

**Kavram Haritalarının Değerlendirme Aracı
Olarak Kullanılması ve Çoktan Seçmeli Testlerle
Karşılaştırılarak İncelenmesi**

**Using Concept Maps As An Alternative Assessment Tool
And Investigation By Comparing With Multiple Choice
Tests**

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ÖZET

Bu araştırmanın temel amacı fen ve teknoloji derslerinde kavram haritalarının değerlendirme aracı olarak kullanımının incelenmesidir. Bu temel amaç doğrultusunda araştırmada, kavram haritalarının puanlandırılması ve kavram haritalarında kullanılan kavramlar ile aynı kavramlara ilişkin çoktan seçmeli test sorularına verilen öğrenci cevaplarının karşılaştırılması amaçlanmıştır. Araştırma 7.sınıfta öğrenim gören 30 öğrenci ile gerçekleştirilmiştir. Araştırma sonucunda öğrencilerin kavram haritalarında konu ile ilgili anahtar kavramları birbirleriyle ilişkilendirmede ve kavramlar arası bağlantılar oluşturmada zorlanırken, aynı kavramlara ilişkin çoktan seçmeli test sorularını doğru cevapladıkları tespit edilmiştir. Yapısal ve ilişkisel puanlama yöntemleri ile değerlendirilen kavram haritalarından elde edilen puanlar, iki puanlama tekniği arasında anlamlı ve yüksek bir korelasyon olduğunu göstermiştir.

***Anahtar Kelimeler:** Alternatif değerlendirme, Kavram haritası, Fen eğitimi*

ABSTRACT

The main purpose of this research is to investigate the use of concept maps as an alternative assessment tool in Science and Technology courses. In accordance with this main purpose, the study aimed at scoring concept maps, and comparing concepts in concept maps with the answers given by students to multiple choice test questions related to the same concepts. The participants of this research were 30 seventh-grade students. The results showed that students had difficulties in making connections between the key concepts and creating linking phrases.

On the other hand, they answered the test questions related to the same concepts in concept maps correctly. Using structural and relational scoring methods to evaluate the concept maps, the scores showed a significant and strong correlation between these two scoring methods.

Keywords: *Alternative assessment, concept map, science education*

1. Introduction

Concept maps are graphical and, metacognitive tools for organizing and representing knowledge (Novak & Gowin, 1984). They can be used as a learning tool, an instructional strategy, a tool in the instructional design process and an assessment tool for measuring students' understanding of core science concepts and processes (McClure, Sonak, & Suen, 1999; Novak, 1990; Robinson, 1999). Using concept maps as an assessment tool can minimize the random factors associated with testing and does not limit students in their answers (Nakhleh, 1994). Another important benefit of using concept maps as an assessment tool is to discover or illustrate the limitations and strengths of students' understanding of a science concept or process. Thus, allowing students' misconceptions to come to the fore and give educators the opportunity to address them during instruction (Novak, 1993; Novak, Gowin, & Johansen, 1983), several studies have explored concept mapping as an assessment tool to explore students' conceptions related to core scientific ideas and processes (Barenholz & Tamir, 1992; Gaffney, 1992; Henno & Reiska, 2008; Sahin 2002; Trowbidge & Wandese, 1994). The studies have shown that concept maps play an important role in helping researchers understand how students internally construct conceptual knowledge. Hence, it is important for concept maps, like any other assessment tool, to have a reliable scoring system. Therefore, researchers have focused to use different scoring methods for concept maps.

1.1. Methods of Scoring Concept Maps

Educators interested in use of concept mapping for assessment of students learning have proposed different scoring models. Novak and Gowin (1984) have proposed structural scoring methods. As seen in Figure 1, structural scoring methods use four criteria: connections between concepts, displays of hierarchical structure, cross connections and examples.

