Fostering primary school students' understanding of cells and other related concepts with interactive computer animation instruction accompanied by teacher and student-prepared concept maps

[1]Ercan AKPINAR and [2]Omer ERGIN

Dokuz Eylul University, Buca Faculty of Education, İzmir/TURKEY

E-mail: [1]ercan.akpinar@deu.edu.tr, [2]omer.ergin@deu.edu.tr

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Contents

Abstract

The purpose of this study was to investigate the effects of instruction (application) including interactive computer animation accompanied by teacher and student-prepared concept maps on primary students' biology achievement during instruction, as well as revealing attitudes towards science as a school subject. A quasi-experimental pre-test/post-test control group design was used in this study. The experimental group had 31 students and the control group had 34 students. The experimental group received instruction including interactive computer animation accompanied by teacher- and student-prepared concept maps, while the control group received traditional instruction. A biology achievement test and an attitude scale toward science were used as data collection instruments. The present study indicates that the experimental group had significantly higher scores than the control group in the biology achievement test (regarding cells and other related concepts). Regarding students' attitudes toward science as a school subject, there was no significant difference between the experimental and control groups in the pre- and post-test results. However there was a statistically significant difference between the gain scores of the control group and the experimental group in favor of the experimental group.

Keywords: computer animation, concept map, cell concept, attitude toward science

Introduction

Primary science programs (curricula) of developed countries have had highly-developed student-centered science programs since the middle of the 1970's (Hodson & Hodson, 1998). These programs are strongly influenced by constructivist theory. In contrast, in Turkey, the primary science programs were influenced by the behaviorist view from 1924 to 1989. Although the program employed in 1992 had some constructivist influence, it was heavily based on behaviorist theory, and this influence continued until the late 1990s (Unal & Akpınar, 2004).

In 2000, the Turkish Ministry of National Education radically changed the National Primary Science Curriculum to include some constructivist views (Kılıç, 2001) and it was put into practice until 2004. Between 2004 and 2005, The Turkish Ministry of National Education made some new changes to the National Primary Science Curriculum. These changes have redirected the curriculum to be based heavily on constructivist views and have given up former perspectives. This new curriculum is one that is student-centered (Akpınar & Ergin, 2005, Turkish National Primary Science Curriculum, 2005).

The new curriculum offers students opportunities to engage in hands-on and minds-on activities, and to construct meaningful learning based on their own prior knowledge and experiences. In this curriculum, the students assume responsibility for acquiring active learning strategies including learning how to learn, discovering, and carrying out research. Moreover, it offers students the chance to work cooperatively and share their knowledge and experiences with each other. When the science teacher begins the course, the most important thing he or she should do is to consider students' prior knowledge and beliefs. The curriculum gives the role of a facilitator to the science teacher. The science teacher is not a transporter of knowledge, but a learner who is actively engaged in the classroom activities as if he or she is learning with the students and is preparing a self-learning environment (Turkish National Primary Science Curriculum, 2005).

As a result, constructivist theory has been the dominant paradigm of teaching science in Turkey since the beginning of the year 2000. The major role of the science teacher, according to this theory, is to create a learning climate that helps students acquire and make sense of knowledge. The science teacher should employ some learning and teaching strategies together with methods to encourage and help students to become active learners in science courses. Concept maps and computer mediated cognitive tools are very useful for actively engaging students . So, in this study, we used interactive computer animations accompanied by concept maps in order to determine whether this instruction method fostered students' understanding of cells and other related concepts in in a primary school science course biology lesson. It was also investigated whether or not this instruction had a positive effect on the students' attitudes toward science.

Concept Map

Concept mapping is based on the constructivist model of learning (Nicoll, Francisco, & Nakhleh, 2001). Concept mapping has been used widely as a constructivist-learning model and it is more widely accepted in science education than in comparison to the past (Martin, Sexton, Wanger, & Gerlovich, 1998; Willerman & Harg, 1991). In the research done by Novak, who developed this tool, concept mapping has become a viable educational medium. Perhaps, most importantly, concept maps have been reported to be a potent instructional tool for promoting what Ausubel has described as meaningful learning (Horton et al., 1993). Concept maps were originally designed to help both teacher and students organize their own understanding of a subject, but they have been used in a variety of disciplines, employing different strategies and evaluation schemes (Nicoll, Francisco, & Nakhleh, 2001). These tools add a visual dimension to written text and provide a way for students to organize their thoughts. Concept maps can be used as a developmental tool to find out what the students think and how they relate one concept to another. Moreover, there are other ways in which teachers can use concept maps in science teaching (Sherman, 2000).

