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Using Concept Maps as a Method of Assessment in Work-Energy Subject

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Abstract: The purpose of this study is to analyze the concepts of work-energy subject in 7th grade science course and the relations among them. Concept maps were used as a method of assessment and relationships between concepts of work-energy topic were examined using this way. The research was performed by contribution of 50 students within a period of 7 weeks. Each student formed his/her concept map related to the topic. These maps were assessed according to Novak's score system. The assessment was made with two raters and g coefficient was found as 0.97. Additionally work-energy achievement test was applied at the end of this process. Results obtained from the concept maps and the results of the test were compared. As a result, the correlation between the two assessment methods was computed as 0.416. The relationships between the concepts were examined deeply. Serious defects were determined in the linking words in the concept maps of the students.

Key words: Concept map, work, energy, assessment, science education

INTRODUCTION

One of the methods that play an important role in the measurement and evaluation of data structuring in science education is concept maps. Concept maps show the relations that the students establish between the concepts in their minds. Concept maps contribute to the students in both meaningful learning and learning how to learn (Novak and Gowin, 1984). Concept maps were developed in 1972 in the course of Novak' research programme at Cornell University where he sought to follow and understand changes in students' knowledge of science (Novak and Musonda, 1991). That research was based on learning psychology of Ausubel (1978). According to Ausubel, learning is about what the learner already knows. In that respect, concept maps contribute to setting up relationships between the existing knowledge and new knowledge for meaningful learning. Concept mapping activities are more effective than reading passage, attending lectures and participating in class discussions for attaining knowledge retention and transfer (Nesbit and Adesope, 2006).

Concept maps are tools used in submission and organization of knowledge. These tools are generally made up of concepts, which are circled or put in a box and lines drawn for indicating the relationship between these concepts and linking word or word groups written on them. Concepts and the relationships between them are established in compliance to a certain hierarchical order. The combination of two concepts and a labeled line forms a proposition. Another characteristic of concept maps is cross-links. Cross-links are relations between concepts in different segments (White and Gunstone, 1992).

When we survey literature, there are many studies on concept maps in the field of science, related to practice in different fields and for different purposes. Concept maps are considered as auxiliary tools for obtaining information related to existing knowledge structure of students (Ruiz-Primo and Shavelson, 1996; Zele *et al*., 2004), assessment of knowledge (Rice *et al*., 1998), adding new knowledge to the concepts which already exist in the minds of the students (Kinchin *et al*., 2000), investigating of achievement gain and conceptual reorganization (Carter *et al*., 2003), assessing conceptual understanding

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(Kaya, 2008; Tekkaya, 2003), tracing conceptual development (Novak, 2005), investigating conceptual change (Uzuntiryaki and Geban, 2005), exploring cognitive structure (Tsai and Huang, 2002; Thompson and Mintzes, 2002), investigating students' mental model (Chang, 2007), teaching/learning of concepts (Sket and Glazer, 2005), knowledge integration (Fuang and Diao, 2008), investigating misconceptions (Lee, 2007) and improving problem solving skills (Bagno *et al*., 2000; Lee and Nelson, 2005).

Concept maps can be formed by the students by using pencil and paper (this technique is known as construct-a-map-from-scratch) or can be complemented by the students by leaving some parts empty on the previously prepared concept maps (fill-in-the-nodes where nodes are left blank, fill-in-the- lines are left blank) (Ruiz-Primo *et al*., 2001a, b; Schau *et al*., 2001). Among these techniques, construct-a-map-from-scratch technique is a low-directed one where the others are high-directed. Application of high-directed maps is more practical since it is easier and takes less time. However, although the construction of low-directed maps is harder and requires more time, they reflect better knowledge structure of students (Ruiz-Primo *et al*., 2001a). Since this present study was performed in order to expose knowledge structure of the students, it was considered more suitable to use construct-a-map technique. One of the most important components of concept maps is the relationship between concepts. Analysis of these relationships is very important as stressed by Novak and Gowin (1984). In the recent studies it is suggested that these relationships can be examined statically and dynamically (Safayeni *et al*., 2005; Derbentseva *et al*., 2007). Static relationships reflect organization, description and identification of information. Dynamic relationships indicate the functionality of consistency among concepts. Concept maps, before all else, are based on static relationships, however, dynamic relationships are also very important.

