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The effects of computer-assisted material on students' cognitive levels, misconceptions and attitudes towards science

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Abstract

The purpose of this study was to investigate the effects of a Computer-assisted Instruction Material (CAIM) related to "photosynthesis" topic on student cognitive development, misconceptions and attitudes. The study conducted in 2002–2003 academic year and was carried out in two different classes taught by the same teacher, in which there were fifty two 11th grade high school students, in central city of Trabzon in Turkey. An experimental research design including the photosynthesis achievement test (PAT), the photosynthesis concept test (PCT) and science attitude scale (SAS) was applied at the beginning and at the end of the research as pre-test and post-test. After the treatment, general achievement in PAT increased by 10% in favour of experiment group (EG) at ($p < 0.05$) significant level. Although the increase in cognitive development at knowledge level was 14.8% in the EG and 18.2% in the control group (CG), the development at comprehension and application levels were 19.8–18.5 in the EG and 1.75–0.86 in the CG, respectively. This result showed that using CAIM in teaching photosynthesis topic was very effective for students to reach comprehension and application levels of cognitive domain. However, CAIM did not change major misconceptions related to photosynthesis topic in EG as expected. Meanwhile, same misconceptions in EG about source of energy for plants and their nutrition were decreased more than CG. It was also found out that there was little change about students' attitudes towards science education in both groups.

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1. Introduction

The well-known aim of science education is to teach the science concepts meaningfully and make students become aware of how these concepts can be used in their daily lives. In this process, learning the basic concepts during the primary and secondary education is very crucial in terms of learning the advanced concepts. It was argued that if new concepts were compatible with previous concepts, the meaningful learning would occur (Ausubel, 1968). It is important to know what prior knowledge students bring to a learning environment in order to help them construct new knowledge (Tsai, 2000).

The concepts are not materials, events or creatures but they are units of thought assembled into certain groups. They exist in ideas and only the examples of the concepts are found in the real world (Çepni, Ayas, Johnson, & Turgut, 1997).

Difficult and hardly understandable concepts may be differently structured in students' mind. It is reported that students may have developed ideas about certain events and concepts before any formal instruction in science education (Amir & Tamir, 1994). The students' conceptions, which may not be defined as scientific are named as "misconception", "alternative conception", "naive theories", and "children science" in the literature (Barker & Carr, 1989; Simpson & Arnold, 1982; Treagust, 1988). In the last decade, there have been a number of studies focusing on student misconceptions about photosynthesis at middle and secondary schools (Erdmann, 2001; Hazel & Prosser, 1994).

It has been reported that the "photosynthesis" is one of the most important abstract concepts being difficult in teaching and learning at all levels of schooling (Bahar, Johnstone, & Hansell, 1999; Lawson & Thompson, 1988; Storey, 1989). This topic is taught by starting with primary school levels. It is also perceived by most teachers to be one of the most problematic concepts in the biology (Çapa, 2000; Eisen & Stavy, 1992).

Photosynthesis refers to the process in which the organic matters are synthesized from inorganic sources by using the energy of light (Schraer & Stoltze, 1990). It plays central role in understanding many aspects of living systems. All living things depend indirectly on photosynthesis for their food (Meyer et al., 1985). The energy that is used by all organisms is captured by means of photosynthesis system from the sunlight and it is stored in as carbohydrate in plant tissues (Gözükara, 1989). Even more importantly, an understanding of photosynthesis and respiration is a pre-requisite for any systematic understanding of ecology. Food chains and food web begin with photosynthesis and end in respiration. The photosynthesis and respiration play essential roles in the flow of energy through ecosystems. It is through photosynthesis and respiration that the energy in sunlight is captured and made available to support metabolic processes in all livings (Anderson, Sheldon, & DuBay, 1990). Because of the importance and the difficulty of the subject, science teachers seek for alternative teaching approaches in their teaching.

Once traditional teaching methods are used in teaching science subjects, students understand subject at knowledge level and they usually memorize the science concepts without understanding the real meaning. As a result, they do not conceptualize the science concepts well as intended. Thus, all these factors influence student's attitudes, cognitive development and achievement in science and science education. It is obvious that alternative teaching approaches needed to teach this sort of difficult concepts in science education.

Today's information and communications technologies can be applied to science education. Among these technologies, the use of computers is the most popular and well known in educational settings. Computer-assisted instruction (CAI) plays an important role in contemporary teaching and learning of science concepts (Chang, 2001). Besides, it is evident that for effective use of computers in science classroom, CAIMs need to be developed. Computers can be used as a supplementary tool in order to reach to educational goals (Bayraktar, 2000).

