The Effects of Computer Animations and Cooperative Learning Methods in Micro, Macro and Symbolic Level Learning of States of Matter

Kemal Doymuş*
Ümit Şimşek**
Ataman Karaçöp***

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Abstract

Problem Statement: In chemistry education, most first-year undergraduates experience difficulties understanding three related meanings of topics: the macroscopic meaning, the microscopic meaning, and the symbolic meaning. The present study deals with the multiple (macro, micro, and symbolic) meanings of topics in the states of matter in college chemistry.

Purpose of Study: This study investigated the effects of computer animations and cooperative learning on students' comprehension of chemistry topics at the macro, micro, and symbolic levels.

Method: The subjects of the present study comprised 64 university students enrolled in three classes of the general chemistry course taught in the first year of the elementary education science teacher program during the 2006–2007 academic year. One of the classes was used as the cooperative group, the second class was used as the animation group, and the third class served as the control group. Three dependent variables were measured: micro level meaning, non-micro level (macro and symbolic) meaning and students of varying reasoning abilities. Understanding of the micro level was determined by a States of Matter Test (SMT). Understanding of the non-micro level (macro and symbolic) was determined by a Course Exam

* Corresponding Author. Assoc. Prof. Dr., Atatürk University Kazım Karabekir Faculty of Education, kdoymus@atauni.edu.tr

** PhD, Atatürk University Kazım Karabekir Faculty of Education, simsekum@atauni.edu.tr

*** Atatürk University Kazım Karabekir Faculty of Education, akaracop@atauni.edu.tr

(CE). Students' varying reasoning abilities were determined by a Test of Logical Thinking (TOLT).

Findings and Results: A one-way analysis of variance (ANOVA) found no significant differences in the TOLT scores of the control, animation, and cooperative groups. Results showed significant differences in the SMT scores by treatment even when the effects of the TOLT scores were removed. The control group had SMT scores that were significantly different from those of the animation and cooperative groups, while the scores of the two experimental groups did not differ significantly. In addition, no differences were found in terms of understanding at the non-micro level (macro and symbolic). Furthermore, for micro level meanings depicted in this study, the maximum effects were achieved with both computer animations and cooperative learning methods.

Conclusions and Recommendations: This study demonstrated that cooperative learning methods used in small groups helped students understand the states of matter at the micro level and develop cognitive models. Consequently, when correct and suitable learning methods are used, we think that it is more likely that the sources of misunderstanding will be remedied, while at the same time micro level understanding will improve.

Keywords: Computer animation, cooperative learning, micro level, state of matter

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In general science and chemistry education, three levels of understanding have been identified (Johnstone, 1991; Gabel, 1993): (1) the macroscopic level, that is, the meanings of topics are expressed in terms of phenomena, substances, energy, and so on; (2) the microscopic (sometimes called submicroscopic) level, that is, the meanings of topics are expressed in terms of molecules, atoms, ions, and so on; and (3) the symbolic level, that is, the meanings of topics are expressed in terms of formulae, equations, ionic drawings, and so on.

The present study deals with the multiple [micro and non-micro (macro and symbolic)] meanings of topics in the states of matter in college chemistry. College chemistry students have experience going from the macro meaning to the micro meaning and back to the macro, using formula, atomic symbols, and so on. For them, the formula H_2O refers to the substance of water as well as to a single molecule of water. Their mental switching between macro and micro aspects of science curriculum topics is conducted easily and almost automatically (Johnstone, 1993). However, students often experience difficulties understanding the multiple meanings of chemistry topics. For example, they have to learn to consider the phase changes of substances, but they also have to learn the microscopic meaning in terms of the rearrangement of particles, and the symbolic representation in terms of chemical equations (words, iconic drawings, formulae). For them, the conceptual demands of shifting between the three meaning domains can be overwhelming.

Their difficulties in understanding macro-micro meanings—for instance, explaining observations of phenomena in terms of interactions between particles—have been reported in several studies (Benson, Wittrock, & Bauer, 1993; Treagust, Chittleborough, & Mamiala, 2003). Students also appear to experience difficulties understanding symbolic representations; for instance, they handle symbols as algebraic entities without clear interpretations from a macro-micro perspective (Ben-Zvi, Eylon, & Silberstein, 1988; Friedel & Maloney, 1992). As learning to link phenomena with particles and symbolic representations constitutes one of the most important objectives of science education, chemistry students need to develop the ability to teach the macro, micro, and symbolic issue. We assume that students, being educated as chemists, have developed the habit of discussing multiple meanings in a flexible and implicit manner. As a consequence, students encounter difficulties when learning topics at a macro-micro-symbolic interface. To eliminate difficulties in understanding the multiple meanings of general chemistry topics, new educational methods have developed as alternatives to teacher-centered lecturing, such as animation, hands-on and cooperative learning, and inquiry-based and student-centered instruction.

Animation models are useful for teaching chemistry, general science, physics and biology at the micro level. Two-dimensional animated computer models show the dynamic characteristic of chemistry (Sanger, Phelps, & Fienhold, 2000; Ebenezer, 2001). Animated models in three dimensions can be rotated and used to teach spatial relationships (Barnea, & Dori, 1996; Fleming, Hart, & Savage, 2000). Animations are also effective aids for teaching micro and non-micro meanings that involve motion at the molecular level (Gilbert, 2005). An animation is considered three dimensional if it has foreshortened lines, overlapping lines, differences in the relative sizes of objects, and distortion of angles (Shubbar, 1990). Animation models can be viewed by students at a computer terminal, on their own time and as many times as desired, or in the classroom by projection (Theall, 2003). When learning with molecular level representations, students construct mental models based on their observations that are personal, qualitative, and often incomplete, because they often do not understand the underlying concepts that the model represents (Greca, & Moreira, 2000).

