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AUTHOR	Enger, Sandra K.
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ABSTRACT

A pilot study to investigate the use of concept mapping for assessment purposes was conducted during the spring of 1996. Thirteen teachers from a random sample of science teachers affiliated with the Iowa-Scope, Sequence, and Coordination Project and 12 other teachers affiliated with the project participated in the concept mapping study. Student concept maps were scored by the participating teachers using the "Expert Science Teaching Educational Evaluation Model (ESTEEM) Concept Mapping Scoring Rubric." Even with attempts to standardize implementation of the concept mapping procedures, teachers had a tendency to divert from the pre-established guidelines. Concept mapping can be used for a diverse set of topics and issues and can be used across grade levels. Even with the use of a rubric, scoring concept maps is a subjective process. In addition to quantitative analyses of concept maps, qualitative inspection can provide evidence of misconceptions and growth in student understanding. Since concept maps are a personal construction of understanding, a concept map would seem to warrant a personal, in-depth look. Numerous variables such as skill level with concept mapping, concept difficulty, different classrooms, and scoring of the maps are factors that make interpretation of data problematic. An appendix presents a figure illustrating the use of concept maps in student assessment. (Contains one figure, one appendix figure, one table, and six references.) (Author/SLD)

Concept Mapping:
Visualizing Student Understanding

Sandra K. Enger
Iowa-Scope, Sequence, and Coordination Project
The University of Iowa
Science Education Center
761 Van Allen
Iowa City, IA 52242

319-335-0254
sandra-enger@uiowa.edu

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Concept Mapping: Visualizing Student Understanding

Abstract

A pilot study to investigate the use of concept mapping for assessment purposes was conducted during the spring of 1996. A random sample of science teachers affiliated with the Iowa-Scope, Sequence, and Coordination Project (Iowa-SS&C Project) participated in the concept mapping study. Student concept maps were scored by the participating teachers using the *Expert Science Teaching Educational Evaluation Model (ESTEEM) Concept Mapping Scoring Rubric*. Even with attempts to standardize implementation of the concept mapping procedures, teachers had a tendency to divert from the pre-established guidelines. Concept mapping can be used for a diverse set of topics and issues and can be used across grade levels. Even with the use of a rubric, scoring concept maps is a subjective process. In addition to quantitative analyses of concept maps, qualitative inspection of concept maps can provide evidence of misconceptions and growth in student understanding. Since concept maps are a personal construction of understanding, a concept map would seem to warrant a personal, in-depth look. Numerous variables such as skill level with concept mapping, concept difficulty, different classrooms, and scoring of the maps are factors which make interpretations of the data problematic.

Introduction

According to Novak and Gowin (1984) a concept is a regularity in events or objects designated by some label. Concept maps are intended to represent meaningful relationships among concepts in the form of propositions. A proposition consists of two or more concept labels linked by words in a semantic network (Novak & Gowin, 1984). A concept map can be thought of as a schematic that represents a set of concept meanings embedded in a propositional framework. The concept map provides a schematic summary of learning that has occurred after a learning task has been completed.

Concept maps should be hierarchical with more general, more inclusive concepts subsuming more specific concepts. Since most, if not all, concepts fit into a conceptual domain which consists of numerous interlinked pieces, concept maps, in addition to being a hierarchical representation, should also have cross-links that show interrelationships among the concepts on the map. Parts of the map may have linear representations or segments, but as conceptual understanding increases, cross-linking of the segment would be expected for a concept domain. Linking words added to connect and provide meaning to linkages on the map. Concept mapping is a technique for externalizing concepts and propositions (Novak & Gowin, 1984).

In education, the challenge has been not only to help students elaborate conceptual understanding already possessed, but to modify those knowledge structures that contain misconceptions or alternative conceptions of frameworks (Novak, 1990). Concept maps have also been recognized for their usefulness in the identification of student misconceptions. Using concept maps for assessment purposes presents challenges for both scoring and interpretation, and the activity of concept mapping also requires instruction and practice to become "fluent" in the act of setting concepts out on paper. When concept mapping, a student's conceptual understanding is translated into a graphic representation of that understanding onto a two dimensional space. This representation can be informally or formally assessed in an attempt to make an interpretation relative to the student's conceptual understanding.

Concept Mapping Pilot Study Description

A pilot study to investigate the potential use of concept mapping for assessment purposes was conducted during the spring of 1996. A random sample of science teachers affiliated with the Iowa-Scope, Sequence, and Coordination Project (Iowa-SS&C Project) was invited to participate in the concept mapping study. This participatory invitation was also extended to all Iowa-SS&C teachers.