Many science teachers, researchers and other educators have recommended using CAIM in science classrooms. Some researchers argued that student achievement increases with the use of computers in science education (Chang, 2001; Coye & Stonebraker, 1994; Ferguson & Chapmen, 1993; Lee, 2001; Powell, Aeby, & Carpenter-Aebyc, 2003; Rowe & Gregor, 1999; Tjaden & Martin, 1995; Tsai & Chou, 2002). In addition, it is reported that student abilities and skills in scientific investigations are affected positively by CAI (Bayraktar, 2000; Shute & Bonar, 1986). Moreover, it is also stated that the use of computers makes students feel confident and helps them to discover interactions among the components of a complex system (Ramjus, 1990).

On the other hand, some researchers advocate that the traditional learning method is more useful than CAI in science teaching (Morrell, 1992; Wainwright, 1989). They argued that the use of computers negatively influences the students' attitudes and achievement in the teaching learning process. Other researchers did not find an important difference between the methods (Coye & Stonebraker, 1994; Tjaden & Martin, 1995).

It was reported that CAI has some advantages in developing students' abilities on making synthesis and evaluation (Baki, 2000). If CAI materials are developed and implemented in an effective way, student's achievement and affinity increases in science lessons (Lee, 2001; Şahin & Yıldırım, 1999).

1.1. Study of context

Using computer materials in teaching and learning science began in the 1980s in Turkey. Although computers were initially used in administrative works of schools, later they were increasingly utilized in science education as the qualified software and hardware became available. The Ministry of National Education and The World Bank signed an agreement to increase the quality of education in every level of Turkish schools in 1990. Many Curriculum Laboratory Schools equipped with laboratory materials were opened in this term (Çetinkaya et al., 1999). Since then most of the schools in urban areas have computers and the rest of them see computers as valuable tools in education and have been setting up computer laboratories in their schools.

Teachers play an important role in the use of computers in classrooms (Baki, 2000). It is for this reason that, the Turkish Ministry of National Education has been trying to train teachers in using computers in their teaching, by providing intensive in-service training courses. In conjunction with this, all faculties of education in Turkey have been providing computer courses for student teachers during their pre-service training period regardless of their disciplines since 1998 (YÖK, 1998).

Three aims of using computers in science education in Turkey were noted (Türkmen, 2000). Students should be able to

- use computers and have knowledge about the using area,
- become computer literate,
- support lessons with CAIMs.

Because of the availability of qualified hardware and software, the use of ICT has considerably increased in the teaching–learning process of science education in many parts of the world including Turkey (Bayraktar, 2000). Although there have been many CAIMs prepared for photosynthesis, we believe that there have been little research on how CAIMs influence students' cognitive development, attitudes and misconceptions.

2. Purpose

The purpose of this study was to assess the effects of the CAIM (developed for the unit of photosynthesis) on students' misconceptions, cognitive learning levels and attitudes towards science.

3. Material and method

3.1. Computer software

The steps below were followed during the development process of CAIM:

- The content analysis of photosynthesis at high school level was made with science teachers, biologists at the university and science educators at the faculty of education.
- A detailed plan of the topic was done by taking into account difficult concepts in terms of learning and misconceptions about photosynthesis through reviewing the current literature and the researchers' experiences.
- The presentation of the material was made by using PowerPoint, Photoshop 6.0 and Paint shop pro 7.

In addition in preparing the CAIM, the main concepts in "photosynthesis" topic, connections with other subjects and the behavioral objectives in the biology curriculum were taken into consideration.

3.2. Sample

The sample of this study consisted of five experienced science teachers and 52 students from two high schools. To check the quality and functions of the developed materials, in-depth interviews were carried out with the participant teachers. The sample was randomly assigned into two groups, experiment ($n = 26$) and control groups ($n = 26$). While the experiment group was taught with CAIM, the other group continued their instructions with the regular teaching method.

3.3. Data collection instruments

The photosynthesis achievement test, the photosynthesis concept test and the biology attitude scale were used in the study.