Students must learn to navigate model types to solve problems like chemists do (Barnea, & Dori, 1996). Studies show that students who use a combination of model types representing the same concept have a better understanding of molecular level chemistry (Wu, Krajcik, & Soloway, 2001). Sanger and Badger (2001) found that students who viewed electron plots and animations as a supplement to the traditional wooden molecular model kits and demonstrations to learn about molecular polarity and miscibility responded correctly more often on hourly exams than did students who did not view the electron plots and animations. In addition to the availability of computer models, simulations have been created that mimic reactions or systems in areas of science that are too dangerous or costly for students to study otherwise (Yair, Mintz, & Litvak, 2001). Moreover, several chemistry education researchers have demonstrated that computer animations can help students think about chemical processes on the molecular level (Williamson, & Abraham, 1995).

Cooperative learning can be defined as a learning method where students combine in small mixed groups and help each other for a common academic aim, boost each other's self-esteem, develop communication abilities, increase problem solving and critical thinking abilities, and take an active part in learning (Eilks, 2005; Gillies, 2006; Hennessy & Evans, 2006; Lin, 2006). Cooperative learning, which is more efficient than other instructional methods, is widely used in education (Siegel, 2005). In recent years, it has become a strong alternative to the standard education strategies used in high schools and universities. The reason for its popularity is the fact that it gives students the chance to learn from each other's different approaches and decisions by cooperating according to the strategies and problem-solving techniques that are used (Bearison, Magzomes, & Filardo, 1986).

Studies related to cooperative learning in chemistry education show that, on average, using aspects of cooperative learning can enhance chemistry achievement for high school and college students. Based on the results of these studies, it is strongly recommended that chemistry instructors continue incorporating cooperative learning practices into their classes (Bowen, 2000; Doymus, 2008). For cooperative learning to be successful, students should be grouped carefully. In these groups, there should be students from different academic levels and different ethnicities with different learning habits (Maloof, & White, 2005).

One study stated that the topic "states of matter", one of the basic and most important subjects of a general chemistry course, could not be learned completely at macro and symbolic level, and that a complete learning of this subject was possible through micro-level learning rather than through macro and symbolic level learning (Yezierski, & Birk, 2006). To promote change in students' comprehension of chemistry topics at the micro level, researchers have implemented such teaching pedagogies as inquiry-based learning, cooperative learning, discrepant events, (social) constructivism, analogies, concrete models and visual tools/multiple representations. In recent years, using visual tools such as static or computer animated molecular models accompanied with oral and written discourse has gained prominence and was acknowledged to be promising in the construction of scientific conceptions (Adadan, 2006).

The purpose of this study was to investigate the effects of computer animations and cooperative learning on students' comprehension of chemistry topics (states of matter) at macro, micro, and symbolic levels. Specifically, the effects of animation (dynamic, two- and three-dimensional graphic representation) and cooperative learning on the comprehension of states of matter are examined at macro, micro, and symbolic levels. Differences in effects upon students of varying reasoning abilities are explored. The specific research question is:

Does instruction using traditional teaching, cooperative learning and computer animation create differences in students' comprehension of multiple meanings of the states of matter (macro and symbolic and micro levels)?

Method

Research Design

The experimental design for this study is a posttest-only control group designed for multiple meaning. This experimental design was chosen to eliminate any interaction that could occur between a pretest and the treatment for achievement. Although elimination of the pretest makes it impossible to show statistically that the groups are equal with respect to prior knowledge, it was important to avoid the experimental contamination that could have occurred from interaction between the pretest and the treatment. However, in the absence of a pretest, randomization should provide sufficient assurance that the groups lacked initial bias (Creswell, 2003).

Sample

The subjects of the present study comprised 64 university students enrolled in three classes of the general chemistry course taught in the first year of the elementary education science teacher education program during the 2006–2007 academic year. One class was randomly selected as the cooperative group (n=23: 9 female, 14 male), in which the cooperative learning method was applied. A second class was randomly selected as the computer animation group (n= 21: 8 female, 13 male), in which the computer animation technique was applied. The remaining class served as the control group (n=20: 8 female, 12 male), in which traditional teaching methods were applied. Pre-service science teachers are admitted to this department only after they have successfully passed a university entrance exam. The mean age of the participants was 19.47 (SD=1.44). Neither age nor gender differed significantly among the groups. Ages ranged from 18 to 23 years. Volunteers were given background information regarding the study prior to consent. During the training period, instruction for all groups was delivered by the researchers.

Instruments

Three dependent variables were measured: micro level meaning, non-micro level (macro and symbolic) meaning and students of varying reasoning abilities. Understanding at the micro level was determined by a States of Matter Test (SMT). Understanding at the non-micro level (macro and symbolic) was determined by a Course Exam (CE). Students' varying reasoning abilities were determined by a Test of Logical Thinking (TOLT).