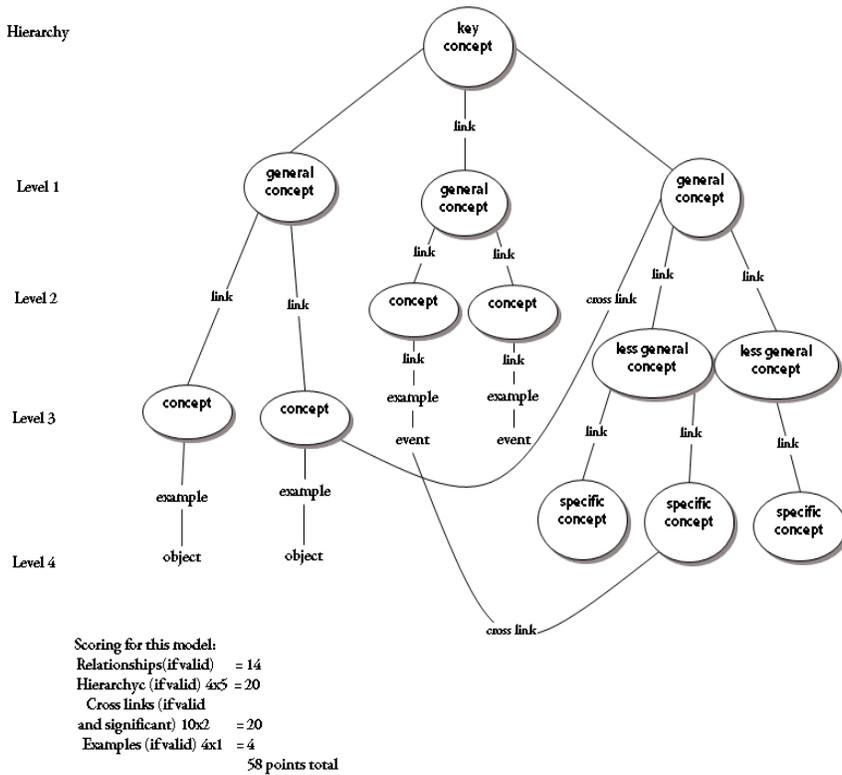


Figure 1 Protocol for structural scoring method (Novak & Gowin, 1984, p. 37)

McClure et al. (1999) have adapted the relational scoring method originally developed by McClure and Bell in 1990. In this method, concept maps are scored based on the relationships between concepts, the accuracy of labels and the directions of arrows, which indicate either a hierarchical or causal relationship between the concepts (Baralos, 2002). As seen in Figure 2, each map receives a score between zero and three in this rating method. The relational scoring method is more effective than the structured scoring method for determining the correct relationships between the concepts (McClure et al., 1999; Ruiz-Primo & Shavelson, 1996; West, Park, Pomeroy, & Sandoval, 2002).

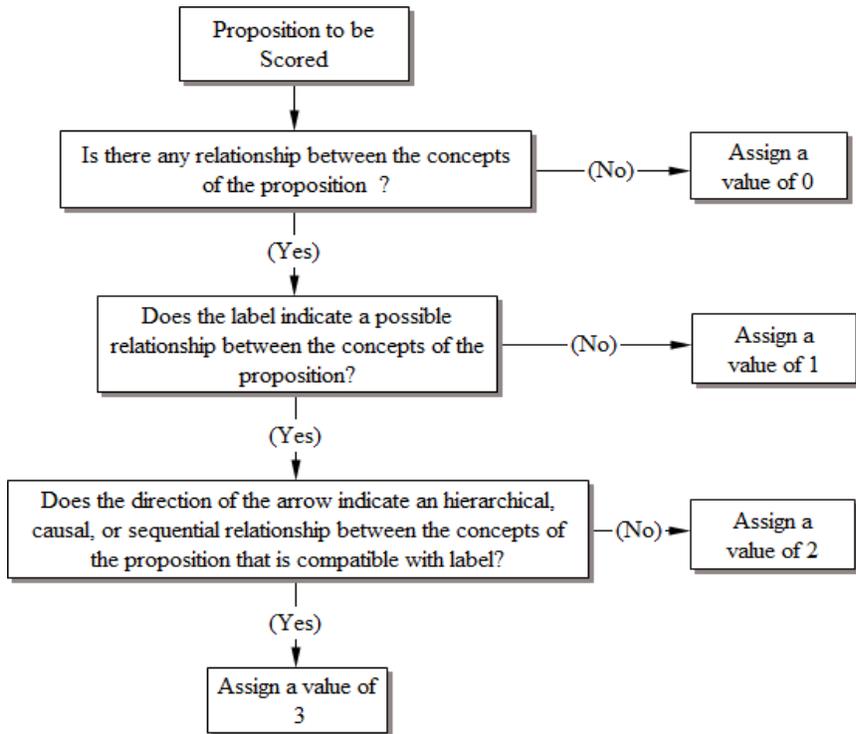


Figure 2. Protocol for relational scoring method (McClure et al., 1999, p. 482)

1.2. Purpose of the study

The main purpose of this study was to investigate using concept maps as an alternative assessment tool in a 7th grade science and technology course. In addition to the main purpose of the study, the other objectives are as follows:

- to investigate the validity and reliability of relational and structural scoring methods for concept maps;

- to examine the meaningful relationships between the concepts in concept maps;

- to compare the meaningful relationships in concept maps to the questions that evaluate similar conceptual understanding in achievement test;

- to investigate classroom teacher' views on using concept map as an assessment tool.