McClure *et al*. (1999) categorized Novak's comments on using concept maps in science education in four groups: (1) learning strategy, (2) instructional strategy, (3) strategy for planning curriculum and (4) means of assessing students' understanding of science concepts. For example, Romance and Vitale (2001) used concept maps for in-depth science concept instruction, Hilbert and Renkl (2008) used concept maps for learning strategy. In this study, concept maps are used in order to assess students' understanding in work-energy subjects related to group 4.

In science education, concept maps are frequently used as an assessment method (Ruiz-Primo and Shavelson, 1996; McClure *et al*., 1999; Slotte and Lonka, 1999; Zieneddine and Abd-El-Khalick, 2001; BouJaoude and Attieh, 2003; Stoddart *et al*., 2000; West *et al*., 2002; Yin *et al*., 2005; Hollenbeck *et al*., 2006; Liu *et al*., 2005). Different scoring methods were used in evaluation in earlier studies of literature. One of these methods is based on scoring by comparing students' maps with criterion or master map (Rye and Rubba, 2002). Another method is founding scoring of concept maps on correctness of propositions (Rice *et al*., 1998). Nicoll *et al*. (2001) presented an alternative analysis method for concept map with large number of concept nodes and links. This method is a three-tier (utility, stability, complexity) system for evaluating concept map links. McClure *et al*. (1999) assessed concept maps with 6 different scoring methods (1) holistic, (2) holistic with master map, (3) relational, (4) relational with master map, (5) structural and (6) structural with master map. Structural scoring method, adapted from the scoring method defined by Novak and Gowin (1984), is used in this study.

Ruiz-Primo and Shavelson (1996) reported that reliability and validity studies were required related to different concept mapping techniques prior to using and evaluating concept maps. McClure *et al*. (1999) stated that reliability of six different scoring methods used for the evaluation of concept maps, change between 0.23 and 0.76 according to g-coefficients calculation. Among these methods, relational with master map was determined as the one with highest reliability and structural with master map as the one with lowest reliability. Rice *et al*. (1998) used concept maps in evaluating the level of knowledge and understanding in science achievement, graded maps with two researchers in his studies and found interrater agreement as 0.98. Ruiz-Primo *et al*. (2001) compared fill-in-the-map and construct-a-map-from-scratch which are two different concept map techniques from different view-points in their studies. Average interrater reliability for concept maps was found as 0.99 graded by three raters with three different scoring types: proposition accuracy, convergence and salience.

Making a study on the correlation between multiple choice test scores and concept map scores for validity of concept maps, is a very common situation in literature. Past and recent many studies carried out for the validity of concept maps, share the same opinion that there are middle and high correlations between concept map scores and standardized multiple choice scores of the students, although value ranges change (Rice *et al*., 1998; Schau *et al*., 2001; Ruiz-Primo *et al*., 2001b; Rye and Rubba, 2002).

When literature is considered, it is interesting that there are limited number of studies related to concepts maps concerning work and energy. Goldring and Osborne (1994) made a research on the level of students in understanding some concepts related to energy. Research was made with 75 students. A questionnaire consisting of 26 questions of 6 groups which contained qualitative and quantitative knowledge and understanding was made. At the end of the research, it was determined that only five students (7%) achieved the highest score. It was observed that approximately 50% of the students do not have enough understanding of basic concepts and ideas related to energy. These findings were further supported by oral interviews. A weak correlation was found between answers of the quantitative questions and qualitative questions. In this study, it was proposed to use concept maps for the improvement of science understanding of students.

Cornwell (1996) explored a number of pedagogical techniques and tool including a computer algebra system, the dynamic simulation program working model and concept maps. Mechanical engineering students were asked on a scale from one to five how lecture, in-class group work, homework, working model demonstrations, concept maps and computer algebra helped the students in five areas. The five areas were: (1) problem solving skills, (2) learning and comprehension of dynamics material, (3) motivation and interest in dynamics, (4) ability to visualize problems and develop intuition and (5) enjoyment of dynamics. When the results were analyzed, in dynamics topic where the basic principles of Newton's Laws and concepts like work-energy and impulse-momentum were used, concept maps and lecture were determined as the most auxiliary factors for problem solving skills and learning/comprehension.