The SMT is an instrument that requires students to make drawings, give explanations, and select the correct responses to multiple-choice questions. The categories of responses for the SMT were established by a panel of experts. Responses given in terms of molecules, atoms, ions and so on are classified as showing micro level understanding. Responses that repeat the question or are irrelevant or unclear are classified as showing no understanding. These responses were not taken into consideration for this study. The criteria and scale used in this study were developed by adapting the scale used for misconceptions by Haidar and Abraham (1991). For statistical analysis, numeric scores of '1' were assigned to satisfactory micro level responses and '0' to all other categories of responses. This test was developed by the author and three chemistry teachers. The validity of the test was checked by a professor and two other chemistry teachers. The SMT was divided into five modules. Each module consisted of three questions (two open-ended, one multiple choice). This test gave continuous scale scores ranging from 0 to 15. A panel expert established the content validity, while the percent agreement for multiple graders on papers randomly chosen established the inter-rater reliability. The percentage agreement of the SMT was established at 77% or higher.

The CE had fifteen multiple-choice questions on states of matter, with each question worth five points. The CE was developed by the author and two chemistry teachers, and piloted with undergraduates from two college chemistry classes. Item analyses were performed for each question and confusing or vague questions were rewritten before the test was used in the study. After item analysis, nothing was changed in the scale so as not to violate its content validity. The CE was administered to students who had seen the relevant unit before to determine its reliability; the reliability co-efficiency (Cronbach Alpha) was found to be 0.69. Also for the validity of the developed CE, opinions of chemistry lecturers and researchers on the subject were taken into consideration. Researchers pointed out that the gains of the CE related to the subject of the states of matter have been high towards measurement.

The TOLT was used to identify potential differences in the cognitive skills of students and to control for this extraneous effect if it were influential on their learning. The TOLT, developed by Tobin and Capie (1981), is used to determine the formal reasoning ability of students. The test contains 10 items, eight two-tier multiple choice questions and two open-ended items. This test gives continuous scale scores ranging from 0 to 10. The internal reliability for this test is reported as 0.85 (Harwood, & McMahon, 1997). Tobin and Capie report a strong correlation of 0.80 between scores on the TOLT and formal reasoning skills, namely, controlling variables, and proportional, combinatorial, probabilistic, and correlation reasoning. The TOLT used for this study was translated into Turkish. The appropriateness of the questions to the Turkish language in terms of expression and meaning was analyzed by two instructors from the Turkish Language Teaching Department of Atatürk University Kazım Karabekir Education Faculty and the suggested corrections were made by the researcher. Consistency between the adapted and original versions was checked by two instructors at the Language Center of Atatürk University; these necessary revisions were made as well. The validity analysis, which aimed to find out whether the scale measured the targeted skills, was carried out by three experts from the departments of Elementary Mathematics Education and Elementary Sciences Education. Based on recommendations from these experts, two open-ended questions were extracted from the scale. Therefore, eight items of the original TOLT were used. This test gives continuous scale scores ranging from 0 to 8. The TOLT was administered to students who had seen the relevant unit before to determine its reliability. The reliability co-efficiency (Cronbach Alpha) was found to be 0.72. Examples of TOLT, SMT and CE questions are given in the appendix.

Animations

For students to understand the state of matter of a substance, it can be useful to use animations showing the intermolecular and intramolecular bonds that make up a chemical compound and the molecules of these compounds. For this reason, three main categories of animations were used in lectures during the teaching of states of matter. The animations used are summarized in Table 1.

Table 1

Animations Used in the State of Matter Instruction

Animation	Topic Shown	Length
Category 1	Molecular structure of chemical compounds	2 minutes
Category 2	Intermolecular and intramolecular bonds	2 minutes
Category 3	Matter phase and state change	2.5 minutes

Category 1 animations were prepared to demonstrate and teach the molecular structure of a chemical compound at the micro level. Category 2 animations were prepared to demonstrate and teach intermolecular and intramolecular bonds at the molecular level. Category 3 animations were prepared to demonstrate and teach states of matter. One example of a category 3 animation is given in Figure 1.

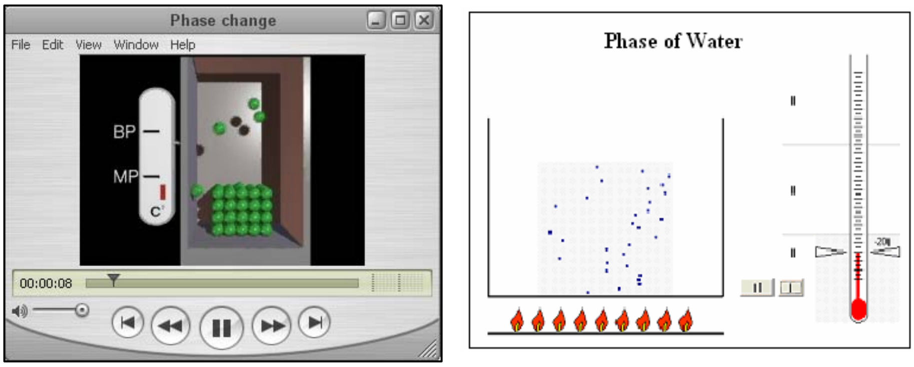

Figure 1. Snapshots of animations representing two different phase changes
http://mutuslab.cs.uwindsor.ca/schurko/animations/waterphases/status_water.htm