Concept mapping is an active learning tool with numerous applications in science education (Snead & Young, 2003; Nicoll, Francisco & Nakhleh, 2001; Ruiz-Primo, Schultz, Li & Shavelson, 2001; Francisco, Nicoll, & Trautmann, 1998; Ruiz-Primo & Shavelson, 1996; Willerman & Harg, 1991; Wallace & Wintzes, 1990; Cliburn, 1990; Arnaundin, Mintzes, Dunn, & Sbafer, 1984). For instance, Willerman & Harg (1991) studied the effect of concept maps as advance organizers for improving the science achievement of eighth-grade students. Eighty-two eighth-grade students in four science classes participated in their study. The experimental group completed the concept mapping at the beginning of the science unit under the teacher's supervision. At the end of the two-week unit, a science test was administered to the experimental and the control group. The results of a one-tailed t-test indicated that there was a significant difference between the two groups. Wallace & Wintzes (1990) examined the concurrent validity of concept maps as vehicles for documenting and exploring conceptual change in biology. The subjects were randomly assigned to one of two application groups. The students in both groups were administered a multiple-choice/free-response inventory which assayed their knowledge of "Life Zones in the Ocean" before and after instruction (application). The students in the experimental group showed evidence of significant and substantial changes in the complexity and propositional structure of their knowledge base, as revealed by their concept maps. No changes were found in the control group. Besides, there are some studies that have used concept maps as alternative assessment devices (Nicoll, Francisco & Nakhleh, 2001; Ruiz-Primo, Schultz, Li & Shavelson, 2001; Ruiz-Primo & Shavelson, 1996)

Interactive Computer Animation

Computer-based cognitive tools are tools that can help learners build their knowledge structures by constructing and manipulating knowledge representation. Computer-based cognitive tools have the potential to meet the requirements of a constructivist framework as tools and resources for their ability to help students acquire knowledge and make sense of it (Orhun, 2002). The computer, as a cognitive tool, engages students in interactions, principally with their own meanings or understandings, as well as those of others, in order to build a more complete, richer understanding. The computer, as a cognitive tool, allows the learner to externalize their thinking, enrich it, manipulate it and change it, all by interacting with one or more conceptual models on the computer (Quinn & Wild, 1998). The computer is expected to contribute to the acquisition of varied knowledge as well as to promote student independence and growth of responsibility for schoolwork (Jedeskog & Nissen, 2004). Specifically, using animation may increase conceptual understanding by promoting the formation of dynamic mental models of the phenomena. The dynamic quality of animation may promote deeper encoding of information than that of static pictures (Williamson & Abraham, 1995:532). Because of the many benefits of animation in science teaching, science education researchers have focused on computer animation to help students' understanding of complicated science concepts. For instance, Williamson and Abraham (1995) explored the effect of computer animation depicting the particular nature of matter on college students' mental models of chemical phenomena, and they found that computer animation has a more positive effect on students' conceptual understanding than traditional instruction. In another study, entitled "A Hypermedia Environment to Explore and Negotiate Student's Conceptions: Animation of Solution Process of Table Salt" carried out with 11th grade students, Ebenezer (2001) reported that animation can be used to explore, negotiate, and assess students' conceptions of the submicroscopic aspects of solution chemistry. Also, there are many other studies that widely apply computer animation, simulation and other computer assisted or mediated tools in science education (Ardac & Akaygün, 2004; Windsehitl & Andre, 1998; Yıldırım, 1995). Moreover, there are some studies that use some methods together in science education studies including concept mapping and visualization (Brandt et al., 2001), concept mapping and concept change (Uzuntiryaki, 1998) and concept mapping and the learning cycle (Odom & Kelly, 2001). However, there are few studies that combine computer animation and concept mapping in science education. In the present study, interactive computer animation and the teacher- and student-prepared concept maps were used together to investigate the effects of the instruction (application) including interactive computer animation and teacher and student-prepared concept maps on primary school students' understanding of cells and other related concepts. The present study also investigated students' attitudes towards science as a school subject.