3.4. Photosynthesis achievement test

To measure students' photosynthesis achievement, a photosynthesis achievement test (PAT) was developed by the authors of this study and its content validity and reliability were checked as guided by other researchers (Black, 1986; Davis, 1988; Linn & Gronlund, 1995). The PAT aimed at investigating students' levels of understanding photosynthesis concepts. The PAT items were selected from the textbooks and preparation books written for the University Entrance Examination consisting of 25-item multiple choices tests (including 5 items at the knowledge level, 11 at the comprehension level, and 9 at the application level). The knowledge levels of these items were arranged according to the levels of behavioral objectives in the Biology Curriculum (M.E.B., 1998). Subsequently, these items were grouped into the three levels of the cognitive domain (knowledge, comprehension, and application) of Bloom's taxonomy. *Knowledge* items involve recalls or recognition of ideas or concepts; *comprehension* items emphasize on student understanding of ideas or concepts; *application* items require students to apply the acquired knowledge or application of knowledge on new situation (Colletta & Chiappetta, 1989). Sample questions are given below. The reliability of the test ($r = 0.81$) was determined by using Spearman's rank order correlation formula.

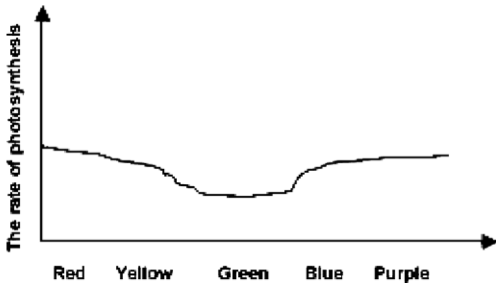
Sample questions?

Knowledge level	
What type of energy convert into solar energy by Plants?	Which does not happen during the photosynthesis in the electron transport system?
(a) Electric energy	(a) The electrons coming from hydrogen are captured by ferredoxin
(b) Chemical bound energy	(b) Chlorophyll is neutralized
(c) Movement energy	(c) NADP in the system is transported to electron and proton
(d) Heat energy	(d) The proton of the hydrogen is captured
(e) Light energy	(e) Oxygen is neutralized
Comprehension level	
Which of the following increase steadily with the rate of photosynthesis?	Which of the following statements is true for the case of photosynthesis reaction and its last product?

(a) Light intensity
(b) The number of chloroplast
(c) Water amount
(d) CO_2 density
(e) Temperature

	Cyclic photophosphorylation	Non-cyclic photophosphorylation	Dark reactions
(a)	O_2	CO_2	Glucose
(b)	ATP	O_2	$NADPH_2$
(c)	ATP	$NADPH_2$	Glucose
(d)	NADP	ATP	ATP
(e)	ATP	CO_2	NADPH

Application level



The above graph shows relationships between the rate of photosynthesis and light color in green plants. According to the above graph, if the world exposure only green light, what could happen?
(a) The number of animals could decrease in the world
(b) In plants, metabolism could stop
(c) Photosynthesis would completely stop
(d) The sugar amount synthesized by plants could increase
(e) The Oxygen amount released to atmosphere would increase

3.5. Photosynthesis concept test

A written test was designed to ascertain students' misconceptions about photosynthesis. The test contained 13 questions, including both open-ended and multiple-choice items. The photosynthesis concept test (PCT) was modified on the basis of review of related literature (Anderson et al., 1990). Three questions were added to the test by means of the obtained interview data.

The test is divided into two parts. In the first part, there are two main concepts about photosynthesis; respiration and food. In the second part, we sought to underline conceptual difficulties concerning students' understanding of how plants and animals use substance and energy. In addition, students were asked to explain their conception on the relationship between photosynthesis and respiration. Students were also asked to explain why plants are called as producers.

3.6. Science attitude scale

Cerrah's (2002) attitudes scale was adapted as science attitude scale (SAS) in this study to assess the sample's (participants') attitudes towards science lessons. The scale comprises of two parts: In the first part, five questions were asked students to determine their ideas about biology lesson. The second part comprises 18 sentences occurring in a Likert-type scale and with four alternatives. In these sentences there are positive and negative statements. In the scale, positive statements were scored as 1, 2, 3, 4, according to its grade. Negative statements were scored as 1, 2, 3, 4 according to its grade. SAS was given at the beginning and end of the implementation to the two groups. For the analysis of data, following scale was taken into consideration:

- 0.5–1.49 points: negative attitude
- 1.50–2.49 points: more or less positive attitude
- 2.50–3.0 points: a positive attitude

3.7. Procedure

This study was conducted during the fall semester of 2002–2003 academic year at a high school in Trabzon for four-weeks. An experimental research design including PAT, PCT and SAS were applied at the beginning and end of the research as pre-test and post-test measures. The material was introduced by the researchers to the science teacher before the treatment. In teaching process, CAIM was presented students via data-show by the teacher, and then the students had opportunity to work on the same program in the groups. Educational activities in CAIM were organized around observing figures, graphs, awarding and providing animation, solving problems rather than reading long boring scientific knowledge or oral explanation done by the teacher. As mentioned earlier the control group was given traditionally designed instruction (teacher-centered method), which is a dominant approach in contemporary Turkish Educational System.