In another study that carried out relations to concept maps in work and energy subjects (Shymansky *et al*., 1997), conceptual understanding and conceptual improvement of 10th grade students were examined. In this study, classical mechanical concepts of the students (kinematics, Newton's laws of motion, work and energy) were discussed and in order to evaluate the understanding of the students over and over again, concept map and follow-up interview methods were used. The research continued in a period of 14 weeks with 22 students enrolled for the physics class. Data was collected from students four times at different stages of the study. Follow-up interviews were used for explanation, expansion and approval of concept map information. At the end of the research, it was seen that knowledge structure of the students remained the same for 10 weeks and did not change for 4 weeks after the end of the training, either. Moreover, misconceptions, that the students have about classical and mechanical subjects obtained from students' concept maps during the research, were listed. Among these, the ones related to work and energy are as follows: force and energy are same, force and work are equivalent, movement implies doing work, energy and work are same, potential energy is motion dependent and energy is not conserved.

Kucukozer (2006) aimed to better understand construction of the meaning of physics concepts in mechanics (Newton's third law) during a teaching sequence at the upper secondary school level. She reported that the notions of object and the concept of gravitations were simultaneously founder notions. The analysis of the data in the study showed that how much the use of the different physical and conceptual resources such as several categories of knowledge, the elements of the situation, influences the construction of meaning.

Work-energy is a very important topic in school science. Energy is especially important because it is a basic topic not only in physics but also other science disciplines, such as chemistry, biology, engineering etc. The basic concepts which are on the topic of work-energy, like force, distance, velocity, gravity, power, kinetic and potential energy, are fundamental concepts in that they underlie some the other topics of physics. Unlike some of the concepts found in physics, work-energy is often experienced by students in their daily lives. Therefore, we believe that it is crucial to examine closely the knowledge structures which they construct in their minds about the concepts related to the subject of work-energy. In this study, concept mapping is used as an assessment tool to explore both the concepts of work-energy, which the students have and the relationships between these concepts. When the literature is examined, there is no in-depth research about the knowledge structures used in the subject of work-energy. The scarcity of qualitative studies done on this subject makes it advisable to continue this research.

In this study, the concepts of the 7th grade work and energy subjects in the curriculum and the relationship between these concepts were analyzed. Within this scope, the goals of the study can be listed as follows:

- Using concept maps as an assessment method
- Exposing concept structure of the students in work and energy subject
- Examining the relationship between the concept map scores and achievement test scores of the students

MATERIALS AND METHODS

Participants: This research was made with 50 7th grade students in science and technology course, 28 girls and 22 boys. Students, who were involved in the research, were from two different classes in an elementary school located in a socio-economically developed neighborhood of Ankara. All students have the same teacher for science and technology class.

Procedure: Data collection was realized in spring of 2005-2006 academic years. The research lasted for 7 weeks/21 courses and it was conducted by the first of the writers of this study while the class teacher was also there as an observer. In the first week, concept maps were introduced to the students in general terms and it was explained to them how to construct concept maps. Following five weeks the researcher trained the students in work-energy issues and at that stage different concept maps were drawn with the students to familiarize the students with concept maps. At the last week of the research, two lessons were used for work-energy matters and for every student to construct his/her own concept map. In the last course an achievement test was made. Each student was given a paper of 50×30 cm. They were not allowed to use any other material except for pencil, eraser and the mentioned paper. In that respect, concept maps were used as an assessment method. Seventeen concepts related to the subject, which are included in the curriculum, were determined at the beginning of concept map construction process of students. These concepts were written on the board with no predetermined order. These concepts are namely, work, energy, power, mechanical energy, kinetic energy, potential energy, elastic potential energy, gravitational potential energy, velocity, force, mass, weight, height, elasticity, stretch, compress and distance. Later on, students formed their individual maps using these concepts. These concept maps were assessed according to the criteria suggested by Novak and Gowin (1984). These criteria can be shown as follows:

No. of concepts	:	Two points for every concept
Hierarchy	:	Ten points for location of concepts according to their degree of proximity on the concept map
Correctness of proposition	:	Two points for each correct proposition between the concepts
Accuracy of proposition	:	Two points for accuracy of proposition between the concepts
Direction of proposition	:	Two points for correct understanding of the relationship between concepts when read in the direction mentioned in the proposition
Cross link	:	Every cross link between the concepts was scored over 10 points according to its correctness and accuracy

Table 1: Variance of analysis

Source of variance	Sum of squares	df	Mean squares	Variance ratio (F)
Examinee (P)	1159.66	24	1159.66	33.85
Raters (I)	699.38	1	699.38	20.42
Residual (R)	822.12	24	34.26	
Total	29353.38			

The achievement test used in the research was work-energy achievement test. This test consists of 28 multiple choice questions which were categorized in four levels: knowledge, comprehension, problem solving and scientific method process. The rationale behind choosing this test is that: the concepts related to the questions in the achievement test and 17 concepts which are expected to exist in the concept map overlap with each other.