In this study, the topic of cells was selected as a main theme because a cell represents a complex conceptual system that includes many interrelated functional parts (eg., membrane, nucleus, and cytoplasm). In general, the cell plays a fundamental role in the primary and middle school students' understanding of life processes because it is the basic structural and functional unit of living things (Glynn & Takahasti, 1998). A basic understanding of the cell is considered to be an essential component of scientific literacy (American Association for the Advancement of Science, 1993 in cited Glynn, Takahasti, 1998). The cell is characterized as being a topic that is difficult for students at different educational levels to understand (Flores & Galleges, 2003). The most frequently encountered problem in primary schools is the incoherent use of definitions. Even if the students see a cell under a light microscope, they can't see the structure of the cell or other organelles in detail. Using interactive computer animation accompanied by concept maps may foster students' understanding of the cell. Since the topic contains many abstract concepts, and most of these concepts are in Latin with no equivalent terms in Turkish, the subject may be difficult for the students to understand.

Methodology

The subjects of the study were sixth grade students in a primary school in Turkey. This study involved an experimental and a control group. The study was limited to concepts about the cell and other basic concepts related to cells. A biology achievement test and an attitude scale were used as data collection instruments. A quasi-experimental pre-test/post-test control group design (Campbell & Stanley, 1966) was used in this study. The 65 participants in this study were 6th grade students enrolled in a middle-class urban primary school in İzmir in Turkey. Nearly all the participants were 11-year-olds (except for two students). The primary school is equipped with computers and a science laboratory. There are 23 computers in the computer laboratory. The science laboratory is well-equipped. The experimental group consisted of 31 students and the control group consisted of 34 students. Two different teachers taught both groups until 6th grade. In 6 th grade, they were allotted to their classes according to their achievement levels in various subjects such as science, mathematics, Turkish language, etc. Since the Turkish Ministry of National Education does not allow changes in the classes after the school term has begun, two of the 6th classes were assigned randomly as experimental and control groups at the beginning of the study. The experimental group received instruction including interactive computer animation accompanied by teacher and student-prepared concept maps, while the control group received traditional instruction. This study was conducted over three weeks during which the cell and other related concepts were covered as part of the regular curriculum in the sixth grade general science course (each instruction took 40 minutes and continued for 3 hours a week over a period of 3 weeks, including data collection). The same teacher taught both the experimental and control groups in order to minimize the teacher differences. Before starting the instruction, the teacher was trained in how to instruct the program. The teacher was also trained to standardize the administration procedures and implementation of the instruction.

Prior to the 6th grade, in 4th grade the students in both groups learnt about living and non-living things in the environment. In 5th grade a plants and animals unit was taught. For example, students learnt about animal and plant nutrition. The mentioned units in the 4th and 5th grade are not taught in detail. To summarize, the students were not taught cell topics before 6th grade. Therefore, the students in both groups had similar backgrounds.

Instruction

The students worked alone or in pairs as they used the interactive-animation of the computer. While using the animation, the students were given worksheets. They were asked to draw the cell and the organelles they saw and answer some questions. Primarily, students were taught about animal cells and related concepts through interactive animation, and then they were asked to make a concept map about animal cells. The experimental group was taught how to prepare a concept map. After the students in the experimental group had finished their concept maps, they compared them with those of the teacher and the researcher. The concept maps drawn by the teacher and the researcher were displayed on Datashow and the students were given the opportunity to control and evaluate their own maps and decide whether they had the right connections between the concepts. Briefly, the students learned the concepts through the computer, and then they were asked to form their own maps and compare them with those of the teacher and researcher. An example of a concept map prepared by a student is given in Appendix A.