3.8. Data analysis

In order to compare the differences between control and experiment groups for the PAT and SAS, the independent *t*-test was applied.

4. Results

4.1. Students' achievement

As seen in Table 1, at the beginning the pre-test means of EG and CG was 51.55 and 50.46, respectively. These results showed that the sample's present knowledge levels were very close to each

Table 1
Means, standard deviation, *t* value in PAT

Tests	Groups	Numbers of students	Means	Standard deviation	*t*-test
Pre-test	EG	26	51.55	15.19	0.31
	CG	26	50.46	9.73	
Post-test	EG	26	70.81	18.68	2.27
	CG	26	59.69	15.68	

other and there was not a statistical difference between the groups ($t = 0.31, p > 0.05$). At the end of the treatment, the post-test scores were 70.81 and 59.69 for two groups (approximately 10% change occurred at EC). A statistical significant difference was found between EG and CG ($t = 2.27$, $p < 0.05$). This means that CAIM was more effective at science achievement in EG than CG.

4.2. Students' attitudes

The means related to science attitude of the two groups before the treatment were 1.70 and 1.79, and there was not statistical significant difference between the two groups ($t = 0.04, p > 0.05$). The post-test scores were 2.09 and 2.64 after the treatment and there was a statistical difference between EC and CG ($t = 2.21, p < 0.05$) (Table 2). These results illustrate that the developed CAIM influences students' attitudes towards science lessons in a positive way. However, expected attitude changes have not occurred in EG.

4.3. Cognitive developments

As seen in the Table 3, the achievement percent on knowledge, comprehension and application level in EG was 14.8, 19.8 and 18.5 after the treatment. In the CG, this variation for knowledge, comprehension and application level was 18.2, 1.75 and 0.86, respectively. This shows that the CAIM is quite influential on students' higher cognitive levels of learning compare to CG in which the majority of the students reach only knowledge level.

4.4. Misconceptions

Before the implementation, we looked at percentages for each question in the pre-test. There was not much difference between the groups in terms of their prior knowledge and misconceptions. For example, the first question as percent in experimental and control groups are 77% and 81% for misconceptions, respectively. After the implementation, some of the related concepts are examined in detail.

4.4.1. Misconceptions about photosynthesis

The students' responses indicated that they held misconceptions about photosynthesis in 1a, b and c (Table 4): 15%, 54% and 8%, respectively, in the experiment group and 29%, 37% and 15%, respectively, in the control group. After the treatment, the students' responses indicated that their

Table 2
Means, standard deviation, t value in SAS

Tests	Groups	Numbers of students	Means	Standard deviation	t-test
Pre-test	EG	26	1.70	0.17	0.04
	CG	26	1.79	0.18	
Post-test	EG	26	2.09	0.29	2.21
	CG	26	2.64	0.18	

Table 3
The effects on cognitive levels of CAIM and traditional teaching approach

Cognitive levels	Questions	Pre-test (%)		Post-test (%)		Differences (%)		Average differences (%)	
		EG	CG	EG	CG	EG	CG	EG	CG
Knowledge	1	88	92	92	100	4	8	**14.8**	**18.2**
	2	30	48	63	22	33	26		
	3	52	41	70	48	18	7		
	4	59	81	70	81	11	0		
	5	59	30	67	80	8	50		
Comprehension	6	41	56	37	56	−4	0	**19.8**	**1.75**
	7	63	88	81	59	18	−21		
	8	67	48	81	42	14	6		
	9	30	70	74	70	44	0		
	10	48	59	63	63	15	4		
	11	78	48	74	59	−4	11		
	12	22	56	52	70	30	14		
	13	30	22	81	22	51	0		
	14	44	59	59	59	15	0		
	15	56	63	63	63	7	0		
	16	44	67	52	74	26	7		
	17	70	67	96	67	26	0		
Application	18	74	67	70	70	−4	3	**18.5**	**0.86**
	19	70	70	96	70	26	0		
	20	56	41	63	41	7	0		
	21	33	63	56	67	23	4		
	22	52	59	52	63	0	4		
	23	33	30	67	22	34	−8		
	24	48	56	85	56	37	0		
	25	78	41	85	44	7	3		

misconception decreased to 8%, 15% and 0% in the experiment group, and 23%, 29% and 11% in the control group.