2. Methods

2.1. Context, Participants and Procedures

The eight-week study was conducted in a science and technology course at a public elementary school focusing on students' understanding of force, work and energy. The concepts of "force, work and energy" are important basic topics in a science and technology curriculum, and research emphasize that students hold many misconceptions about this topic (Champagne, Klopfer, & Anderson, 1980; Clement, 1982; Demirci, 2001; Eryılmaz, 2002; Ozsevgenc, 2006; Rosenquist & McDermott, 1987; Segueira & Leite, 1991). For these reasons, this topic was selected for evaluating concept maps in the current study.

The participants consist of 30 seventh-grade students (11 boys and 19 girls) at a public middle school. The students were introduced about how to construct concept maps during the first week. The training sessions focused on the following topics: "What is a concept map?"; "How is a concept map constructed?"; "How can concept maps be useful for learning?"; and "What is the purpose of concept maps?". Following six weeks of training, the students also performed several concept map activities on different science topics (animal and plant cells, human body systems and states of matter and etc.) in groups of 5-6 students. At the end of the study, the students were first asked to construct individual concept maps incorporating key concepts related to force, work and energy. The 27 key concepts were energy, potential energy (p. energy), kinetic energy (k. energy), work, force, spring, elasticity, dynamometers, weight, height, velocity, mass, simple machines (s. machine), levers, scissors, wheelbarrows, tweezers, screws, cogwheels, inclined planes, pulleys, blocks and tackles, fixed pulleys (f. pulley), movable pulleys (m. pulley), frictional force (f. force), surfaces, and balloons. Then, an achievement test was administered to all the students.

2.2. Designing an Achievement Test

Prior to the beginning of this study, a 20-item achievement test was developed by the researchers with the help of two experts. A table of specifications listed the objectives to be used in creating both the test items and the key list of concepts. The Cronbach's alpha reliability of the test was calculated as 0.73. The students received five points for each correct answer; therefore, the 20 questions were rated on a 100-point scale.

2.3. Interview

A semi-structured interview was conducted at the end of the study to ascertain the science and technology teacher's views about using concept maps as an assessment tool. The audio-recorded interview lasted 45 minutes and was transcribed verbatim. The interview questions are described below.

Do you use concept maps in your courses?

What do you think about using concept maps as assessment tool?

Can you compare traditional assessment tools, such as achievement tests and true-false questions with concept maps in terms of educational outcomes?

What do you think about the validity and reliability of the two concept maps scoring techniques (relational and structural)?

2.4. Scoring concepts maps and inter-rater reliability

A total of 30 concept maps were scored by two independent raters. As suggested in McClure et al. (1999), the raters recorded the time elapsed while scoring the concept maps for both the structural and relational methods. In total (30 concept maps), the raters spent 75 minutes on the relational scoring method and 58 minutes on the structural scoring method. The raters spent an average of 2.5 minutes to score students' concept maps using the relational scoring method, and 1.9 minutes using the structural scoring method.

The raters scored each concept map twice: once using the structural method (Novak & Gowin, 1984) and once using the relational method (McClure et al., 1999). Pearson correlation and generalizability coefficients were calculated to determine inter-rater reliability. As seen in Table 1, strong and statistically significant correlations were found between the raters for both the scoring methods.

Table 1. Correlation between the scores given by two raters according to scoring methods

Scoring method	Rater 1		Rater 2		r
	Mean	SD	Mean	SD	
Relational	36.77	15.99	39.57	16.68	0.95*
Structural	19.47	11.66	20.33	10.55	0.94*

* $p < 0.01$.

