The improvement of ecology teaching in secondary schools: effects of concept maps in the restructuring of previous knowledge

El mejoramiento de la enseñanza de la ecología en escuelas secundarias: efectos de los mapas conceptuales en la reestructuración del conocimiento

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Abstract

This paper examined the effects of concept mapping as an assessment tool for learning about the ecosystem. Ninth grade students were encouraged to construct a concept map on the basis of a diagram that might cover their basic knowledge of the ecosystem, which had been gained previously. An assessment procedure developed by Markham et al. (1994) was applied for the examination of the maps. Teaching activities were carried out in the classrooms for two weeks in the light of the concept maps constructed. Afterwards, the students were asked to reconstruct another concept map from the same diagram and the second maps were assessed according to previously applied criteria. Findings indicated that this assessment strategy had promoted meaningful learning. The level of meaningful learning was associated with the creation of elaborate hierarchical map structures and the linking of new information into an existing knowledge base.

Key words: *Concept mapping, ecology, instruction, biology.*

Resumen

Este trabajo examinó los efectos de los mapas conceptuales como herramientas para evaluar el aprendizaje del ecosistema. Estudiantes del grado 9 construyeron un mapa conceptual con base en un diagrama que refleja su conocimiento básico del ecosistema. Un procedimiento de la evaluación desarrollado por Markham et el al. (1994) fue utilizado para examinar los mapas. Con base en estos mapas construidos, fueron realizadas las clases por dos semanas. Después los estudiantes construyeron otros mapas conceptuales los cuales fueron evaluados según criterios previamente aplicados. Los resultados indicaron que esta estrategia produjo el aprendizaje significativo y el nivel de este aprendizaje fue asociado con la estructura jerárquida de los mapas y asociación de la nueva información con el conocimiento existente.

Palabras clave: *mapas conceptuales, ecología, enseñanza, biología.*

INTRODUCTION

As a complex system, thinking about ecosystems is an important skill for navigating information highways, making decisions, and solving problems in both personal and professional realms. For this reason, the main aim of education should be the fostering of systematic thinking. People should analyze phenomena and problems in wider contexts (Hogan, 2000). During education, pupils should be aware of multiple causes and effects on relationships between matters and anticipate the long term consequences of a present action. It is possible to claim that one of the main purposes of education is to foster the student's abilities to analyze concepts and synthesize them into complex cognitive structures in order to understand their relationships. From this point of view, constructivist recommendations for education have suggested that the best way to teach is to figure out what the student already knows and then teach from there (Ausubel *et al.*, 1978). According to Ausubel (1977) meaningful learning takes place when "the learning task is related in a nonarbitrary and nonverbatim fashion to the learner's existing structure of knowledge". This suggests that a learner must actively integrate new concepts into an existing knowledge structure in order to truly understand them. The learner's prior existing knowledge is the most important influence on learning. According to this perspective, teachers should identify what is known and develop their instruction so that it corresponds with this prior knowledge.

In this article, we investigated the knowledge restructuring ability of 9th grade pupils by using concept maps to structure the material covered in an ecosystem course on the basis of previous work (MARKHAM *et al*. 1994). In the study, concept maps were used to examine the changes in the structural complexity of student's knowledge about ecosystems during a successive five week course. Specially, we sought evidence for the growth in the structural complexity of the students' knowledge framework during this ecology course and how rote learning changes the pupils' previous knowledge framework about ecosystems. Although much of the literature in science education research suggests that formal instruction in science has a profound effect on the structural complexity of students' knowledge frameworks, longitudinal studies addressing these issues are rare (NOVAK & MUSONDO, 1991). For this reason, the present study was designed to see if it is possible to enable the students to change or elaborate upon their previous knowledge of the ecosystem by means of a rote teaching activity.

It is considered that pupils should be able to learn ecological concepts from a meaningful rote presentation well enough to understand the main environmental issues. In order to promote meaningful learning it was thought that the students' main framework for ecology should be detected. In order to promote the growth of basic knowledge the elimination of misconceptions is needed. Students' previous knowledge can be used to help develop an effective teaching activity in the class. The present study was designed to see whether concept maps might promote meaningful learning by restructuring previous basic knowledge.