Reliability and validity: Twenty five random concept maps were evaluated by four researchers in groups of two according to the criteria of assessment. Generalizability analysis was made in order to determine interraters' reliability. Generalizability coefficient was calculated with the following formula:

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

where, σ_p^2 states individual variance and σ_e^2 is error variance (Atilgan, 2006). Interraters' generalizability coefficient was found as 0.97.

Pearson moment multiplication correlation coefficient of interraters was calculated with SPSS program and was found as 0.994 ($p<0.01$). This coefficient indicates that there is a statistically meaningful, high and positive relationship between raters. According to the results of the analysis made here, it can be said that evaluation is reliable and valid. Content of validity of achievement test was provided by taking opinions of the experts.

Achievement test was made to 226 students in 7th grade and Cronbach Alpha reliability coefficient was calculated as 0.79. Item analysis of the test indicated that mean difficulty value of the test is 0.457 and mean biserial correlation value of items is 0.496. This test was used directly since the analysis show that this test is valid and reliable and it is convenient for the age group subject to this research. The results of analysis of variance are shown in Table 1.

RESULTS

Results obtained from concept maps: In the study concept maps drawn by 50 students were scored by the researchers of this study according to assessment criteria. Concept map scores of the students can be seen in Fig. 1.

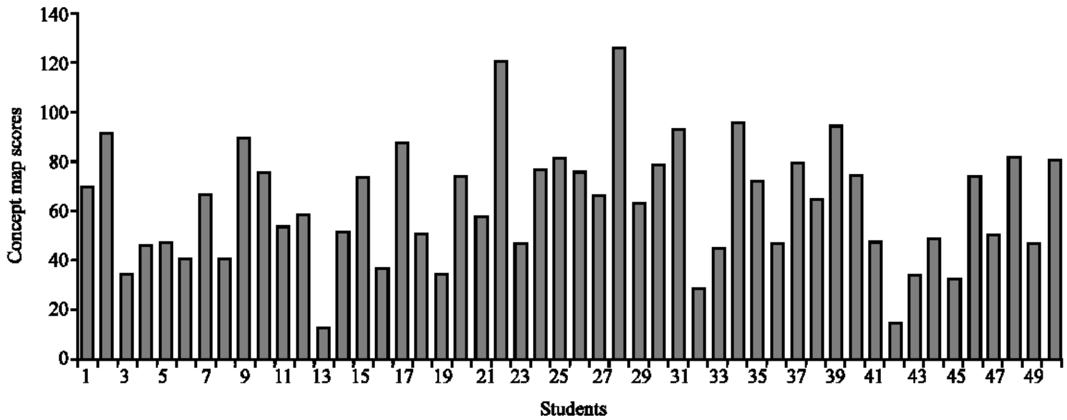

Fig. 1: Distribution of concept map scores according to students

Table 2: Scale codes of concept map scores and distribution of students

Scale codes	Intervals of score	No. of students	Students (%)
Excellent	125-103	2	4
Good	102-81	7	14
Average	80-58	18	36
Poor	57-35	16	32
Invalid	34-12	7	14

Table 3: The percentage of the concept in the concept maps

Concepts	No. of students	Students (%)
Work	50	100
Energy	47	94
Kinetic energy	47	94
Potential energy	47	94
Mechanical energy	44	88
Force	42	84
Distance	42	84
Power	40	80
Velocity	38	76
Height	38	76
Gravitational potential energy	38	76
Elastic potential energy	37	75
Compress	35	70
Weight	34	68
Mass	33	66
Stretch	33	66
Elasticity	33	66

Concept map scores are between 12 and 125. The average score is 61.9. Scores were scaled in order to comment on them easily. Scale codes and distribution of students according to these criteria is given in Table 2.

It can be seen in Table 2 that approximately 68% of the student scores were accumulated in average and poor scale codes. There are only 2 students in the scale code determined as excellent. Use percentage of 17 concepts, which were mentioned previously in procedure, in the evaluated concept maps drawn by the students, is given in Table 3.