Prior to the actual pilot study, a pre-pilot study was conducted by an Iowa-SS&C teacher who was experienced in using concept maps in the science classroom. The purposes of this pre-pilot study were to obtain input related to facilitating concept mapping instruction and to gain feedback from the use of the *Expert Science Teaching Educational Evaluation Model (ESTEEM) Concept Mapping Scoring Rubric* to score concept maps. The information from this preliminary study was incorporated in the pilot study. Appendix A: Using Concept Maps for Student Assessment was set out by the teacher who conducted the pre-pilot study to illustrate the ways in which he conceptualized the use of concept maps for student assessment.

Before beginning the pilot study in their classrooms, in-service training in concept mapping and practice in the use of the *ESTEEM Concept Mapping Scoring Rubric* was provided at each of the project sites by Iowa-SS&C staff for the Iowa-SS&C teachers who would be participating in the study. Participant training included actual practice in constructing concept maps and training in the use of the *ESTEEM Concept Mapping Scoring Rubric*. The scoring procedures in the rubric were practiced, and this practice was accompanied by discussions that led to clarification and interpretation of score levels in the rubric.

This application and discussion process of the training was intended to help achieve interrater agreement in interpretation and use of the *ESTEEM* rubric, since each teacher participant would be scoring their students' pretest and posttest concept maps according to the rubric. Scoring concept maps is a time intensive process, and both pretest and posttest maps were to be scored by teachers using the *ESTEEM Concept Mapping Scoring Rubric.*

The *ESTEEM Concept Mapping Rubric* Description

The *ESTEEM Concept Mapping Rubric* consists of five categories: key and non-key words, lines, meaningful connections, meaningful segments, and meaningful total pattern. Using an oblique rotation, the five categories were assembled through a principal component factor analysis which resulted in five factors (categories) that accounted for 86% of the variability (Burry-Stock, 1995). In the *ESTEEM Manual*, Burry-Stock notes that the rubric was developed using much of the work from Novak (1990) and Novak and Gowin (1984). A sample of the scoring scheme for pattern hierarchy which is a subpart of the category fifth category, Meaningful Total Pattern, is excerpted as an example of the rubric. An excerpt of Category 3: Meaningful Connections from the *Esteem Concept Mapping Rubric* follows.

Category 3: Meaningful Connections

Connecting lines are labeled with a word or symbol:

5 Connecting lines are labeled with a word or symbol approximately 90% or more of the time.

3 Connecting lines are labeled with a word or symbol approximately 70% or more of the time.

1 Connecting lines are labeled with a word or symbol approximately 50% or less of the time.

Category 3: Meaningful Connections

Connections meaningful:

5 The relationships between the concepts are meaningful approximately 90% or more of the time.

3 The relationships between the concepts are meaningful approximately 70% or more of the time.

1 The relationships between the concepts are meaningful approximately 50% or less of the time.

Competency level descriptors are expert, proficient, competent, advanced beginner, and novice. Respective cut points for these levels are 85%, 70%, 35%, 15%, and 1%. The designation of these competency levels is based on the work of Berliner (1986) and Dreyfus and Dreyfus (1986) (cited in Burry-Stock, 1995).

Pilot Study Participation

Twenty-five Iowa-SS&C teachers, 13 of whom were from the random sample, participated in the study. Each participant in the pilot study selected one of their science classes for participation in the study. Guidelines were provided to teachers for implementation of concept mapping with their selected class of students. Instruction and practice with concept mapping to facilitate students' skill with concept mapping was suggested. Teachers were asked to keep a log of their use of concept mapping with their classes. When the students had some skill level with concept mapping, students produced a concept map to be used as a pretest to the unit of study.

The use of 12 to 15 key words that related to a concept or domain was suggested for both the pretest and posttest maps. Limiting the number of key words helped to keep the task of concept mapping more feasible for students who were inexperienced with concept mapping. The students could generate as many other words (non-key words) as they wished so were not limited to just using 12 to 15 words. Again, since scoring concept maps can be a very time intensive process, for the purposes of the pilot study, the use of fewer key words also reduced some of the time associated with scoring the maps.

Students were also asked to write a paragraph about the conceptual understandings represented on their posttest maps. This supporting, explanatory paragraph was requested to provide a comparison piece for the concept maps. Participating teachers were also asked to provide contextual information about the unit of study being completed by the classes.