Procedure

The cooperative class was divided into five heterogeneous groups: two groups of four students and three groups of five students. Before the beginning of the instruction, the teacher gave information about learning objectives, the instruction process, rules for working in a cooperative group, group member roles, and assessment strategies (Johnson & Johnson, 1999). Students in the groups were encouraged to decide who would be the leader. Later, the heads of the groups were determined by the group members. The subject of related states of matter was presented to the group members by the group heads. Each group studied their subject out of and in class. All activities were completed by students under the guidance of the teacher. While students were discussing in their small groups, the teacher visited all the groups and asked guiding questions to lead students in appropriate directions. All the cooperative groups prepared their own reports after the activities were completed. Each group was given 40 minutes to present their work in the classroom and 10 minutes for discussion with the class. During this discussion, the group answered questions from the class. All groups completed their topics in three weeks.

In the animation group, the researcher spent the first five minutes of the lesson asking questions of the class to determine their previous knowledge on the subject. Later, the subject was taught and the related animations were shown to the class over a period of 35 minutes. The animations were shown by projecting them onto a board, using a projection device compatible with computers. After the presentation of the animations, questions related to the subject were asked by the teacher for 10 minutes. Parts of the subject poorly understood were determined from the answers. These parts were covered again, using the animations.

In the control group, the subject was taught using traditional instructional methods. The researcher planned activities for the presentation of the subject that would be taught during the lesson. This was done not through classical teaching presentation style but by giving assignments to students on the subject of states of matter, and by providing workbooks for students to use to construct the information to be presented to them. The same content was taught in the animation and cooperative group and the learning objectives were the same. In contrast with the experimental groups, students in the control group were required to use their textbooks; students were passive participants and rarely asked questions; they did not benefit from the library or Internet sources; activities such as computer animations or brainstorming were not used. Instead, generally the teacher wrote concepts on the board and then explained them; students listened and took notes as the teacher lectured on the content. During this process, students' performances were observed and instruction was directed according to their feedback. The author taught states of matter to the treatment groups for three hours per week for three weeks. The TOLT, SMT, and CE were given to the treatment groups at the end of the study.

Data analysis

One-way analyses of covariance (ANCOVA) tests were used to analyze differences among the control, cooperative, and animation groups, with reasoning ability (TOLT) as a covariant. ANCOVA tests were formed for the CE and the SMT. Post-hoc tests were used to determine how the groups differed. Furthermore, descriptive statistics related to total mean scores of the TOLT, SMT, and CE were analyzed for the groups.

Findings and Results

Descriptive statistics related to the total mean scores of the TOLT, SMT, and CE for the treatment groups are presented in Table 2. According to this data, mean scores of the groups range from 3.25 to 3.86, from 5.70 to 8.43, and from 36.50 to 38.81 for TOLT, SMT and CE, respectively.

Table 2

Descriptive Statistics for TOLT, SMT, and CE

GROUPS		TOLT	SMT	CE
Control	Mean	3.25	5.70	36.50
	N	20	20	20
	Sd. Deviation	1.86	1.95	8.13
Cooperative	Mean	3.70	7.74	36.96
	N	23	23	23
	Sd. Deviation	1.74	1.57	7.19
Animation	Mean	3.86	8.43	38.81
	N	21	21	21
	Sd. Deviation	1.53	0.98	8.79

To determine the relationships between the measures used, a correlation matrix of the TOLT scores, SMT scores, and CE scores was calculated for the states of matter topic. A lower correlation existed between the TOLT and SMT scores ($r= 0.06$). The correlation between the TOLT scores and the CE scores was $r= 0.34$. According to the data in Table 2, the mean TOLT scores of the groups varied, although not significantly.

One-way analyses of variance (ANOVA) tests were used to analyze differences among the control, cooperative, and animation groups based on reasoning ability. Data obtained from the TOLT are given in Table 3.

Table 3

ANOVA Results for TOLT Scores

	Sum of Squares	DF	Mean Square	F	p
Between Groups	4.043	2	2.022	0.688	0.506
Within Groups	179.191	61	2.938		
Total	183.234	63			

According to the data in Table 3, a one-way analysis of variance (ANOVA) found no significant differences in the TOLT scores of the control, animation, and cooperative groups [$F(2,63)= 0.688$; $p >0.05$)]. This finding supports the assumption that the groups should be considered equivalent. The TOLT results showed no differences among the treatment groups in this study (Table 3). This also helps to substantiate the assumption that the groups were similar. The TOLT mean scores in this study were higher than those found for college science students by Tobin and Capie (1981), but lower than those found for college chemistry students by Graves (1998). One explanation for this may lie in the fact that states of matter is generally taught in the second half of the course. By this point, many students without the ability for proportional reasoning or controlling variables have dropped the course. These abilities are required for success in earlier units on stoichiometry, periodicity, chemical bonding, and atomic structure. Since attendance was required for inclusion in the study, it may be that a large proportion of students with low TOLT scores chose not to attend class and were not included in the study.

Micro level understanding was measured by the SMT. Each SMT was given during the week after the completion of the states of matter instruction. According to data in Table 2, the animation and cooperative groups' TOLT scores were 6.1% and 4.5% higher than that of the control group, respectively. The animation and cooperative groups' SMT scores were 37.3% and 20.4% higher than that of the control group, respectively. Therefore, the TOLT score was used as a covariate in the subsequent analyses to partial out its effects.