Almost all of the students used concepts like work, energy, kinetic energy and potential energy in their maps. Although mechanical energy contains kinetic and potential energy, the percentage of using it in the maps (88%) is less than the percentage of using kinetic energy and potential energy concepts. It was determined that the rate of using the concepts force and distance are the same (84%). It is believed that since these two concepts are mentioned together during the definition of work concept, when one is used it recalls the other. It can be said that the concepts mentioned here are considered as preferential concepts and that is why they are used in the maps. The rest of the concepts are close to each other like in Table 3 and have descending rates of use. It can be said that these concepts are considered as secondarily preferential by the students.

Table 4: Minimum, maximum means and standard deviations of students' concept map link components

Link components	N	Minimum	Maximum	Mean±SD
Correctness of Proposition	50	0	17	4.1±4.3
Direction of Proposition	50	0	17	7.8±4.6
Accuracy of Proposition	50	0	7	1.8±2.1

It is inevitable that the relationship between the concepts must be examined taking into consideration the reality that the main purpose of concept maps is to investigate the relationship between the concepts. The following findings were reached after examining the relationship that the students established between the concepts. Maximum, minimum and mean values related to number of direct propositions, correct directions and open propositions in concept maps are shown in Table 4.

Another point that reveals relationships in concept maps is cross links. It is very interesting that only three students used one cross link each. Since 30% of the students established a relationship between the concept power with concepts like mechanical energy, force, weight, mass, tension rather than the concepts work, energy; it makes us think that they use this concept in daily life instead of muscular force. Figure 1 shows a student concept map related to using the concept power