2.5. Generalization Analysis

Generalizability (G) theory is helpful for determining the reliability between raters. It considers the potential errors arising from scorer variation (Atılgan, 2007). Ruiz-Primo and Shavelson (1996) have stated that applying G theory in concept map assessment is appropriate because concept map assessment involves many sources of variation, such as concepts, propositions, raters and scoring systems. All of these sources of variation can be considered to be sources of error variation in G theory (Yin & Shavelson, 2008). Some researchers have used G theory to examine the reliability of concept map scores (Erduran-Avcı, Ünlü, & Yağbasan, 2009; Lomask, Baron, Greig, & Harrison, 1992; McClure et al., 1999; Ruiz-Primo, Schultz, & Shavelson, 1996; Yin & Shavelson, 2008;). According to Yin and Shavelson (2008), G theory's power, convenience, and flexibility make it preferable to classical test theory for examining

measurement error and reliability in concept map assessments.

To determine the consistency of the raters in this study, a generalization analysis was performed. The generalization variance, which is also the reliability coefficient, is the ratio of the observed point variance to the expected point variance. The variance analysis results for structural scoring and relational scoring methods are shown in Table 2.

Table 2. Results of variance analysis for structural and relational scoring methods

Source	Structural Scoring Method				Relational Scoring Method			
	SS	df	MS	F	SS	df	MS	F
Persons	6941.1	29	239.3	30.8	15089.3	29	520.3	38.5
Raters	8.82	1	8.8	1.1	117.6	1	117.6	8.7
Error	225.7	29	7.8		391.4	29	13.5	
Total	7175.6				15598.3			

The generalization coefficient is calculated using the following formula:

$$g = \frac{\sigma_p^2}{\sigma_p^2 + \frac{\sigma_c^2}{n_i}}$$

where σ_p^2 represents the individual variance and σ_c^2 denotes the error variance.

The generalization coefficient for the structural scoring method was determined to be 0.93. The generalization coefficient for the relational scoring method was determined to be 0.94. The G coefficients for both methods were quite high. These G coefficients and results suggest that both concept maps scoring methods are valid and reliable. Several researchers who have used G coefficients to analyze concept map scores have found similarly high inter-rater reliability (Erduran-Avcı et al., 2009; Ruiz-Primo et al., 1996; Yin & Shavelson, 2008).

3. Findings

The findings are presented under the objectives of the study respectively: I) examination of the accuracy of the relationships between the concepts in student concept maps, II) comparison of the meaningful relationships in concept maps with the questions assessing similar conceptual understanding in the achievement test and III) the classroom teacher's views on concept maps as an assessment tool.

I. Examination of the accuracy of the relationships between the concepts in student concept maps. The accuracy of the relations between the concepts in the student concept maps was also assessed. The frequency of meaningful connections between the key concepts in the student concept maps is presented in Table 3.

Table 3. Frequency of meaningful propositions between key concepts in student concept maps

Key concepts	Frequency of using concepts	Correctly connected concepts and frequency
Energy	28	K. energy (20), p. energy (17), work (12), force (2), F. force (2), inclined plane (1)
K. energy	25	Energy (20), velocity (19), mass(11), f. force (7)
P. energy	23	Height (22), energy (17), weight (17), mass (1)
Dynamometer	23	Spring (15), force (10), elasticity (7), weight (7)
Height	23	P. energy (22)
Weight	22	P. energy (17), dynamometer (7), f. force (1)
Velocity	20	K. energy (19)
S. machine	19	Cogwheel (18), inclined plane (17), lever (16), pulley (16), screw (13), work (7), block and tackles (7), Tweezers (4), force (4), m. pulley (3), scissors (3), wheelbarrow (3), f. pulley (1), spring (1)
Force	18	Dynamometer (10), work (7), f. force (6), s. machine (4), energy (2)
F. force	18	surface (15), k. energy (7), force (6), mass (3), energy (2), work (2), weight (1)
Pulley	17	M. pulley (16), f. pulley (15), block and tackles (5), s. machine (4)
M. pulley	17	Pulley (16), s. machine (3), block and tackles (3)
F. pulley	16	Pulley (15), block and tackles(3), s. machine (1), F. force (15)
Surface	16	F. force (15)
Spring	16	Simple machine, dynamometer (15), elasticity (9)
Elasticity	15	Balloon (13), spring (9), dynamometer (7)
Lever	15	S. machine (16), wheelbarrow (15), scissors (12),
Work	14	Energy (12), s. machine (7), force (7), f. force (2), mass(1)
Balloon	14	Elasticity (13)
Wheelbarrow	14	Lever (15), s. machine (3)
Tweezers	14	Lever (13), s. machine (4)
Scissors	13	Lever (12), s. machine (3)
Mass	11	K. energy (11), f. force (3), p. energy (1), work (1)
Block and tackles	10	S. machine (7), pulley (3), f. pulley (3), m. pulley (3)
Screw	9	S. machine (13)
Cogwheel	6	S. machine (18)
Inclined plane	6	S. machine (17), energy (1)