Concept Mapping Use for Assessment

As evidenced from this pilot study, concept mapping can be used for a diverse set of topics and issues and can be used across grade levels. Participating classes ranged from grade 6 through grade 12 with multiple content areas being studied and concept mapped by students. A general categorization by content area for the maps would place the maps in life science/biology, physical science, or earth science. Biological topics included the respiratory, endocrine, and reproductive systems, blood, heredity and DNA, life origins and evolution, Jurassic Park, AIDS, invertebrates, and plants. Electricity and light were physical science areas, and earth science topics such as weather, rocks, water, and Big Bang were used by other classes. This diversity is in keeping with the constructivist/STS (Science/Technology/Society) underpinnings of SS&C. Students and teachers were encouraged to make interdisciplinary connections as well as studying science that has local, relevant, and personal implications.

The guidelines which had been established in an attempt to standardize the pilot study were implemented by the teachers in a variety of ways. While most of the teachers returned requested materials, some of the teachers did not provide contextual information or did not return student summary paragraphs. The extensiveness and quality of the logs also varied. In a preliminary analysis of the score sheets for the pretests and posttests, problems with scoring procedures using the rubric have been noted. Concept maps are being scored by another set of raters to look not only for data errors, but for interrater agreement in use of the *ESTEEM* rubric and revisions for clarity in the rubric.

Classroom teachers did vary the approach to concept mapping and application of the rubric, perhaps scoring some rubric categories of maps and not others. While the classroom teacher can score and interpret concept mapping to meet their instructional and assessment purposes, this practice limits the ability to make inferences about students' conceptual understanding for study purposes. Without control of numerous variables across classrooms, ambiguity in interpreting levels of performance in a classroom is difficult. Given just the variability in implementation of concept mapping alone, the issues of validity and reliability are also of major importance when using concept maps for assessment purposes (Ruiz-Primo & Shavelson, 1996; Shavelson, Lang, & Lewin, 1994).

Anderson & Huang (1989) (as cited in Shavelson, Lang, & Lewin, 1994)) reported correlations between concept map scores and measures of achievement and ability. A corrrelation of 0.69 was reported on an essay test on a unit and a corresponding concept map. The correlation with school science grades was 0.49. The correlation between concept maps and the Stanford Science Achievement Test was 0.66, and the correlation between concept maps and the Otis Lennon School Ability Test was 0.74. Since concept mapping does require practice to become proficient with just the skill of mapping, this should be kept in mind when making inferences or interpreting correlational data. The difficulty of the concepts and the mastery of concepts would also need to be considered when making interpretations about map scores. Concept maps can be one of multiple instructional or assessment tools that may elicit a kind of student performance not captured by other assessments.

Qualitative and Quantitative Student and Teacher Data

<u>In Biology Students' Words</u>

Related to a unit of study on invertebrates, students in a biology class had these comments about using concept mapping. Not all of the 26 students commented on concept mapping, and the comments that follow are a sample of comments. No particularly negative comments were made by students. Students were asked to write summary paragraphs about the posttest concept map and some of these excerpted comments follow.

> Although some of the lines may have crossed and made everything a little harder to read, I felt I learned more doing it this way. It gave us a chance to see what we learned instead of giving the book answers to the book's questions. It made people think a little harder and prepare a bit better.

> This was a good way of learning because it showed many things about each class and connected them together. When doing a concept map, you can get down to the very smallest details. It 's neat to learn about different behaviors among the invertebrates. I learned many different things about stuff I knew nothing about.

> We started with twenty key words that we had to use. We also had to add at last seven more key words of our own. That was very easy once you got going because you could expand in so many ways on the map. By my ending map you can tell I now know a lot more.
>
> My map represented to me what I learned in the class. I knew more about arthropods and my map reflected it. I didn't know much about segmented worms and my map reflected that. I like them (maps) because if you know a lot about one subject and not alot about another you can still get an A. My map was what I remembered about invertebrates.
>
> I liked doing this concept map because I think the teacher gets a better idea of what the student knows, rather than knowing to fill in 'a', 'b', 'c', or 'd'. It also is more fair to the student because they can really actually study for the correct thing, rather than studying for a multiple choice test, that of which some questions are the dumbest, knit picky questions that are almost completely irrelevant to the topic. I liked doing the concept map.
>
> It was supposed to be fun and test our creative side of our brain.
>
> ... I can't believe how much I know now. I think concept maps makes it easier to learn and understand biology.
>
> My concept map represents what I have learned and how I can relate ideas to each other. This is my favorite way of learning, because I can learn what I want and then I can express what I learned to someone else. This is the fairest kind of test for me because I can tell what I know and don't have to worry about what I don't.
>
> I think this was a good idea it helped me better understand invertebrates.
>
> When I first began to learn about a concept map, I thought it would be difficult and very boring. Little did I know, everyday I use some type of concept map. Using a concept map is like using an outline when you're writing. Using a concept map is also a way to keep everything organized.
>
> The concept map is a good quiz because you can put what you know and it's done independently.
>
> The concept map made it easier for me to explain things, instead of trying to guess what is going to be on the test.