Research question and hypothesis: The main research question in this study was "is there any beneficial effect of a concept maps activity on meaningful learning after a rote teaching activity". The hypotheses suggest that concept maps have a significant effect upon meaningful learning during a rote teaching activity.

METHODOLOGY

A concept mapping procedure on the basis of an ecosystem diagram was used to examine the students' previous knowledge and the restructured knowledge that was reframed after some rote teaching of 9th grade secondary school students. The research was limited to a secondary school in the central part of Antakya-Turkey where one of the researchers has already been working as a biology teacher. A total of 89 pupils were allocated in four classes which took part in the study that covered the first semester of 2003-2004. The pupils were not considered to have had any experience with concept maps, so every class was given a basic concept map course lasting a total of four hours in order to give the students some basic knowledge of, and practice with concept maps. For this, practical projects were done in class, the students and teacher constructed two separate concept maps together about meiosis and energy flow. During this procedure the teacher and pupils did not carry out any activity about the ecosystem. It was considered that the study priority was for the students to gain a basic knowledge of concept maps and skill in concept map construction. To achieve this, written and verbal instructions on concept mapping were given to the students in the first part of course. In the practical part, the students were asked to construct a concept map about mitosis and some key concepts and clues were given to the pupils in order to make their construction activities easy. Separately, in order to measure the students' developing concept mapping ability, homework about the general structure of the cell was given after the practical projects. Using a simplified form of Novak and Gowin's techniques (MARKAM *et al*., 1994), the concept maps constructed by the students were scored for frequencies of concepts, relationships, hierarchies, branching, and cross links. The practical projects showed that the students had gained enough experience in concept map construction.

In the second part of the study, in order to test the students' concept mapping ability and measure their basic knowledge about the matter cycle, energy flow and competition between species, ecosystem diagrams that included biotic and abiotic factors affecting the ecosystem were given to the students. The students were told to construct a concept map in which hierarchies, branching properties and propositional properties between concepts should be considered. One hour was considered to be enough time for the students to construct a concept map. Using an assessment technique previously developed by Novak and Growin, the concept maps were scored for: frequencies of concepts, relationships, hierarchies, branching, and cross links. Also, the concept maps were analyzed for misconceptions and other patterns to be taken into account when designing teaching activities. In accordance with the curriculum, the teaching activity for the ecosystem unit has been limited to 4 hours, during the teaching process, some food chain and matter cycle and energy flow diagrams were used by teacher. But as a whole, the introduction of any ecosystem diagrams to the students during the teaching process was avoided. Also it is another important point that the teacher was conscious of some misconceptions that frequently came across when concept maps were used during the teaching. In the last week of research, after the teaching activities, the concept maps, previously constructed by the students and scored by the teacher were given to the students to be examined for one hour, and it was strongly advised that they shouldn't make any changes in the previous concept maps. Later, the students were asked to construct another concept map from the original diagram, taking into consideration whatever they learned during the teaching period. The teacher informed them that using any outside source during the concept map construction period was forbidden, and strongly advised that the students consider the general rules for the concept mapping procedure.

Assessment criteria: The completed maps were scored using Novak and Gowin's (1984) procedure as simplified by MARKAM *et al.* (1994). One point was awarded for each concept, for each relationship, and for the first instance of branching. Three points were given for each additional instance of branching, five points for each hierarchy level, and ten points for each crosslink. As suggested by NOVAK and GOWIN, only scientifically acceptable connections were recognized in the scoring procedure. In the simplified scoring method we employed, a scientifically acceptable example was scored as a correct "relationship" rather than an instance of a separate category for examples. For determining the reliability and validity of concept mapping as a tool for exploring and documenting the structural complexity of knowledge we used Cronbach's alpha test and for statistical analysis, the Student t test. (Extra note: "Student" is the surname or "apellido" of the person who developed that particular test hence the word should be capitalized.)

RESULTS

The main values of pre and post concept maps constructed by the students from an ecosystem diagram and assessed according to MARKAM, MINTZES and JONES (1994) is shown in figure 1.