Both the control and experimental groups saw an onion skin and blood cells with the naked eye through a microscope. However, the experimental group also had the opportunity to see the cells and all related constructions and organelles with the help of computer animation in detail, and to watch when they need. The teacher gave the same lecture and used the same assignments, and followed the daily course program in both groups. The difference between the groups was the method of instruction, namely, using the interactive computer animation accompanied by concept maps in one case, and not using them in the other. During the study, the researcher observed the control and experimental classes to ensure that the teacher followed the instruction procedures correctly.

Instruments

The Cell Concept Achievement Test (Biology Achievement Test):

This test was developed by the researcher to identify the students' understanding of cell concept and other related concepts. Originally, the test contained 30 multiple-choice items about knowledge, comprehension, and other levels of Bloom's taxonomy. It was administered to a pilot study group of 193 students in seventh grade in three different primary schools. After an item analysis was carried out, a test of 18 items was constructed. The KR-20 reliability of the test was 0.67. The achievement test was administered to both groups before and after the instruction.

Two examples of the test items are:

1. Which of the followings is found in plant cells, but not in animal cells?

A) Cell walls and plastids
C) Chromosomes and ribosome
B) Mitochondria and plastids
D) Cell membranes and endoplasmic reticulum

2.

Cell	Ribosome	Mitochondria	Chloroplast
X	+	+	+
Y	+	-	-
Z	+	+	-

In the Table above, the information pertains to organelles that X, Y, and Z cells contain is shown.

A) X cell synthesizes its own food through light energy
C) Z cell is the leaf cell of a plant
B) Y cell uses oxygen for producing energy
D) X, Y, and Z cells can synthesize protein.

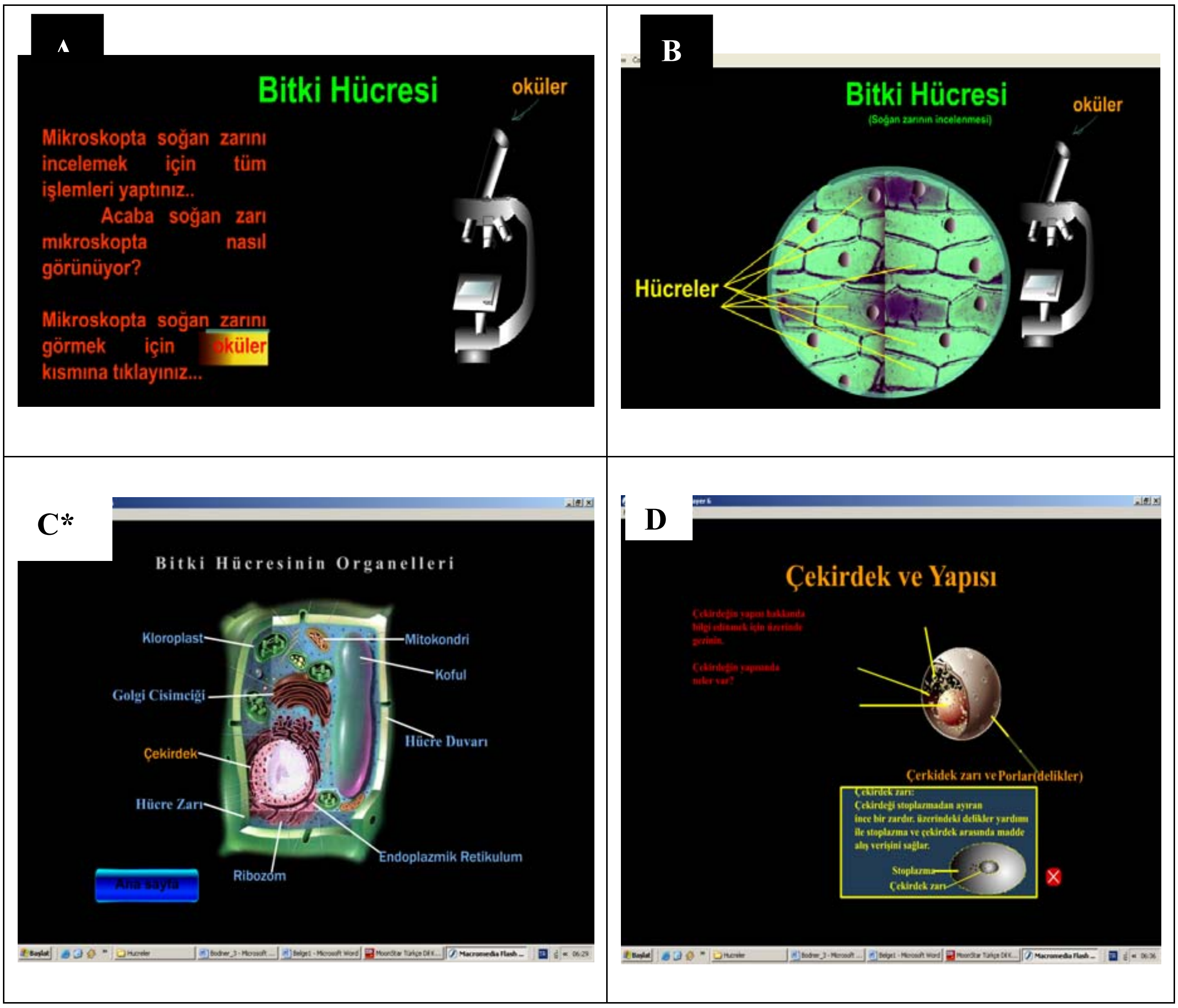
Considering this, which of the following information related to cells is certainly wrong?