4.4.2. Misconceptions concerning sources of energy for plants

The results in Table 4 showed that students had a misconception that “plants get their energy from water, air, soil, fertilizer, worms and insects”. The rate of misconceptions is about 100% in both groups. After the treatment, the rate of misconception decreased to 19% in the experimental group and 71% in the control group.

4.4.3. Misconceptions related to photosynthesis and respiration in plants

The misconceptions were grouped into two categories as 7a and b in Table 4. The pre-test results showed that students had misconception at the rate of 46% and 27% in the experiment group and 37% and 26% in the control group. After treatment, the rate of misconceptions decreased to 15% and 4% in the experiment group; 29% and 15% in the control group, respectively. After the implementation, some of the related concepts are examined in detail.

Table 4
Results of pre and post-test concerning misconceptions

Categories and misconceptions	Pre-test		Post-test	
	EG (%)	CG (%)	EG (%)	CG (%)
1. Photosynthesis				
a. Green plants make photosynthesisto produce energy	15	29	8	23
b. Photosynthesis is only a gas exchange event	54	37	15	29
c. Photosynthesis is the conversion of sunlight into food	8	15	0	11
2. Respiration in plants				
a. Photosynthesis is the respiration of plants	34	19	8	11
b. Respiration occurs in the lungs and is solely the process of gas exchange	12	15	0	11
c. Animals breathe in O_2 and breathe CO_2, while plants breathe in CO_2 and breathe O_2	35	37	31	26
3. Food for a plant				
Plants' food is water, sunlight, air, fertilizer, and inorganic minerals	73	89	12	56
4. Nutrition of plants				
Plants get their food from the soil through their roots	96	92	19	71
5. Sources of energy for plants				
Plants get their energy from water, air, soil, worms, insects, and fertilizer	100	97	19	71
6. Sources of energy for humans				
Humans get their energy from air, water, sun, and exercise	77	85	12	56
7. Relationship between photosynthesis and respiration in plants				
a. Photosynthesis and respiration are function in an opposite and contrasting manner	46	37	15	29
b. Both processes are solely the kind of gases exchange	27	26	4	15
8. Autotrophy				
a. Plants are called as producers since they give fruits and vegetables to humans	19	29	0	26
b. Plants are called as producers since they are food and oxygen sources for the other organisms	31	42	0	29
9. Chemical reaction for photosynthesis				
a. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ + Energy	15	26	0	18
b. $6CO_2 + 6H_2O$ + Energy $\rightarrow C_6H_{12}O_6 + 6O_2$	12	8	4	8
c. $CO_2 \rightarrow O_2$ + Glucose	4	3	0	3
10. Chemical reaction for respiration				
a. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	19	15	0	8
b. O_2 + Food + Energy $\rightarrow CO_2 + H_2 O$	12	8	4	3
c. Glucose + $O_2 \rightarrow CO_2$ + Energy	4	3	0	3

5. Discussion and conclusions

Many researchers argued in their investigations (or experiments) that CAIM is more influential than traditional teaching approaches on student's academic achievement (Bayraktar, 2000; Chang, 2001; Coye & Stonebraker, 1994; Ferguson & Chapmen, 1993; Lee, 2001; Powell et al., 2003; Tjaden & Martin, 1995; Tsai & Chou, 2002). The findings of this study concerning the effects on students' achievement are consistent with the ideas of the above authors. It was revealed in the study that the EG at science achievement was more successful than the CG after the treatment (see Table 1). However, in regard to students' cognitive developments there were some differences between the studied groups. The data obtained from PAT illustrated that, traditional teaching approach had positive effect on knowledge level in the CG. In addition, CAIM was quite influential on both the comprehension and application level of cognitive domain in the EG. According to Chang (2001), CAIMs provide achievement both on students' knowledge and comprehension levels of Bloom's cognitive domain. Tjaden and Martin (1995) stated that CAIMs were not a significant difference in the higher-level achievement test items of students between the experimental group and the control group. It was an interesting result to the authors that the traditional teaching approach was more effective on knowledge level than CAIM (see Table 3 and Fig. 1). From this perspective, the material may be seen insufficient on knowledge level. However, Ausubel's argument on this issue supports this result as he reported that people could learn quite theoretical knowledge by means of traditional teaching approaches in a short time (Ausubel, 1968). This study showed that students gained only theoretical knowledge in an environment where traditional teaching methods take place. After all, an achievement in science shows differences among students depending upon several other variables such as social-economic condition, student quality and teacher experiences (Soyibo & Hudson, 2000).