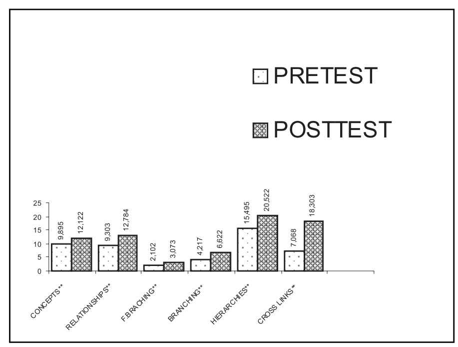

Figure 1. The main values of pre and post concept maps constructed for an ecosystem diagram.

In order to understand whether there is any statistical difference between the pre and post concept maps, the Student t test was applied. Findings have shown that there was a very important statistical difference between the pre and post concept maps with a significance of $P<0.001$ (table 1). Also we examined the reliability and validity of concept mapping as a tool for determining the structural complexity of knowledge, it has been found to be 0.685. This shows that the results were reliable and valid. The profiles suggest a clear incremental growth in the post scoring category after teaching about the ecosystem in the classroom and analysis of the variances confirms that the observed differences are significant ($P<0.001$).

Table 1

Statistical differences between pre and post concept maps

Pre-Post concept maps	*Sample* N=89
Mean	*-101,315*
df	*47,558*
T	*-9,286*
P<0.001	*0,000*

A review of these structural complexity profiles reveals substantial differences between the pre and post maps. For example the mean number of cross links increased when compared to the pre concept map, which may show a better understanding of the ecosystem. In contrast, the mean number of concepts tends to stay stable in the pre and post concept maps.

Figures 2 and 3 are randomly chosen students' concept maps, the results of a brief case study.

The student's first concept map (figure 2) is structured around the requirements of organisms in a linear food chain. The map was relatively simply constructed and all the relationships were acceptable. Significantly, the students realize that wolves not only eat deer, but also rabbits, snakes not only eat mice, but also frogs. Similarly, hawks eat not only snakes but also could eat mice. At least it was possible to accept that this student was able to think in relatively complex manner at a primitive level. The students considered the sun to be the main source of energy, and plants as the food source for first level consumers. This is a typical simple hierarchical structure that may reflect the student's categorical thinking ability. It is possible to comment that the student constructed the map according to the food chain and seemed to ignore chemical reactions and other connections or turnovers in an ecosystem.

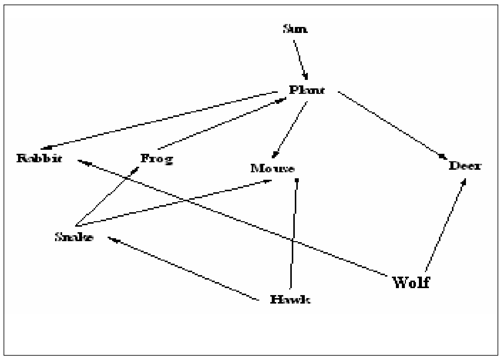

Figure 2. A concept map constructed previously by a student according to the student's basic knowledge.

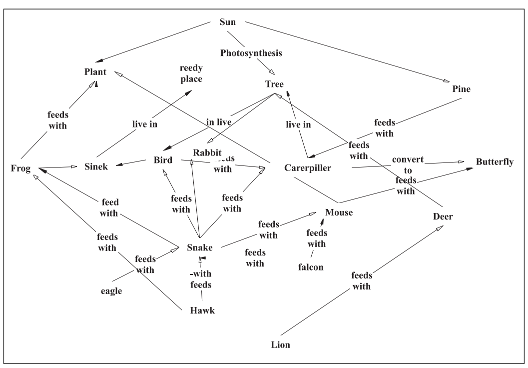

Figure 3. A concept map reconstructed by the same student after the ecosystem was taught in class.

In the subsequent map (figure 3) the student substantially restructures the framework, which is more comprehensive than in the previous map. In the student's reconstruction, more concepts, concept differentiation (branching), some evidence of subsection (hierarchy), and a clearly more identifiable integration (cross linking) of concepts were represented. It appears that student's mind was clearer about habitats of organisms and their relationships. Not only a food chain, also some chemical production mechanisms such as photosynthesis, as well as the larval period and adolescence of some organisms, may be a reflection of structural complexity. After the teaching activity in the classroom, the students apparently were conscious of the ecosystem greater level detail that was reconstructed in his/her ideas about food sources and habitat. It appears that she/he has established a well-differentiated structure for subsequent learning, the availability of more cross links may reflect the structural complexity of the map. It seems especially significant that all of the student's knowledge about the ecosystem is limited to the food chain and some chemical activity. The soil, bacteria, decay, matter cycle and energy flow in the ecosystem seems to be ignored by the student.