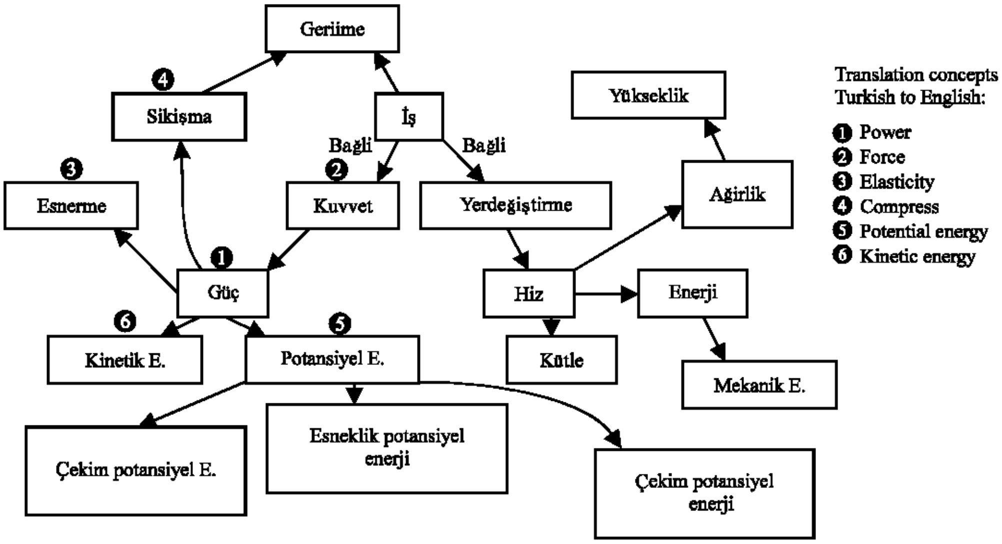

Fig. 2: Example of a concept map where the concept power is used wrongly

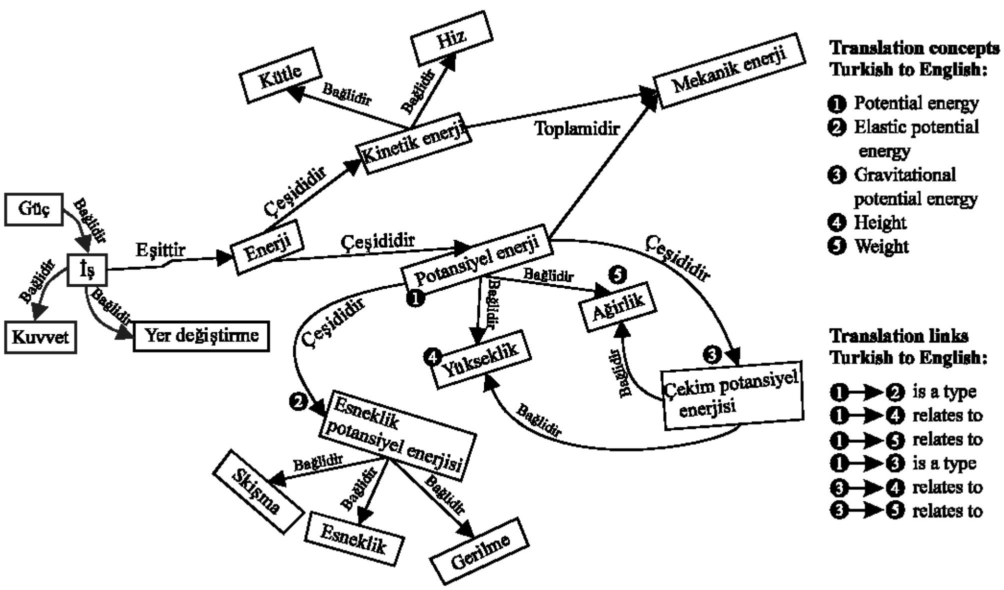

Fig. 3: A student concept map example where the concepts height and weight are directly associated with potential energy

as mentioned above. As the maps are in Turkish, English version of the concepts are written next to the figure for the sake of clarity.

Students were expected to divide potential energy to two, namely elastic potential energy and gravitational potential energy and relate it to weight and height. However, it was seen that only 30% of the students set up a relation between potential energy with gravitational potential energy and elastic potential energy, height and weight concepts are directly associated with potential energy. Figure 2 illustrates a student concept map with this kind of relationship.

Students are expected to relate mechanical energy with kinetic energy and potential energy and indicate in the concept maps that it is composed by these two concepts. However, when the concept maps are analyzed, it was seen that 20% of the students could not directly relate mechanical energy with kinetic and potential

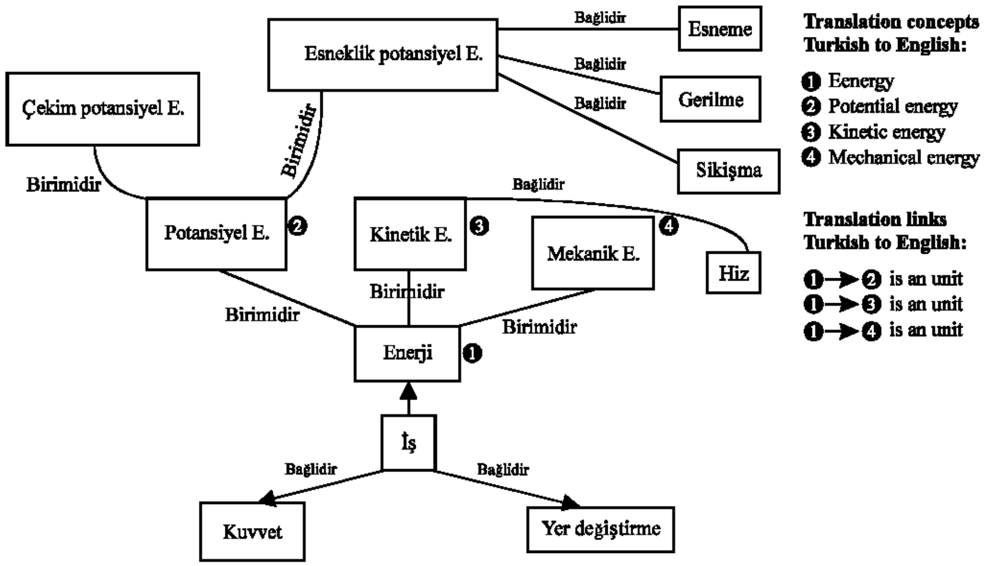

Fig. 4: A student concept map example where the concept mechanical energy is used wrongly