A Biology Teacher's Comments

The teacher of this biology class noted that the topics in the unit of study on invertebrates were very difficult for the students in this class, and that students had previously worked with the concepts in this unit of study in a superficial way. This was the first experience with concept mapping in this class, and the teacher noted that on a scale of from "1" being not skilled in the use of concept mapping to a "5" being highly skilled, that a "2" represented this teacher's perceived skill with concept mapping. This teacher also used the *ESTEEM* rubric with the students as they were learning to concept map. The teacher worked with the students to help them provide examples of what a 5, 3, or 1 might "look like" when scored with the rubric.

A Middle School Concept Mapping Example of the Respiratory System

Students in a seventh grade middle school science class concept mapped their unit of study on the respiratory system. The teacher's goals for the unit of study were to have students 1) define respiration; 2) understand the structure and function of the respiratory system; 3) be able to explain lung function in excretion; and 4) understand the effects of diseases on the respiratory system. Figure 1 and Figure 2 are stem-and -leaf plots of the pretest and posttest data from this teacher's classroom. The pretest score range was from 16 to 35 with a median of 24, and posttest scores ranged from 18 to 36 with a median of 23.

The t-value of 1.466 from a contrast of pretest and posttest map scores was not significant ($p=0.156$) as shown in Table 1. Given the nature of concept maps, rather than leaving the data analysis when no significance was noted for this set of maps, qualitative evidence of student understanding does exist in the maps. A pretest and posttest comparison of the maps can serve to provide evidence of misconceptions, rearrangement and the addition of new information to the map can serve as evidence of student understanding. If the pretest and posttest maps have not changed substantially, this too would raise questions for instruction.

Regis, Albertazzi, & Roletto (1996), in their discussion of the use of concept maps in chemistry over the course of four years, note that concept maps are highly idiosyncratic representations of domain-specific knowledge, and the interindividual differences among the maps were far more striking than the similarities. Their shift in emphasis in scoring moved to a focus on changes in content and organization of concept maps over time. The maps also were used to raise student awareness of their own and others' understandings. Concept maps could serve to be effective tools in both interpersonal and extrapersonal aspects of learning.

Summary

From the pilot study, concept mapping appears to be an instructional and assessment tool that can be used by students. Students' comments about the use of concept mapping tend to be favorable, and concept mapping can empower the student in the assessment process. Students, from their comments, appear to feel more ownership of what they must do to demonstrate their learning and understanding.

Mechanically, concept mapping presents a somewhat difficult task in terms of interpretation and scoring of maps. The scores based upon a rubric do provide information about representation of student understanding, but the information represented on the concept map actually seems to necessitate more than a score based upon a rubric. Since the construction of understanding is unique to an individual, it would seem that analyzing maps necessitates accompanying analyses for interpreting the map.

Information gained from this pilot study that will be used in the design of other such studies suggests that other sources of information from the teacher and student would be useful in interpretation of the maps. A more in-depth set of lesson plans for a unit may help to provide a basis to look for changes in pretest and posttest maps. Classroom observations and student interviews about their represented understandings could provide insight for interpretation of intended meanings. Corroborating evidence from other test formats could also be an aid in making comparisons of concept maps to other formats of assessing understanding.

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Figure 1.

Stem-and-Leaf Plot of Pretest

1	66	
1	8999	
2 H	0001	
2	2	Range = 16 to 35
2 M	44445	Median = 24
2 H	66677	
2	88	
3		
3	2	
3	5	

Figure 2.