DISCUSSION

This study reported here shows that during a rote teaching process according to the curriculum a substantial amount of knowledge restructuring and conceptual change may occur. It appears that much of this structural changes take place during the teaching. The study of ecology can provide students with valuable experiences in analyzing complex systems to help them develop the skills and habits of systems thinkers. It was considered that an effective way to introduce students to systematic thinking was to engage them in analyzing ecological material such as the energy flows in food webs and the matter cycle. Food web analysis tasks require quintessential systems thinking: taking into account all factors within an interconnected model to characterize the state of one variable in the model at a point in time. Also it was considered that concept mapping would provide a tool for achieving a gain in knowledge depth and for developing critical thinking skills about self-development during the early part of their lifespan which might help students to apply empirical findings about the self to their own lives with the use of concept mapping as a strategic assessment guide. For this, it was considered that if each student subsequently constructs pre and post concept maps it was possible to depict his or her understanding of the ecosystem. It is well documented that concept maps provide two-dimensional, hierarchical, node-link representations depicting the major concepts and relationships comprising a knowledge structure. The practice of returning to concept maps served the important function of encouraging reflection on prior knowledge, one of the characteristics which is commonly attributed to experts in many science-related domains (CHI *et al*., 1988). MARKAM *et al.* (1993, 1994) examined the concurrent validity of concept mapping in a college-level biology course. These findings and several others provide strong evidence of internal consistency and for both construct and concurrent validity. Although the simplified scoring system enabled us to describe the structural complexity of the knowledge at two points in time, the primary purpose of these studies has been to contribute to a baseline of descriptive information about knowledge restructuring and conceptual change in understanding the ecosystem. In the studies reported here we have shown that after a rote teaching session in the classroom a substantial amount of knowledge restructuring takes place. It appears that the development strongly hierarchical structures, as well as well-differentiated, and highly integrated frameworks of related concepts has provided strong evidence that preknowledge may be reconstructed by meaningful learning tools such as concept maps. Concept maps play a significant role in mediating growth and incremental growth in structural complexity, which is concomitant with progress. Our findings show that the students' reconstructed concept maps were characterized by a structural knowledge framework complexity that expresses substantial incremental progress. The differences between pre and post concept maps were found to be significant ($P < 0.001$). It is possible to reach a conclusion that rote ecological teaching in the classroom may be helpful for a good analysis of previous knowledge in order to construct a more developed knowledge framework. It has been shown that a teaching activity performed considering the students' misconceptions and over-stressing the framework of the unit with its main points during the teaching was useful. The incremental property of framework structure, the complexity of hierarchical structures and the cross links between concepts may indicate this process. The results also show that some misconceptions that came from the students' preknowledge were resistant to changes. The concept maps constructed previously by students were simple, included few concepts, and the connections were on the basis of food chain relationships. It has been observed that the students mostly ignored multilateral relationships between populations, and mostly considered that only one population fed on another (bilateral relationships). It is possible to claim that most students did not consider the ecosystem as a whole. Instead of this they paid attention to well known food chain relationships between populations. On the other hand it was seen that epistemological and teleological approaches mostly dominate during the construction of concept maps.