Attitude Scale toward Science as a School Subject:

The scale was developed by Geban, Ertepınar, Yılmaz, Altın, & Sahbaz (1994) to identify primary students' attitudes toward science as a school subject. The Attitude scale contains 15 items in a five-point Likert-type scale. The alpha reliability coefficient is 0.83. It was administered as pre- and post-tests to both groups. The students in both groups required approximately 35 minutes to complete both instruments (the achievement test and attitude scale) for the pre-tests and 45 minutes for the post-tests.

Designing and developing interactive computer animations for biology topics

Macromedia Flash MX (Gumustepe, 2003) was used for authoring computer animation regarding animal and plant cells, the structure and function of the cell, cellular organelles, etc. Figure 1 shows some samples taken from the interactive computer animations. The researcher prepared the interactive computer animation with some support from computer experts.



* Plant cell picture is cited in http://sun.menloschool.org/~cweaver/cells/plantcell

Figure 1. *Some views taken from computer screen (in Turkish)*

Figure 1 shows a display screen for the plant cell and its organelles taken from the computer animation according to the design guidelines. When the students click the button named oküler in Turkish (ocular in English) on the screen (**A**), he or she can see the basic structure of plant cells (**B**) and then, when they click another button (objectives), they can see an enlarged plant cell and its basic structures, but this view is not shown above. **C** is a view of an onion cell (plant cell) and **D** is a view of a nucleus of a plant cell. While searching the nucleus on the screen, the students can understand the functions of pores on the nucleus and its structure.

Results

Before and after instruction, the achievement test and attitude scale towards science were administered to both the experimental and control groups. Each correct response in the achievement test was scored as one point. Comparisons were made in terms of the experimental and control groups' pre and post-test achievement score means with t-test analysis. The attitude scale with 5 gradations was scored between 5-1 points, with 5 points for fully agree and 1 point for fully disagree. The findings were analyzed by a t-test.

Table 1. *Comparison of Mean Scores of the Experimental Group (EG) and Control Group (CG) in Biology Achievement (pre-test)*

Groups	**N**	$\overline{X}$	**Sd**	**t**	**p**
EG	31	4.12	1.94	-.838	.405
CG	34	4.50	1.61		

Table 1 shows that there was no statistically significant difference between the mean scores of students in the control and experimental groups in the Biology Achievement Test before the instruction ($p>.05$). Consequently, the two groups were equivalent on this dependent measure. Thus, it can be said that students in both groups had similar knowledge about the cell topic that was examined in this study prior to the teaching.