Stem-and-Leaf Plot of Posttest

1	899	
2 H	0011	Range = 18 to 36
2 M	2222233	Median =23
2	4555	
2 H	6	
2	8	
3		
3	22	
	Outside Values	
3	456	

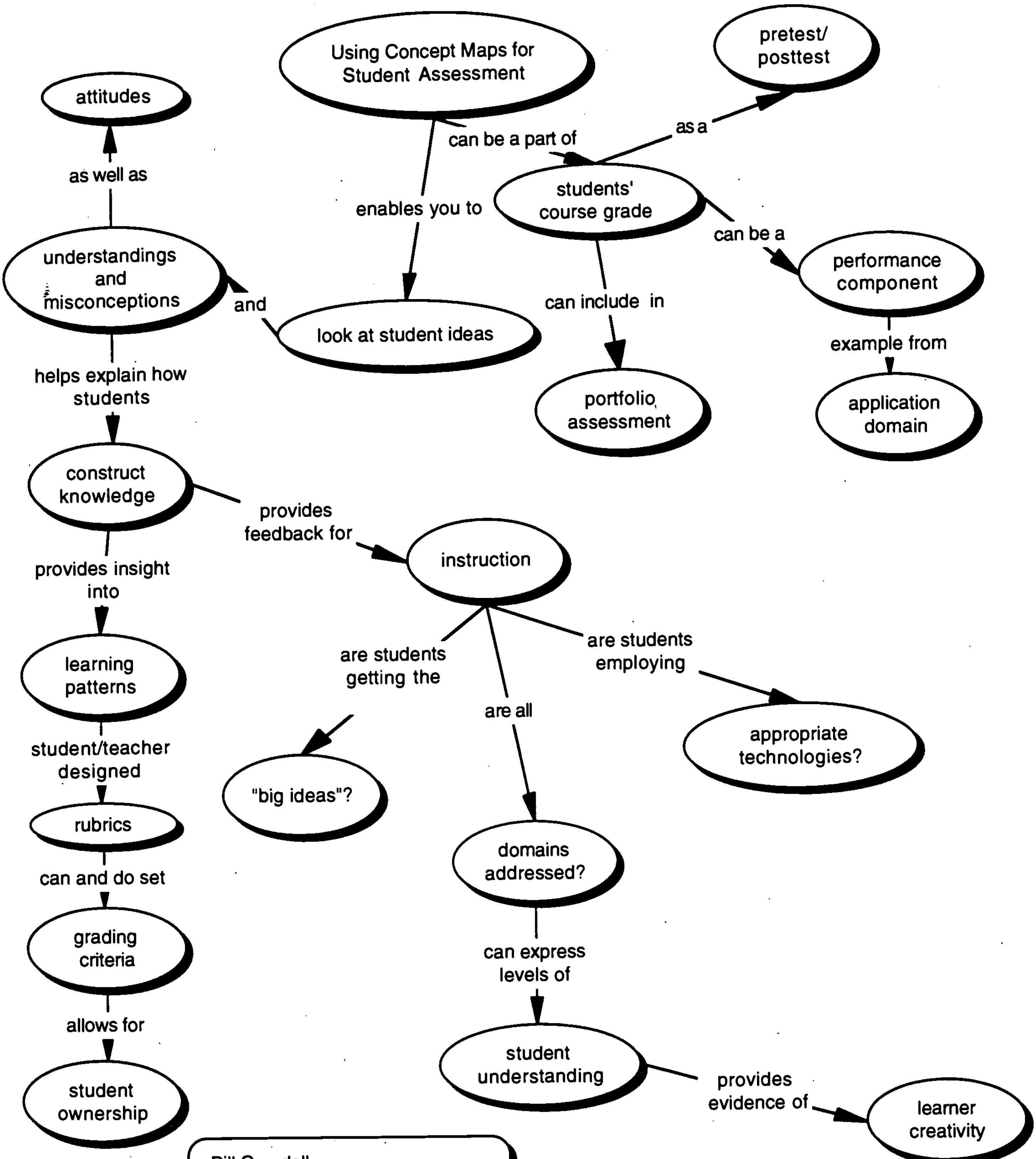
Table 1

Contrast for Pretest and Posttest Concept Maps (N = 25)

	Mean	SD
Pretest Map	23.44	4.74
Posttest Map	24.64	5.26
Difference	1.20	4.09

The t-value of 1.466 was not significant. p=0.156

Appendix A: Using Concept Maps for Student Assessment



Bill Crandall
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Organization/Address: ~~761~~ U of Iowa, 761 Van Allen, Iowa City, Iowa 52242	Telephone: 319-335-0254 / FAX: 319-335-1188 / E-Mail Address: sandra-enger@uiowa.edu / Date: 11/8/96

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