It was noticed that the basic structure of the students' maps was mostly sourced from their daily experiences and from school text books that dominantly mention hunter-prey relationships. The most familiar example of this is that the exhaustion of snakes in a habitat could cause the rats to be overcrowded, so this sort of situation could be found in the ecosystem as a whole. It is possible to come across similar knowledge in different teaching sources that may direct students to misconceptions. KUHN *et al.* (1988) described that learning science covers the sum of an epistemological reconstruction and that the pupils are mostly unconscious of any correct and incorrect knowledge. They tend to accept every idea which is close to their available knowledge that has already been constructed. After assessing the pre concept maps, it has been seen that students did not consider any abiotic effects such as the matter cycle and energy flow in the ecosystem when constructing their concept maps. For this reason the students should given detailed knowledge about these basic parts of the ecosystem while teaching about the ecosystem in the classroom. Assessment of the post concept maps showed that the students had not grasped what was considered to be the main point stressed by the teacher in the classroom. The concept maps were reconstructed in a traditional way with bilateral food chain relationships dominant in the concept maps. The complexity in the structure of the reconstruction of basic knowledge after classroom teaching may indicate an incremental development of student knowledge. Our suspicion is that the main differences seen between concept maps have their source in individual basic knowledge. Students usually tended to accept the food chain as an energy transfer mechanism, but it was noticed that most of them tended to accept the populations as producers and consumers. In comparison pre and post concept maps constructed showed that there was an incremental increase in the structural complexity of the students' knowledge framework and it was concluded that teaching activities in the classroom are significantly affected by a predominant knowledge structure and that any misconceptions gained may play a significant role in mediating concept map reconstruction. It has been seen that the students' preknowledge is made active by using concept maps, which are characterized by a new reconstruction and more complexity in thinking ability. As an example, pre and post concept maps constructed by a student are given in figures 2 and 3. On comparing both concept maps, it was clear that in reconstructed concept maps characterized with an increment there is improvement. There was an increase in number of concepts used, relationships between concepts, sub branches added to first branching points, hierarchical structure and cross links between concepts. In the first concept maps there were only a few prepositions between concepts, but the post concept maps included a lot of acceptable and meaningful prepositions. The most frequently used preposition for constructing concept maps was *"feeds on"; "takes energy", "takes water and minerals" "-takes minerals from", "does photosynthesis"*, were other prepositions and words used to make sensible connections between concepts. A possible explanation for the observation that prepositions were seldom used in the concept maps is that students did not frequently came across concept map use in previous teaching activities. It was noted that most of the students constructed concept maps on the basis of *"hunter-prey"* relationships; this may be due to the effects of previous ecology teaching where textbooks and previous daily experiences may orient students towards this belief. The directions of the arrows used in the concept maps constructed were not always in the same direction. It has been seen that there was a mess in determining the arrows' directions. The independent relationships between populations' feeding was characteristic of most of concept maps. There was a tendency to accept independent relationships between organisms, and construct concept maps according to this. It has been seen that the connections in pre concept maps were mostly constructed in a linear fashion, but in post concept maps complex structure and multidimensional relationships were reproduced. Leach *et al*. (1996) claimed that students used to have a tendency to organize their food chain starting from the producer and ending with the upper consumers; and that this may help the students' understanding of how populations change according to food intake. The prepositions used by students such as *"change into –", "takes mineral from"* may give some clues about the students' ideas about the matter cycle, and energy flow that occur in ecosystems. In this study teleological and mostly anthropomorphic approaches were used by the students in order to explain ecological events. Jungwith (1975) claimed that teleological and anthropomorphic metaphors are very common in textbooks. It is possible to reach a result where students use a mostly teleological and anthromorpic approach to explain ecological events.

The findings of this study have shown that the concept map structuring practice was vital for students during ecology learning. Starting with a few concepts that do not include complicated relationships between concepts could be very useful. On the other hand, grouping and connecting the concepts in a sensible way could be useful for ecology learning and teaching. In the advanced steps, it could be beneficial for the students to use the general principles of the matter cycle and conservation of matter. But there is no place in the Turkish curriculum so far about any practical work such as concept maps for teaching biology in secondary schools. It is advisable that a timetable be allocated for practical concept map work in biology education since it could be very helpful for learning ecology.

CONCLUSIONS

The results of our study suggest that it could be beneficial for teachers to learn the students' previous knowledge framework just before starting meaningful teaching and learning activities. The concept map as a research, as well as a teaching and learning tool, has been adopted by teachers around the world before a long time, but is not commonly used for teachers in the Turkish education system. It is considered that concept map constructing activates should be developed in biology education. Examining concept maps made by students is a guide to the teacher about the propositional validity and structural complexity of their knowledge, including the number and quality of scientifically acceptable concepts and their progressive differentiation. The development of program packages in the Turkish language for the use of students and biology teachers may contribute to teach/learn some subjects that are accepted to be difficult to teach and learn such as cell division, and the ecosystem. The main goal of education is considered to be the development of basic and useful education strategies for every student level.

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