According to the data given in Table 4, the ANCOVA results show significant differences in the SMT scores by treatment even when the effects of the TOLT score are removed [$F(2, 63)= 16.793$; $p <0.05$)].

Table 4

ANCOVA Results for SMT

Source	DF	Mean Square	*F*	*p*
TOLT	1	0.142	0.058	0.810
Groups	2	40.761	16.793	0.000
Error	60	2.427		

Multivariate analysis (post-hoc testing) was used to determine where differences existed. The Games-Howell post-hoc test was chosen because it is robust to unequal cell sizes. The control group had SMT scores significantly different from those of the animation and the cooperative groups. The scores of the two experimental groups did not differ significantly. However, average mean scores of the animation group were higher than those of the cooperative group. Effect sizes calculated were 1.40 and 1.42 for the control group and the animation and cooperative groups, respectively. Effect sizes were calculated by dividing the difference in the means of the control group and one experimental group by the standard deviation of the control group.

Micro level understanding based on the SMT was related to the type of group (control, animation or cooperative) and to the TOLT scores (Table 4). One possible explanation for this might be that, for the simple micro level meanings depicted in this study, the maximum effect was achieved with both animation and cooperative learning. Another possible explanation may be that students only need to be cued to the dynamic particulate nature of these processes. The improved scores of the animation group are surprising when one considers that the animated sequences were short (2 to 2.5 minutes maximum). However, animations were used consistently for the duration of the instruction. Both of these facts add to the possibility that students, especially those with high reasoning ability scores as in this study, may only need to be cued to internally visualize dynamic particle models.

The research on cooperative learning shows that the cooperative setting provides students with opportunities to engage in higher-order thinking skills and in processes of shared thinking, which helps them to not only gain a better understanding but also to build on their own contributions to develop new understandings and knowledge (Gillies, 2006; Hennessy & Evans, 2006; Lin, 2006). Students could not learn by only working in a small group. They need to construct their knowledge. Many students tend not to learn meaningfully, having difficulties relating what is taught to them with their real-world experiences and with other scientific ideas previously learned (Novak, 2002). Because of this, this study focused on the construction of knowledge in small cooperative groups.

Understanding at the non-micro level (macro and symbolic) was measured by the CE. The ANCOVA results for CE scores are given in Table 5.

Table 5

ANCOVA Results for CE

Source	**DF**	**Mean Square**	***F***	***p***
TOLT	1	32.248	0.582	0.449
Groups	2	9.375	0.169	0.845
Error	60	55.450		

According to these ANCOVA results, no significant differences were found between the groups in terms of CE scores [F (2,63) = 0.169; p >.05)]. The CE showed no differences in understanding at the non-micro level (macro and symbolic) among the treatment groups (Table 5). Upon scrutiny of the questions on the CE, a possible explanation was found. The majority of the questions on the instructor-constructed exam were algorithmic in nature. The proposition that students memorized equations and the manipulation of equations that were needed to answer algorithmic problems without gaining micro level understanding may account for the lack of differences among the groups shown by the CE when very different results were found with the SMT scores.

Also, SMT responses indicate some interesting similarities and differences among the groups. The results (Q number 2 on STM) showed that the majority of the students (82, 76, and 72 percent of the control, cooperative and animation groups, respectively) did not understand the behavior of water molecules in ice at between -20 and 0 ^{0}C at the micro level. They did not consider that water can evaporate at every temperature. The main reason for this kind of learning difficulty could be due to textbooks' symbolic representations. This is interesting because, as Yore (1991) pointed out, science students usually see textbooks as very important sources of information that have a strong influence on shaping their teaching. Some responses given to this question by treatment group students are given in Figure 2.

Control	Cooperative	Animation

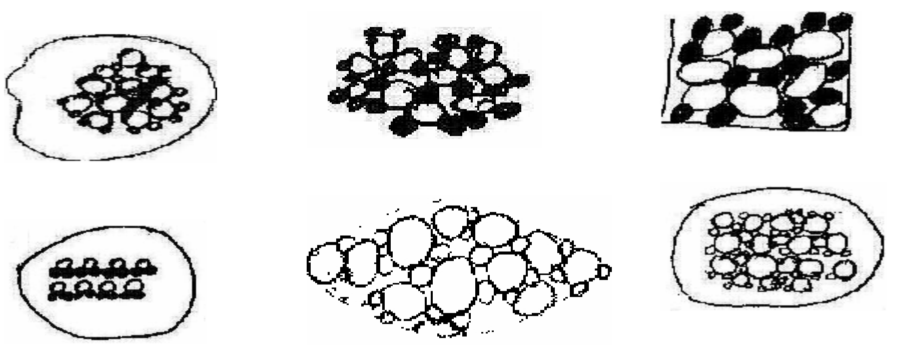

Figure 2. An example from treatment group students' responses concerning the behavior of water molecules in ice between -20 and 0 °C at the micro level

Other similarities in the SMT responses (Q number 4) included answers about the envisaging of molecules in the vapor phase of water; 75% of the control group, 82% of the cooperative group, and 88% of the animation group answered this question correctly. The main reason for this may be the fact that teachers give examples of the vaporization phase of water both in textbooks and on the Internet. Some responses given to this question by treatment group students are given in Figure 3.

