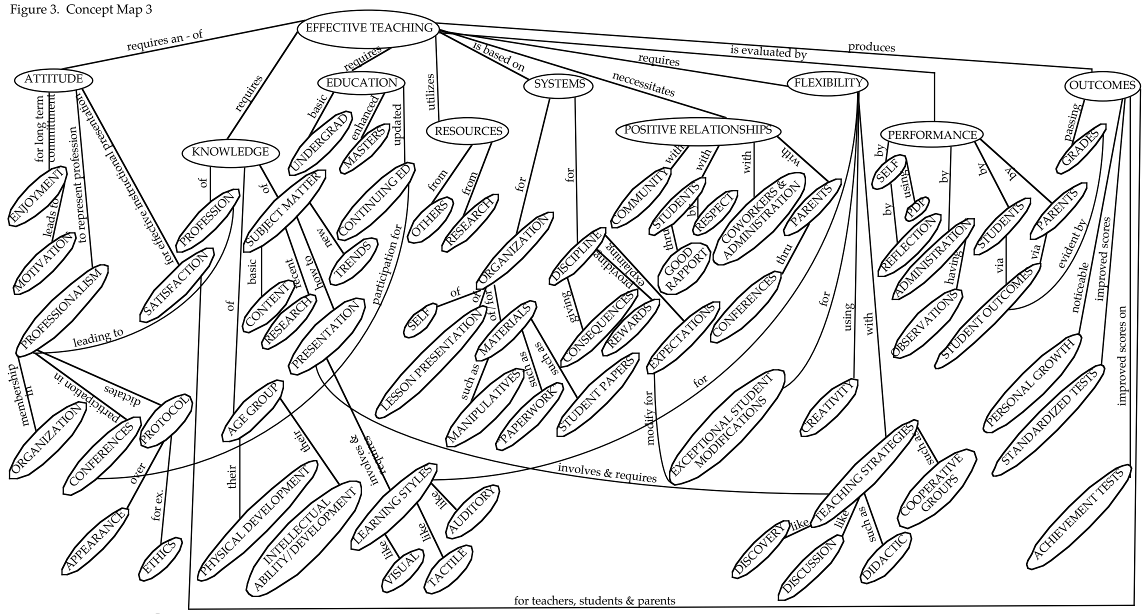

Figure 3. Concept Map 3.

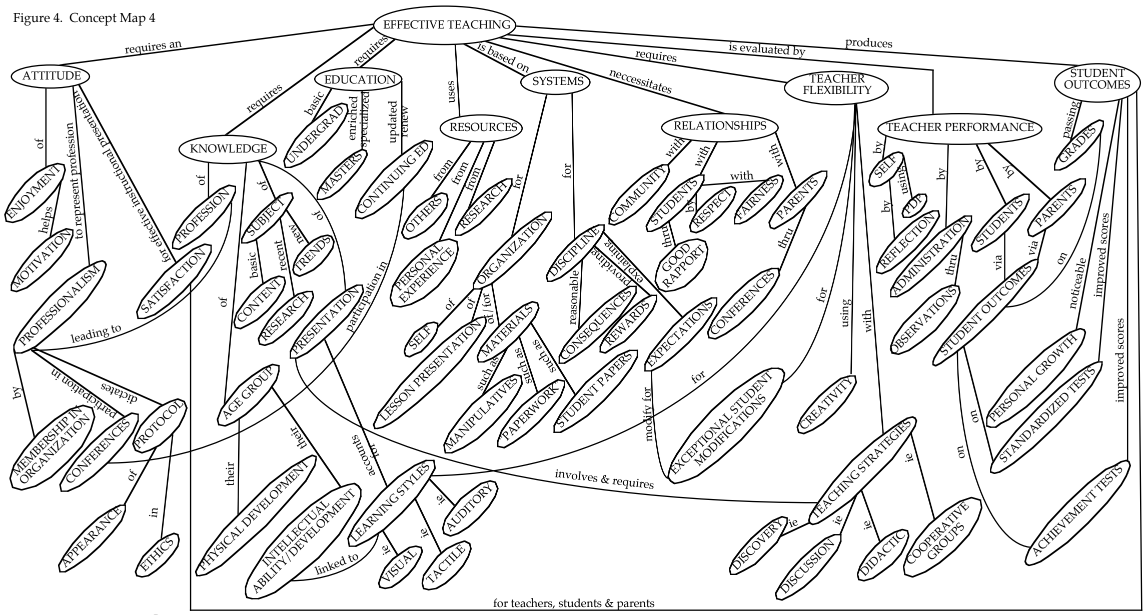

Figure 4. Concept Map 4.