Table 2. *Comparison of Mean Scores of Control Group and Experimental Group in Biology Achievement Test (post-test)*

Groups	**N**	$\overline{X}$	**Sd**	**t**	**p**
EG	31	10.87	2.64	5.77	.000*
CG	34	7.73	1.54		

Table 2 shows that there was a statistically significant difference between the mean scores of the experimental and control groups in favor of the experimental group (*$p<.001$). The pre and post-test scores of both groups were compared within themselves. The achievement of both groups was higher than before (experimental group t= -11.111, p=.000, control group t= -6.544, p=.000). It can be seen from Tables 1 and 2 that the improvement in the mean score of the experimental group was 6.75 points, while in contrast, the corresponding increase in the control group was only 3.23 points. In addition to the pre- and post-tests of the control and the experimental groups, their gain scores were also compared (each subject's pre-test score was subtracted from his or her post-test score. The gain score of each student and the mean gain score of both groups was found. The two means were tested for statistical significance using the t-test for independent samples) and it was recorded that there was a significant difference between the groups in favor of the experimental group (t= 3.541, p= .001). These results indicate that when interactive computer animation and concept mapping are used together, the students more easily grasp the cell concepts.

Table 3. *Comparison of Mean Scores of the Control Group and Experimental Group in Attitude Scale (pre-test)*

Groups	N	$\overline{X}$	Sd	t	p
EG	31	53.00	8.13	-.990	.326
CG	34	54.82	6.13		

Table 3 shows that there was no statistically significant difference between the mean scores of the students in the control and experimental groups with respect to attitude toward science before the instruction.

Table 4. *The Analysis of Data for the Group Comparison with Respect to Attitude Scale Toward Science as a School Subject Results (post-test)*

Groups	N	$\overline{X}$	Sd	t	p
EG	31	56.83	9.50	1.372	.175
CG	34	54.12	6.03		

Table 4 indicates that there was no significant difference between the post-test mean scores of the two groups of students with respect to their attitudes toward science as a school subject after instruction. However, the post-test mean score of the experimental group was higher than that of the control group. In addition to the pre and post-tests of the control and the experimental groups, their attitude gain scores (EG= 3.83, CG=-.70) were also compared. It was concluded that there was a statistically significant difference between the gain scores of the two groups in favor of the experimental group (t=2.156, p=. 039 ($p<.05$)). This result shows that the method used with the experimental group may have had a positive effect on the student's attitudes toward science.

Discussion and Implications

The present study used both interactive computer animation and teacher and student-prepared concept maps together to investigate the effects on primary school students' understanding of cells and other related concepts. In addition, this study investigated students' attitudes toward science. As a result, the students in the experimental group, taught by interactive computer animation and teacher and student-prepared concept maps, learned about the cell and other related concepts better than those taught traditionally in the control group. Regarding students' attitudes toward science as a school subject, there was no significant difference between the experimental and control groups in the pre and post-test results. However, there was a statistically significant difference between the gain scores of the control group and the experimental group in favor of the experimental group. When the gain scores of the experimental group and the control group were taken into consideration, it was concluded that students in the experimental group had more positive attitudes toward science than those in the control group at the end of the instruction.

The findings in the present study are consistent with those in the literature. Williamson and Abraham (1995) explored the effect of computer animation depicting the particulate nature of matter on college students' mental models of the chemical phenomena, and found that it demonstrated a more positive effect on students' conceptual understanding than traditional instruction. In another study, entitled "A Hypermedia Environment to Explore and Negotiate Student's Conceptions: Animation of Solution Process of Table Salt" carried out with 11th grade students, Ebenezer (2001) reported that animation can be used to explore, negotiate, and assess students' conceptions of the submicroscopic aspects of solution chemistry.

Ardaç and Akaygun (2004) reported in their study that the experimental group instructed by multimedia (including animation) got higher scores both in an achievement test and in molecular presentation than compared to the control group. Chuang (1999) (cited in Gülbahar, 2002) indicated that when voice, written text and animation are employed together, students learn better. Ustuner and Sancar (1999) found that using enriched voice, graphics, and animation, during instruction impacted the students' affective behaviors and helped their cognitive levels.