Control	Cooperative	Animation

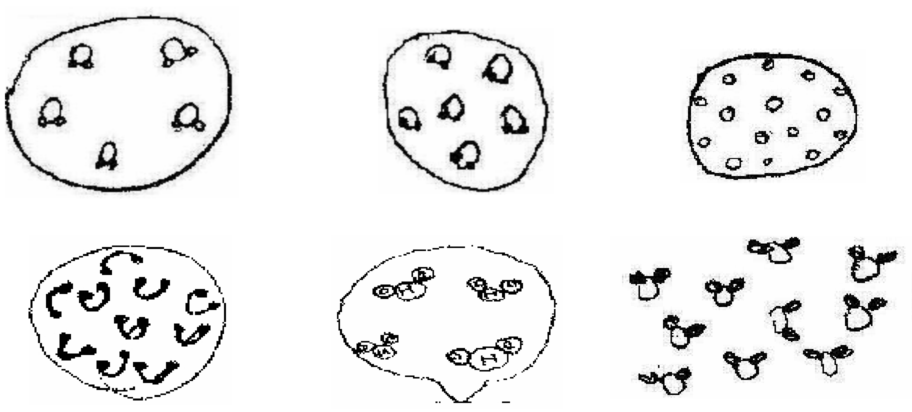

Figure 3. An example from treatment group students' responses concerning the molecules in the vapor phase of water

An interesting difference in the groups was found when the subjects were asked to draw a picture representing the change that occurs when a solid melts (Q number 3 on SMT). A few students chose to conserve particles between the SMT drawing of the solid and their drawing of the liquid. Only 54% of the control group conserved particles, while 65% of the cooperative group and 78% of the animation group conserved particles. Some treatment group students' responses to this question are given in Figure 4.

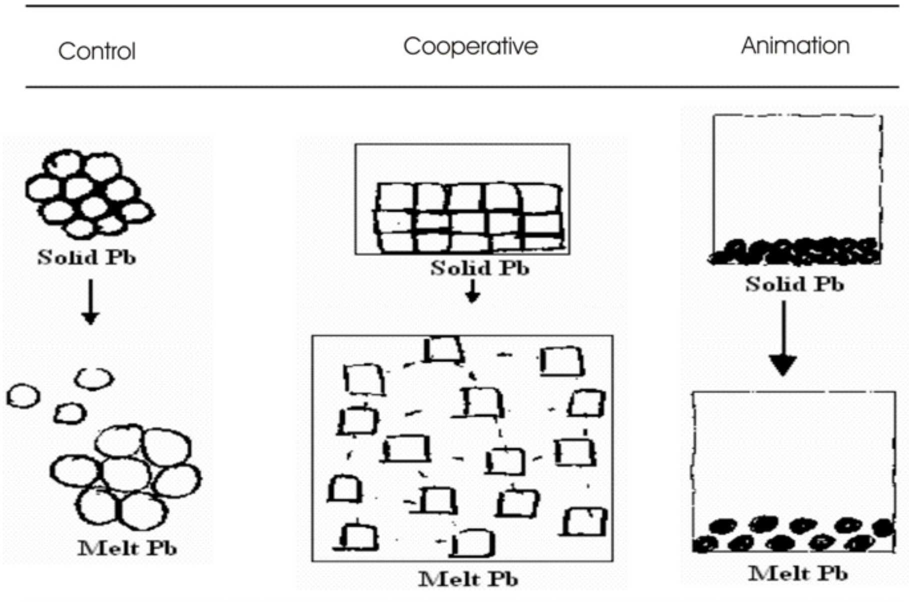

Figure 4. An example from treatment group students' responses concerning the molecules in solid lead and melted lead

Question number 5 on the SMT presented students with two sealed flasks: a blank flask and a flask filled with gas particles. The students were asked to draw the substance in the blank flask after it had been liquefied. Some students spontaneously depicted liquid-vapor equilibrium. 16% percent of the control group, 24% of the cooperative group, and 30% of the animation group drew the particles in a liquid phase with few particles in the gas phase. Some responses given to this question by treatment group students are given in Figure 5.

Control	Cooperative	Animation

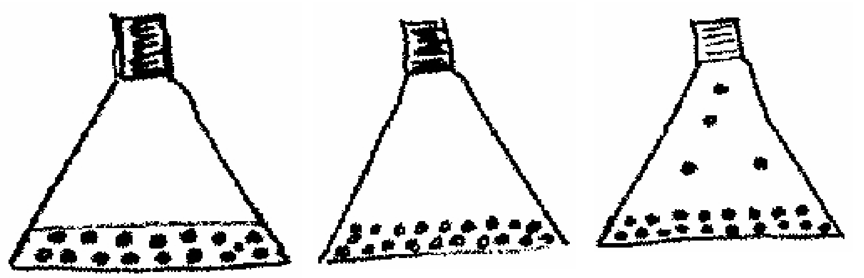

Figure 5. An example from treatment group students' responses concerning the view of water molecules in liquid phase

One possible explanation for these questions' (Q 3 and 5) findings is that use of animations caused the students to begin to think in particulate terms and to attend to more details concerning the behavior of particles. In the cooperative group, students gave more correct answers to these questions. This may be due to they took part in the learning process actively in both in-class and out-of-class discussions.