Table 3 show that “inclined plane” and “cogwheel” were the concepts appearing least often on the student maps, while the students used the “energy” concept most frequently. The students connected “energy” with the concepts of “kinetic energy,” “potential energy,” “work,” “force,” “frictional force” and “inclined plane.” It is especially striking to see that more than half of the students did not connect “energy” with “work.” While most of the students correctly connected “energy” with “kinetic energy” and “potential energy,” none were able to connect “kinetic energy” and “potential energy.” The number of students connecting “kinetic energy” and “speed” (n=19) was greater than the number of students connecting “kinetic energy” and

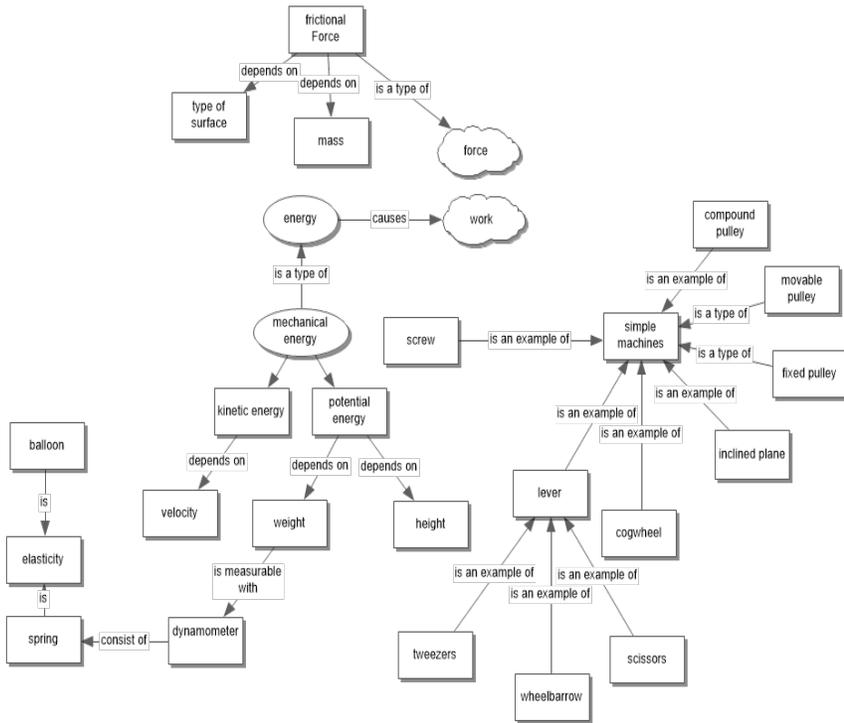


Figure 3b. Example of concept map constructed by a student in English

II. Comparison of the meaningful relationships in the concept maps with the questions assessing similar conceptual understanding in the achievement test.

In this section firstly, scores were obtained from concept maps and achievement test were shown in Table 4.

Table 4. Descriptive statistical results of students' achievement test and concept map scores

	n	Maximum	Minimum	Mean	SD
Achievement test	30	95	25	65.67	16.70
Structural method	30	42	4	20.13	10.93
Relational method	30	66	10	38.40	16.23

As shown in Table 4, students' achievement test scores ranged from 25 to 95. When comparison of students' concept maps scores in terms of relational and structural scoring method, students got higher scores in relational method. On the other hand when comparison of the meaningful relationships in the concept maps with the questions assessing similar conceptual understanding in the achievement test in detail,

the results of the students' correct answers' frequency to the achievement test show that most of the students gave correct answers to the 19th question, which asked the students to "Describe energy as the ability to do work " While most of the students answered this question about the relationship between "work" and "energy" correctly on the achievement test, most of them could not make the connection between these two concepts on their concepts maps. All but three of the students gave a correct answer to the 16th question, which asked them to "realize that potential and kinetic energies can be converted." Surprisingly, none of the students made the connection between "kinetic energy" and "potential energy" on their concept maps, even though they correctly identified the relationship between these two concepts on the achievement test.