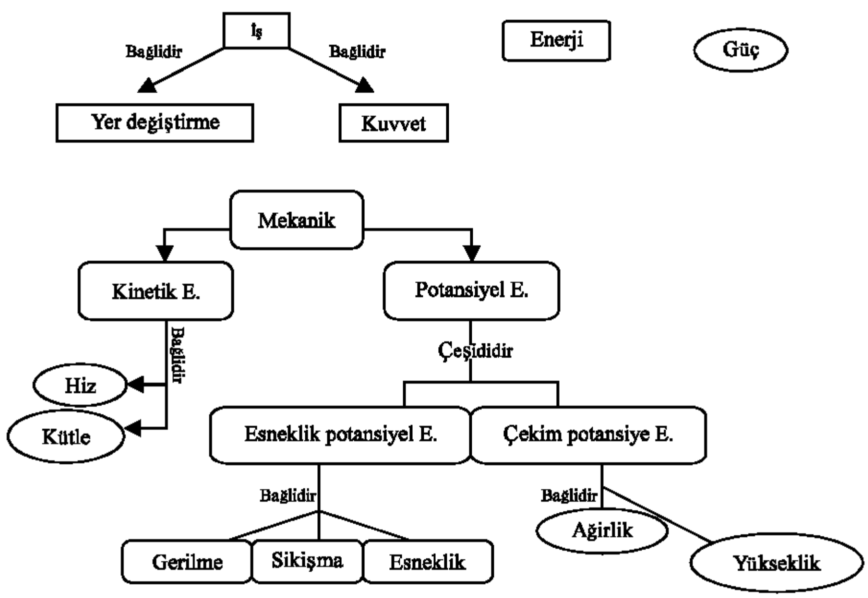

Fig. 5: A student concept map example that composed of small concept maps independent from each other

energy. They related mechanical energy, kinetic energy and potential energy concepts at the same level as energy concept in Fig. 3-5.

It was observed that 14% of the students drew multiple small concept maps which are not related to others. Following concept groups existed in these unrelated small concept maps: work-force-distance, flexion-tension-compaction, mechanical energy-kinetic energy-potential energy-velocity-mass-weight-height.

Fourteen percent of the students reflected correctly the relationship between mass and weight related to force which was realized before work-energy. Ten percent of the students made a direct relation between the concept mass and the concept velocity. The percentage of students who included the concept power in their maps without relating it to any other concepts is 8.

Findings obtained from the achievement test: One point was given to each correct answer while grading the test.

Table 5: Maximum, mean and standard deviations of students' scores of achievement test

N	Maximum	Mean	SD
50	26	18.78	0.05

Table 6: Scale codes of achievement test scores and student distribution

Scale codes	Scores	No. of students	Students (%)
Very good	28-23	10	20
Good	24-18	24	48
Average	17-12	13	26
Poor	11-6	2	4
Bad	5-0	1	2

This way, the highest grade that can be scored from the test is 28. The minimal score that students got in exam was 3. Average of students' scores and standard deviation values can be found in Table 5.

In order to comment easier on achievement test scores, they were graded the same way as in concept. Grading criteria and distribution of students according to these criteria are given in Table 6.

It was seen that 70% of the students score very good and good scale codes when student distribution is examined. It is interesting that there are very few students with poor and bad scale codes (Table 6).

Findings related to the relationship between concept map scores and achievement test scores: Achievement test scores of the students were compared to concept map scores. Pearson moments multiplication correlation coefficient was calculated as 0.416 ($p<0.01$). This coefficient shows that there is a significant, average and positive relationship between concept map scores and achievement test scores of the students.

DISCUSSION

Scores of the participant students on concept maps accumulate at poor and average levels. Only 4% of them are at very good level and 14% of them are at invalid level, which is found to be a significant issue. Level of usage of 17 introduced concepts in evaluated concept maps vary from 66 to 100%. Although all the 17 concepts were on the board and were instructed to the students, the participants used some of the concepts in the concept maps less than others. When the utilization of the concepts was inspected, work, energy, kinetic energy and potential energy were revealed out to be the most commonly used ones. Therefore, it can be stated that these above concepts are primary concepts. Levels of use of the rest concepts are close to each other and show declining percentage. Thus, it can be stated that these are secondary concepts. The difference observed in the use of concepts, which are determined and listed with the contribution of students before test, may also denote that students suffer from building interconceptual relations. Since students build concept maps by relating one concept to another, one can state that they avoid using the ones that are not clearly understood.

Propositions are one of the concept map components that state the relations among concepts. Student concept maps reveal that concepts were connected to each other with lines where propositions were scarcely used. Average number of propositions per concept map is 4 while average number of clear propositions decrease to 2. To illustrate this, work is related to power is not a false proposition but also it is not a clear one. Work is proportional to power is both a true and a clear one. Limited quantity of propositions and students' tendency to define relations with lines in the concept maps indicate that students experienced trouble in building interconceptual relations.