The present study indicates that computer animation and concept maps positively help students' achievement. For further studies, this method should be compared with other instructional methods by adding new instructional materials such as web-based cognitive tools, analogies, etc. Similar research studies can be conducted for different science topics at the primary school level. The number of participants may be increased for further studies, and the instruction may be carried out with four different groups at the same level. One group may be taught with interactive computer animation, another group with concept mapping, the third with interactive computer animation accompanied by concept mapping, and the last group traditionally. In this way, the effective method, in terms of students' achievement and attitudes, can be identified. Students' misconceptions regarding the cell topic before and after instruction can be examined. In order to develop more positive attitudes, these techniques may need to be used for a considerable length of time. Students' attitudes toward concept mapping and the use of the computer can be investigated. Various data collection instruments such as interviews and open-ended questions can be used together with the achievement tests and attitude scales. Similar research studies can be constructed to test the effectiveness of interactive computer animation accompanied by concept mapping in fostering students' understanding of the cell. Teaching abstract concepts the number of computer-based animations should be increased.

References

Akpınar, E., & Ergin, Ö. (2005). The Role of Science Teacher in Constructivist Theory. *İlköğretim-online*, *4*(2),55-64, (online:http://ilkogretim-online.org.tr). (In Turkish)

Ardac, D., & Akaygün, S. (2004). Effectiveness of Multimedia-Based Instruction That Emphasizes Molecular Representation on Students' Understanding of Chemical Change. *Journal of Research in Science Teaching*, *41* (4), 317-337.

Arnaundin, M. W., Mintzes, J. J.,Dunn, C. S., Sbafer, H. (1984). Concept Mapping in College Science Teaching. *Journal of College Science Teaching*. November, 117-122

Brandt, L., Elen, J.,Helemans, J.,Heerman, L., Couwenberg, I.,Volckaert, L., Morisse, H. (2001). The Impact of Concept Mapping and Visualization on the Learning of Secondary School Chemistry Students. *International Journal of Science Education, 23* (12), 1303-1313.

Campbell, D.T. & Stanley, J.C. (1966). *Experimental and Quasi-Experimental Designs for Research. Chicago*. Rand McNally College Publishing Company.

Cliburn, J.W.Jr. (1990). Concepts Maps to promote meaningful learning. *Journal of College Science Teaching*, *19* (4), 212-217.

Ebenezer, J.V. (2001). A Hypermedia Environment to Explore and Negotiate Students's Conceptions: Animation of Solution Process of Table Salt. *Journal of Science Education and Technology, 10* (1), 73-92.

Francisco, J.S., Nicoll, G., Trautmann, M. (1998). Integrating Multiple Teaching Methods into a General Chemistry Classroom. *Journal of Chemistry Education*, *75* (2), 210-213.

Flores, F., Gallegos, L.(2003). Representation of the Cell and its Processes in High Scholl Students: An Integrated View. *International Journal of Science Education*, *25* (2), 269-289.

Geban, Ö., Ertanpınar, H., Yılmaz, G., Atlan, A., & Şahpaz, F. (1994). *The effect of Computer Assisted Learning on students' Achievement and Attitudes.* The proceedings of First National Science Education Symposium. Buca Faculty of Education. İzmir, Turkey (In Turkish).

Glynn, G.M., Takahashi, T. (1998). Learning from Analogy-Enhanced Science Text. *Journal of Research in Science Teaching, 35* (10), 1129-1149.

Gulbahar, Y. (2002). *Assessment of Web Based Courses: A Discussion and Analysis of Learners' Individual Differences and Teaching- Learning Process*. Unpublished Master Dissertation. Middle East Technical University, Turkey.

Gumustepe, Y. (2003). Animation with Macromedia Flash MX. Istanbul: Türkmen Kitabevi. *(In Turkish).*

Hodson, D., & Hodson, J. (1998). From Constructivism to Social Constructivism: A Vygotskian Perspective on Teaching and Learning Science. *School Science Review*, *79* (289), 33-41.