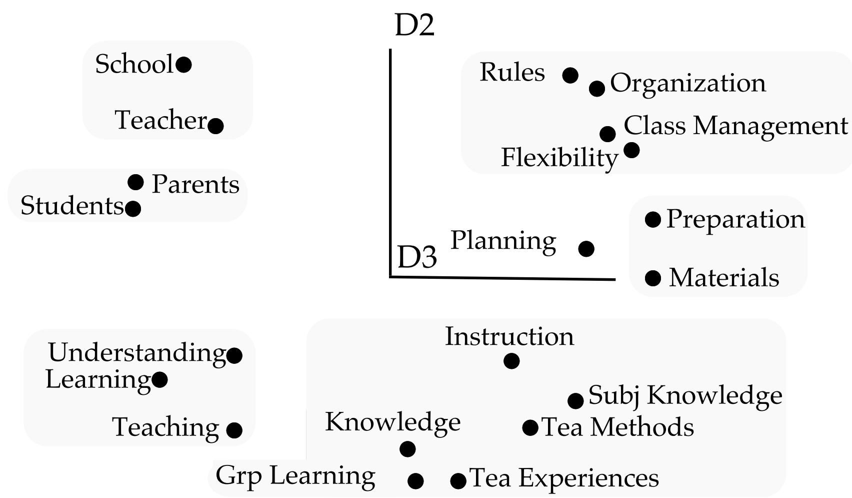

Figure 5. Multidimensional Scaling 1

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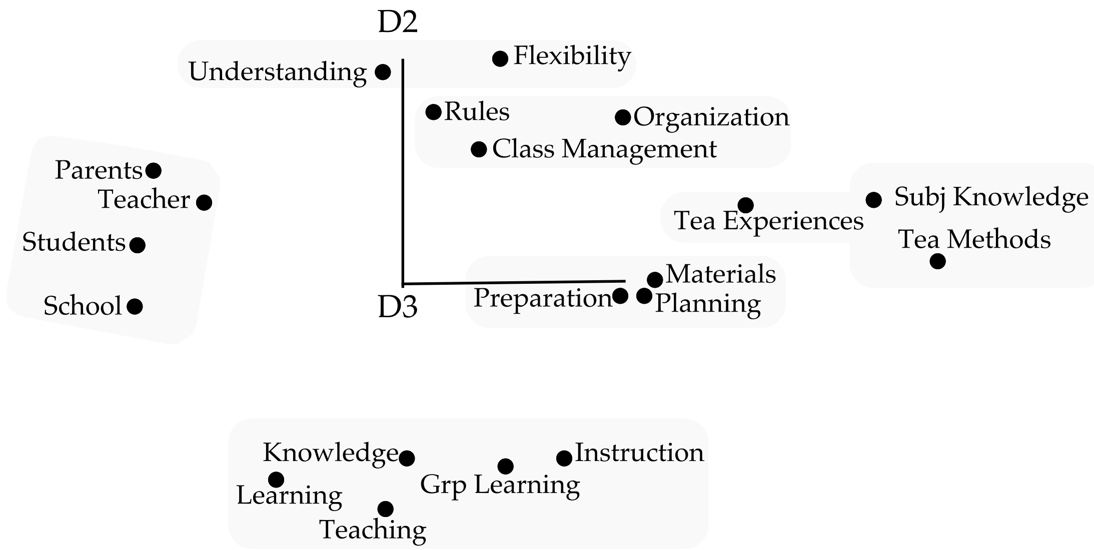

Figure 6. Multidimensional Scaling 2
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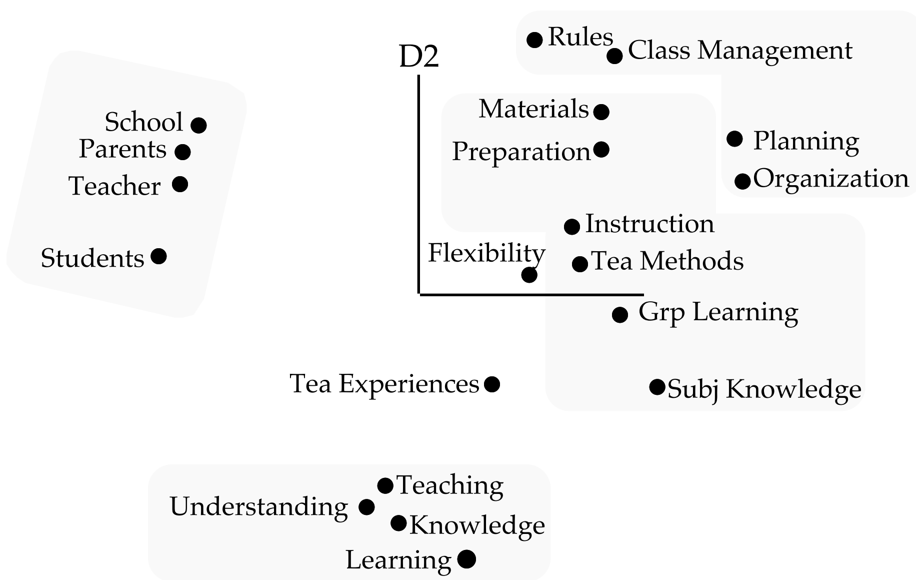

Figure 7. Multidimensional Scaling 3
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