Another important issue that reflects the conceptual interrelations is cross-links. Only 3 students built cross-links. This is also another evidence of deficiency in constructing relations. Another fact supporting the above statement is, some students' concept maps included several independent concept maps with one or more concepts. Although students were expected to relate concept of power, which is a base concept of work and energy topic, to work or energy, 30% of them related it to other concepts like force, weight or mass. Therefore, it can be stated that students equate this concept with the muscular strength, which is a more familiar concept from their daily life. Another important issue about this concept is 8% of the students accommodated it in their concept maps alone, without relating it to another.

Thirty percent of the students stressed that both gravitational potential energy and elastic potential energy were subordinates of potential energy. On the other hand, most of them connected height and weight to potential energy. This reveals that students take gravitational potential energy into consideration when potential energy is mentioned. About 20% of the students related mechanic energy to energy concept as a form of energy in the same hierarchical level with kinetic energy and potential energy. Expected behavior was displaying mechanic energy as a compound of kinetic energy and potential energy.

Deficiencies in correctness and clearness of the propositions and definition of them as only a directed line prove that students have problems with propositions. Since propositions state the relations between concepts, missing labels on the links between concepts makes us think that there are blank spots in students' knowledge structure about work and energy topic. Therefore, it would be a wise way to compare success test results to concept map scores. Both scores were examined in same way according to a 5-grade-scale (very good, good, average, poor, bad). This way comparison between two scores is made easier. Graph 2 and graph 3, which show the distribution of students according to above criteria, show that concept map scores accumulate at the right side of the graph (weaker) where success test scores accumulate left side (stronger). Success test scores pose a better result in comparison to concept map results. Since there is a medium level correlation (r = 0.416) among these two evaluation criteria, both methods have corresponding and non-corresponding sides. Concept map method defines the relations between concepts while success test evaluates information, comprehension, application of concepts and scientific methodology. Therefore, it would be appropriate to use both methods as a complement to each other.

Students with lower scores from the concept maps are explained with the fact that this technique is not familiar to the group. Another reason for this is, concept map technique does not comply with Turkish language structure as stated in Bagci (2003). In Turkish, verbs are placed at the end of the sentence and this makes building propositions harder. We believe that students may overcome this handicap if concept map use is spread throughout the whole instruction process.

One of the main properties in measurement instruments and methodology is reliability. Reliability studies in concept maps are a prime issue as stressed by Ruiz-Primo and Shavelson (1996). Usually, reliability of concept maps is provided by employing different raters and comparing the raters' scoring. Generalization theory is utilized to find out the reliability of raters. In this study of 2 raters, g-coefficient was computed as 0.97. In six different scoring methods' reliability was computed with 2 raters (McClure *et al*., 1999). One of six above methods was the one used in this study and reliability of it was computed as 0.41. Although this reliability level is lower than the level determined in the research, other studies (Rice *et al*., 1998; Ruiz-Primo *et al*., 2001a) found similar scores supporting the results. Researchers think, when the components of the scoring system (number of concepts, hierarchy, proposition correctness, proposition clearness, cross-links) proposed by Novak and Gowin (1984) are taken into consideration, reliability is satisfactory. High reliability factor computed at the research also supports this thesis.

Although there is no reliability problem in scoring concept maps, it is an area of research that if using concept maps is an appropriate way to determine student success. Inspecting correlation between concept map scores and standardized multiple-choice test scores is a common approach in literature. Studies in this area revealed that there exists a medium and high correlation in between (Rice *et al*., 1998; Schau *et al*., 2001; Ruiz-Primo *et al*., 2001a; Rye and Rubba, 2002). In this study a medium level correlation is observed (0.416). Considering examination of interconceptual relations is harder when multiple-choice tests are used, evaluation by exploiting concept maps gain importance. We believe that instead of using these methods alone, a combination of both would be a better approach. Positive correlation between two methods may be accepted as evidence to present thesis.

CONCLUSION

Work and energy is one of the primary topics in physics. Basic concepts of this topic are not only important because they construct a basis for advanced topics of physics but also because they are common in our daily lives. Therefore, examining the students' knowledge structure and completing their deficiencies would contribute to meaningful learning. Concept maps are useful instruments to serve this purpose. By solidifying the relations among concepts, information may be kept by students in their minds with meaningful inter-connections instead of sequential ordering and serve to retention of knowledge. Authors recommend exploiting the advances of concept map use for this purpose as well.

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