Conclusions and Recommendations

This study indicates that if cooperative learning instruction is organized, giving consideration to constructivism, students' achievement of micro level meanings will improve. The present paper could indicate a slight remediation for non-micro (macro and symbolic) level understanding. If the studies can become reality and if teachers can be encouraged to apply them in their classes, students' difficulties with micro meaning can be prevented. Thus, meaningful and effective learning can be provided.

In this study, animations provided a more scientifically correct visual model for submicroscopic processes not easily visualized. A few students viewing the animations had difficulties with the micro meaning as a consequence. Students who viewed the animations held a more particulate view of matter, ions dissolving in water, states of matter, and chemical bonding structure. More conservation of particles between drawings and fewer "continuous matter" drawings were evidence of this. The use of animations may increase understanding of micro meaning by prompting 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. Particle-level animations should be used frequently in chemistry classrooms to help students visualize particle-level behavior. In conjunction with showing these animations, students should be given opportunities to discuss and interpret the animations as they relate them to macroscopic phenomena that they have observed (Yezirski, & Birk, 2006).

Students from the cooperative learning group learned the unit related to the states of matter better than those who were in the group taught by the micro-level conventional method because students who studied on line with this method had the opportunity to utilize Internet facilities in addition to sources from the library. They were able to develop posters, pictures, simulations and animations of their own as an outcome. This was observed when the students in the cooperative learning group presented their research. Previous studies have reported that cooperative learning leads students to research using different sources and reconstruct their knowledge according to their own cognitive nature (Gillies, 2006; Hennessy, & Evans, 2006; Lin, 2006).

This study demonstrated that cooperative learning in small groups helped students understand the subject topic of the states of matter at the micro-level and develop cognitive models. In addition, conventional teaching methods based on teacher presentation were found to be as effective as cooperative learning and computer animation-aided instruction in students' ability to learn the states of matter at macro and symbolic levels. Researchers have shown that students experience more difficulty in micro-level understanding than they do in macro and symbolic levels (Wu et al., 2001). That students' micro-level understanding in the conventional teaching group was lower than that in the cooperative learning and animation groups might stem from the insufficiency of activities that could facilitate micro-level understanding. Consequently, when correct and suitable learning strategies are used, we think that it is more likely that the sources of macro level understanding, symbolic level understanding and misunderstandings will be remedied.

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APPENDIX

State of Matter Evaluation Test (SMT)

Question 6

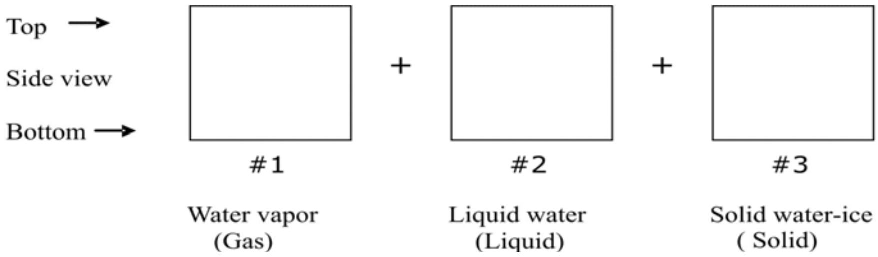
Water exists in three forms (phases): gas (water vapor), liquid, and solid (ice). Use circles to represent water particles in the boxes below.


= water particle

In Box #1, draw 5 water particles in the gas phase.

In Box #2, draw 5 water particles in the liquid phase.

In Box #3, draw 5 water particles in the solid phase.



Test of Logical Thinking (TOLT)

For example, proportional reasoning is measured by the following pair of questions taken from the TOLT.

The Vegetable Seeds

Item 5

A gardener bought a package containing 3 squash seeds and 3 bean seeds. If just one seed is selected from the package what are the chances that it is a bean seed?

a. 1 out of 2 b. l out of 3 c. l out of 4 d. l out of 6 e. 4 out of 6

Reason

1. Four selections are needed because the three squash seeds could have been chosen in a row.
2. There are six seeds from which one bean seed must be chosen.
3. One bean seed needs to be selected from a total of three.
4. One half of the seeds are bean seeds.
5. In addition to a bean seed, three squash seeds could be selected from a total of six.

Course Exam (CE)

Item 4

Under the same conditions of temperature and pressure, a liquid differs from a gas because the particles of the liquid

1. are in constant straight-line motion
2. take the shape of the container they occupy
3. have no regular arrangement
4. have stronger forces of attraction between them
5. have more weak forces of attraction between them

Maddenin Hallerinin Mikro, Makro ve Sembolik Seviyede Öğrenilmesine Bilgisayar Animasyonları ve İşbirlikli Öğrenme Metotlarının Etkileri

(Özet)

Problem Durumu: Kimya eğitimi alan üniversite birinci sınıf öğrencilerinin çoğu kimya konularını makroskobik ve sembolik seviyelere nazaran mikroskobik seviyede anlamada zorluk çekmektedirler. Bu üç anlama seviyesi; 1) madde enerji ve doğa olayları gibi olguların anlaşıldığı makroskobik seviye, 2) molekül, atom, iyonlar ve buna benzer olguların anlaşıldığı mikroskobik seviye ve 3) formüller, eşitlikler ve iyon hareketleri gibi olguların anlaşıldığı sembolik seviye olarak ifade edilmektedir. Önemli olan bir husus bu üç seviyede öğrenmenin nasıl gerçekleştirileceği problemidir. Bu çalışmada, görsel modellerin kullanıldığı bilgisayar animasyonları ve öğrenci merkezli yöntemlerinden biri olan işbirlikli öğrenme metodunun öğrencilerin üniversite kimya eğitiminde maddenin halleri konusunu makro, mikro ve sembolik sevide anlamalarına nasıl bir etki yapacağı araştırılmıştır.