Horton, P. B., McConney, A. A., Gallo, M., Woods, A. L., Senn, G. J., Hamelin, D. (1993). An Investigation of the Effectiveness of Concept Mapping as an Instructional Tool. *Science Education*, *77* (1), 95-111

Jedeskog, G., Nissen, J. (2004). ICT in the Classroom: Is Doing More İmportant ThanKnowing? *Educational and Informational Technologies*, *9* (1), 37-45

Kılıc, G.B. (2001). Constructivist Science Teaching. Educational Sciences. *Theory & Practice*, *1*, 7-22 (In Turkish)

Martin, R., Sexton, C., Wanger, K., Gerlovich, J. (1998*). Science for All Children: Methods for Constructing Understanding*. Massachusetts: Allyn and Bacon.

Nicoll, G., Francisco, J., Nakhleh, M. (2001). A three-tier System for Assessing Concept Map Links: A Methodological Study. *International Journal of Science Education*, *23* (8), 863-875.

Odom, A.L., Kelly, P.U. (2001). Integrating Concept Mapping and The Learning Cycle to Teach Diffusion and Osmosis Concepts to High School Biology Students. *Science Education, 85*, 615-635.

Orhun, E.(2002). Computer-based Cognitive Tools. In E. Orhun & P.A.M. Kommers (Eds.). Information and Communication Technologies in Education: A Focus of Cognitive Tools. (pp.17-26). Izmir: Ege University Press.

Quinn, C., Wild, M. (1998). Implications of Educational Theory for Design of Instructional Multimedia. *British Journal of Educational Techology, 29* (1), 73-82.

Ruiz-Primo, M. A., Schultz, S. E., Li, M., Shavelson, R. J. (2001). Comparison of the Reliability and Validity of Scores from Two Concept mapping Techniques. *Journal of Research in Science Teaching,* 38 (2), 260-278.

Ruiz-Primo, M. A., Shavelson, R .J. (1996). Problems and Issues in the Use of Concept Maps in Science Assessment. *Journal of Research in Science Teaching,* 33 (6), 569-600.

Sherman, J. S. (2000). *Science and Science Teaching*. New York :Houghton Mifflin Company.

Snead, D., Young, B. (2003). Using Concept Map to Aid African American Students' understanding in Middle Grade Science. *The Journal of Negro Education*, *72* (3), 333-343.

Turkish National Primary Science Program. (2005). Turkish Ministry of Educational Bulletin Board Journal. Retrieved May 5, 2006, from http://ttkb.meb.gov.tr.index1024.htm.

Unal, G. & Akpınar, E. (2004). *To What extent Science Teacher Think Constructivist*? EARLI (European Association for Research on Learning and Instruction)'2004.Bahçeir University, 5-9 July 2004 Istanbul, Turkey.

Ustuner, I. & Sancar, M. (1999). The Effect of Computer Software on Physics Students' Learning and Using computer. *Journal of Buca Faculty*, *10*, 165-171 (In Turkish)

Uzuntiryaki, E .(1998). *Effect of Conceptual Change Approach Accompanied with Concept Mapping on Understanding of Solution*. Unpublished Master Dissertation. Middle East Technical University, Turkey.

Wallace, S. D., Wintzes, J. J. (1990). The Concept Map As a Research Tool: Exploring Conceptual Change in Biology. *Journal of Research in Science Teaching*, *27* (10), 1033-1052.

Willerman, M., Harg, R. A. M. (1991). The Concept Map as an Advance Organizer. *Journal of Research in Science Teaching,* *28* (8), 705-711.

Williamson, V. M., Abraham, M. R. (1995). The Effects of Computer Animation on the Particulate Mental Models of College Chemistry Students. *Journal of Research in Science Teaching, 32* (5), 521-534.

Windsehitl, M & Andre, T. (1998). Using Computer Simulations to Enhance Conceptual Change: The Role of Constructivist Instruction and Student Epistemological Belifs. *Journal of Research In Science Teaching*, 35 (2), 145-160.

Yıldırım, S. (1995). *Effects of Computer Assisted Instruction and Worksheet Study on Students' Chemistry Achievement and Attitudes Toward Chemistry at High School level*. Unpublished Master Dissertation. Middle East Technical University, Turkey.

Appendix A

A Concept Map of an Animal Cell created by a Student (In Turkish)