As shown that in Table 3, very few students made the correct connections between "energy," "kinetic energy" and "frictional force." Nevertheless, most of the students gave correct answers to the 20th question, which emphasized similar relationships. Although many students did not draw "friction force" on their concept maps, they did give correct answers to the 6th , 19th and 20th questions, which focused on these concepts. Nine students made the correct connection between the "spring" and "elasticity" concepts, but 28 students gave the correct answers to the 1st and 3rd questions on the achievement test (Table 3). In addition, all of the students gave correct answers to the 13th question, which measured their knowledge of the elastic constant of strings. Six students correctly answered the second question, which dealt with the direction and force of spring when they are tightened. None of the students were able to connect "force" with the "spring" and "elasticity" concepts in their maps.

Questions 5, 7, 8, 9, 11 and 20 of the achievement test focused on measuring students' knowledge of simple machines. Most of the students gave correct answers to the 5th and 20th questions, which focused on the relationships among "simple machines," "work" and "force". Fewer students gave correct answers to the 8th and 11th questions, which focused on the concepts of "simple machines," "energy" and "power". Compared to other questions, fewer students provided correct responses to the 7th and 9th questions, focused on students' understanding of the working principles of different types of simple machines. When the concept maps were examined, it became evident that students had great difficulty in establishing the connection between "simple machines" and "force." Similar to the results of the achievement test, the maps revealed that the students only weakly grasped the connection between different types of simple machines. For example, the students rarely included simple machines such as "pulley," "scissors," "tweezers," "wheelbarrow" and "lever" in their concept maps. Furthermore, the few correct answers to the questions about these concepts (simple machines) on the achievement test demonstrated that the students has difficulty seeing the connection between the simple machines they came across in their daily lives and the representation of simple machines in formal school curriculum.

III. The classroom teacher's views on using concept map as an assessment tool. The results of the semi-structured interview with the science and technology teacher

at the end of the study revealed that the teacher reacted positively to the use of the concept map as an assessment tool. The teacher stated that before the study, he rarely used concept maps to assess his students' conceptual understanding and thought that concept maps were more suitable as teaching than as assessment tools. The following are the relevant portions of the teacher's interview responses.

Researcher: Do you use concept maps in your courses?

Teacher: To tell you the truth, I have used concept maps several times in my courses so far. If a teacher explains to students what a concept map is and the student knows what it is and how it is constructed, then student-constructed concept maps will improve the teaching of science concepts to students.

Researcher: What do you think about using concept maps as an assessment tool?

Teacher: Concept maps are crucial for me because they associate all the topics covered in a science unit and allow the students to learn more easily. Before this study, I thought that concept maps were more appropriate for helping students comprehend the topic rather than as a measurement and assessment tool, but now I think that we should use concept maps in both the teaching and assessment of science concepts...It should be noted that concept maps are not considered to be an assessment tool by many teachers because we have not received any in-service training. We do not know how to use student-constructed concept maps for assessment purposes.

The teacher reported on what had changed in his science and technology classroom as a result of using concept maps as an assessment tool. He also discussed the differences between traditional assessment tools and concept maps and which of his perceptions of science and technology teaching and learning had changed. Below are some excerpts of the interview that addressed these topics.

Researcher: Could you compare traditional assessment tools, such as achievement tests and true-false questions, with concept maps in terms of educational outcomes?

Teacher: Many students come to my classes with varied beliefs about scientific phenomena, and they actually constructed their own concepts from what they had seen in the world with their own eyes. I saw that concept maps are an effective tool for assessing students' prior conceptual knowledge, including their alternative conceptions. It is really difficult to identify students' partial understanding, particularly their specific misconceptions, through achievement tests or true-false questions. Moreover, using concept maps as an assessment tool helps the students to organize the subject matter and simplify the conceptual learning...I

also notice that most students panic before traditional assessments and feel like they want to die. By contrast, I think that their anxiety toward assessments will decrease over time when they use their own concept maps to assess their scientific understanding...I should also tell you that after this study, I started to perceive that assessment and instruction are partners rather than separate entities because concept maps work both ways; however, achievement tests, matching questions and true-false questions separate assessment from teaching.

The teacher felt that the relational scoring technique for assessing student concept maps was much easier for teachers than the structural method. He also added that the relational scoring technique is more valid, reliable and practical for teachers than the structural methods. The interview included the following excerpts on this subject.