In preparing CAIM, learning activities and assessment questions should be prepared at upper cognitive levels. In teaching process, students should not be motivated to read and memorize scientific knowledge but, they try to be constructed concepts by interacting learning materials repeatedly. At the end, all the gains should be discussed in a group activity approach.

Many studies have been implemented about the influences of computer based instructions on students attitudes are not agree whether it makes positive changes in attitudes towards science

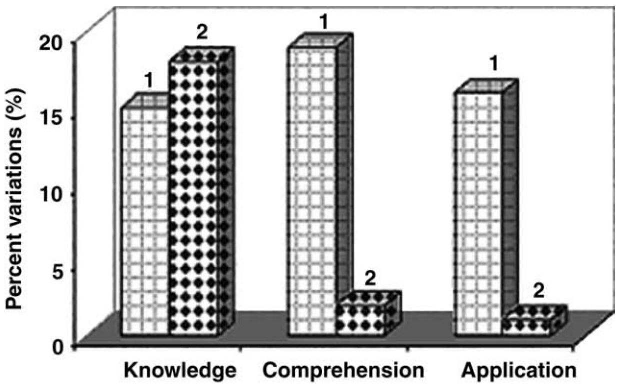


Fig. 1. The effects on cognitive levels of CAIM and traditional teaching approach (1: The experimental group, 2: The control group).

and science lessons. (Francisa, Katzb, Susan, & Jonesc, 2000; Mitra, 1998). For example, Selwyn (1999) and Ertepınar, Demircioğlu, Geban, and Yavuz (1998) reported that CAIM develops a positive attitude towards science education. In contrast to this Shaw and Marlow (1999) said that CAIM do not show a positive effect on students' attitudes. Besides, students' attitudes towards science are quite negative if traditional teaching methods are used in science classes (Colletta & Chiappetta, 1989). In this study, however, the CAIM did not change students' attitudes towards science lessons as much as expected (see Table 2). Similar results were also found for CG.

Misconceptions are very important during the learning processes of individuals. It is well known that it is not easy to eliminate misconceptions by just employing traditional instructional methods. One of the alternative ways of overcoming this problem is to develop and use CAIMs in science classrooms. In this study, CAIM provided a significant contribution for students to understand photosynthesis without having many misconceptions in the EG (Table 4). However, the current study revealed that there were still some misconceptions in the experiment group even after the treatment. These misconceptions were generally related to the abstract concepts as energy sources for plants and their nutrients and thus to visualize and conceptualize them is difficult for students. This shows that misconceptions may be reduced and/or dismissed if teaching–learning activities are given at comprehension and application levels (Karamustafaoğlu, Sevim, Mustafaoğlu, & Çepni, 2003). Therefore, educational materials for CAIM should be prepared at least comprehension and application levels of cognitive domain. Reducing misconceptions are also depended on the teaching approaches of these materials. We believed that one way of the reducing students' misconceptions is to interact with CAIM not individually, but with a group work.

Selwyn (1999) and Ertepınar et al. (1998) reported that CAIM develops a positive attitude towards science education. In contrast to this Shaw and Marlow (1999) said that CAIM do not show a positive effect on students' attitudes. Besides, students' attitudes towards science are quite negative if traditional teaching methods are used in science classes (Colletta & Chiappetta, 1989). In this study, however, the CAIM did not change students' attitudes towards science lessons as much as expected (see Table 2). It can be concluded that CAIM could improve student achievement, change misconceptions, improve cognitive levels, but it is very difficult to change students' attitude toward science lessons in a short time.

CAIMs should be prepared in a manner that it should be suitable for both group working and individually. The fallowing factors also usually effect students' attitudes towards science lessons. These are; the levels of students' families awareness about technology and technological developments, families and teachers' encouragements using CAIM, and consistency with the main principles (learning theories) of science education. (Shashaani & K, A., 2001)

It can be concluded that CAIM could improve student achievement, some extent change misconceptions, improve cognitive levels, but it is very difficult to argue that it can change students' attitude toward science lessons in a short time.

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