Researcher: What do you think about the two concept map scoring techniques, relational and structural, in terms of validity and reliability?

Teacher: In the structural method, there are many criteria, such as hierarchy, proposition, example and crosslinks. In the relational method, by contrast, you only need to focus on the accuracy of relations among the concepts constructed by the students. I think that this increases the reliability of the assessment because one is dealing with only one thing in the relational method. Of course, the relational method is also more practical. In addition, you may make mistakes when assessing the students' concept maps using the structural scoring technique, which decreases the objectivity of the assessment and creates many other educational problems in the classroom. For example, I may consider a relation between concepts to be a cross-link, while others may think of the same relation as a proposition.

The teacher had only one piece of negative feedback about using concept maps as an assessment tool. He thought that it took up most of the class time and required much more effort. Here is the relevant part of the interview:

Teacher: As teachers, we also overlook the "time" and "effort" aspects because you cannot check all of the concept maps that students draw in a class; you can only get to a few of them.

Therefore, teachers should assess students' concept maps elsewhere (home, for example). If he does so, then he should identify the mistakes one by one. This evaluation requires a substantial effort.

4. Conclusions and Recommendations

In this study, the students' understandings of the force, work and energy concepts were assessed through two different assessment methods: traditional achievement test and concept mapping. The results showed that students had difficulties in making connections between the key concepts and in creating linking phrase. As mentioned before, elementary school students had misconceptions about force, work and energy concepts.

The students might have difficulty in making connections among these concepts, as this subject is very hard for many students to fully understand. In addition, in Turkey, students generally are assessed by traditional methods such as multiple choice tests, and they get used to this method.

Using concept maps as an assessment tool is important for understanding how students construct knowledge in their minds (Hassard & Dias, 2009). Having students construct maps from scratch and then discussing the process in a group may lead to spontaneous self-assessment. Teachers should be very familiar with the concept map technique if they decide to use it as an assessment tool. They should know how to develop concept maps, how to score them, and how to use different concept map techniques. Our analysis of the relationship between the structural and relational scoring methods found a strong and significant correlation between them. The results showed that on average, it took less time for raters to score the concept maps using the structural method than using the relational method. In contrast to our results, McClure et al. (1999) found that assessing concept maps using the relational method is less time consuming. The contradiction between the studies may have resulted from our students' inability to construct hierarchical concept maps. The authors of this study recommend using the relational scoring method, even though it requires more time, because the quality of the concepts and links can be rated and because it is subjective, and therefore more useful, for analyzing complex concept maps.

Constructing and assessing concept maps can be difficult for teachers and may require more time (Uzuntiryaki, 1998), but many researchers have suggested that concept maps are a useful assessment tool at all educational levels (Delgado & Rivera, 2008; Jacobs-Lawson & Hershey, 2002; Ruiz-Primo, 2004). For example, İnceç (2008) has suggested that concept maps are powerful tools for evaluating conceptual knowledge. Moreover, the continuous use of concept maps enhances students' creative thinking skills and motivation for learning. The interview with the science and technology teacher at the end of the study revealed that he was starting to consider concept maps as an assessment tool, even though he had not previously thought them capable of assessing students' knowledge of science. He stated that using concept maps changed his view of teaching and learning science. For example, he discovered more details of how students understand science and was able to monitor their progress in conceptual understanding over time. He also mentioned that concept maps are a useful tool for intertwining assessment and learning in a science and technology classroom. They can also reduce students' anxieties toward assessments. The only negative feedback from the teacher involved the time and effort involved.

In this study even though the students were given training sessions on concept map construction in the early stages of this study, they had difficulty constructing concept maps. Therefore, if teachers consider their students' cognitive structures and ages and supply information about concept maps to the class at the beginning of term, this technique can be used effectively.

Students' effective construction of concept maps is very important for the teacher to elicit students' alternative ideas about core scientific ideas and processes and to monitor students' academic progress. If students fail to use concept maps effectively to document their knowledge, teachers can have a flawed understanding of students' ideas about the topics covered by the curriculum. Therefore, students must be trained on effective concept map construction and evaluation. Similarly, teachers should be supported through professional development 1) to understand the purpose and importance of using concept maps as an assessment tools. 2) use of concept maps for teaching and learning and 3) assessment of concept maps. Collectively, these efforts can have a greater impact on the quality of students on their learning of core scientific concepts and practices.

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