Araştırmanın Amacı: Bu çalışmanın amacı, üniversite birinci sınıf öğrencilerinin maddenin halleri konusunu mikro, makro ve sembolik seviyelerde anlamaları üzerine bilgisayar animasyonları ve işbirlikli öğrenme metotlarının etkilerini belirlemektir.

Araştırmanın Yöntemi: Bu araştırmanın örneklemini 2006–2007 akademik yılında genel kimya dersini alan üç farklı sınıftaki toplam 64 fen bilgisi öğretmenliği birinci sınıf öğrencisi oluşturmuştur. Bu sınıflarda biri işbirlikli öğrenme metodunun uygulandığı işbirlikli grup, ikincisi bilgisayar animasyonları tekniğinin uygulandığı animasyon grubu ve üçüncüsü geleneksel öğretimin uygulandığı kontrol grubu olarak belirlenmiştir. Animasyon grubuna gösterilmek üzere ünite konularıyla ilgili hazırlanan bilgisayar animasyonları, dersin işleniş basamağında her bir animasyon iki dakikalık zaman içerecek şekilde sunulmuştur. Animasyon gösteriminin ardından konu ile ilgili sınıf tartışmaları yapılmış öğrencilerin yanlış ve eksik anlamaları olduğu durumlarda animasyonlar tekrar gösterilerek bu eksiklikleri giderici çalışmalar yapılmıştır. İşbirlikli öğrenme yönteminin uygulandığı sınıf 4-5 öğrenciden oluşan 5 heterojen gruba ayrıldı. Her gruba ilgili ünitenin konuları dağıtıldı. Gruplar konularını sınıf içerisinde ve sınıf dışarısında yapmış oldukları çalışmalarla hazırladılar. Hazırlıklar tamamlandıktan sonra her grup sınıf içerisinde 35 dakikalık sunum ve 15 dakikalık tartışma şeklinde sunumlarını tamamladılar. Kontrol grubunda ise ünite ile ilgili hazırlanan ders materyali doğrultusunda öğretmen sunumu soru-cevap vb. tekniklerin kullanıldığı geleneksel öğretim yöntemine göre ders işlendi. Çalışma bütün gruplarda üç haftalık süre zarfında yürütülmüştür. Araştırmada veri toplama aracı olarak Maddenin Halleri Testi (MHT), Ders Testi (DT) ve Mantıksal Düşünme Testi (MDT) kullanılmıştır. MDT, uygulamaya katılan öğrencilerin mantıksal düşünme düzeylerini tespit etmek amacıyla uygulanmıştır. Mantıksal düşünmenin dört alt boyutu ifade edilmektedir. MDT bu alt boyutları içine alan sekiz sorudan oluşmuştur ve değerlendirilirken doğru cevaplar 1 ve yanlış cevaplar 0(sıfır) puan olarak alınmıştır.

MHT, öğrencilerin maddenin halleri, bileşikler ve bağ yapılarına ilişkin soruları mikro seviyede çizimler yaparak göstermelerini içeren bir testtir. Bu testin puanlaması; mikro seviyede anlama puanları olarak değerlendirilmiştir. Puanlamada mikro seviyede memnun edici anlama puanlarına 1 puan verilmiş ve diğer cevap türleri puanlamaya alınmamıştır. Mikro seviye deki puanlar; moleküller, atomlar, iyonlar gibi terimlere verilen cevaplarından elde edilmiştir.
DT, öğrencilerin maddenin halleri konusundaki makro ve sembolik (mikro seviyede olmayan) seviyedeki anlamalarını tespit etmek için kullanılmıştır. Bu test çoktan seçmeli 15 sorudan oluşturulmuştur. Testin güvenirliğini belirlemek için daha önce maddenin halleri ünitesini görmüş olan öğrenci grubuna test uygulanmış ve güvenirlik katsayısı 0,69 olarak bulunmuştur. Test sonuçları değerlendirilirken her bir sorunun doğru cevabı 5 puan olarak değerlendirilmiştir. Araştırma gruplarının DT ve MHT'den elde edilen puanları için tek yönlü kovaryans (ANCOVA) analizi kullanılmıştır.

Araştırmanın Bulguları

Mantıksal düşünme testinden elde edilen puanlara ait tek yönlü varyans (ANOVA) analizi sonuçları, kontrol, animasyon ve işbirlikli grupların mantıksal düşünme puanları arasında istatistiksel olarak anlamlı bir farklılık olmadığını göstermiştir. Bulgular araştırmaya katılan öğrencilerin mantıksal düşünme bakımından benzer özelliklere sahip oldukları varsayımını desteklemektedir. Maddenin halleri testinden elde edilen puanlara ait tek yönlü kovaryans (ANCOVA) analizi sonuçlarından, animasyon ve işbirlikli gruplardaki öğrencilerin kontrol grubuna göre daha yüksek mikro seviyede anlama puanlarına sahip oldukları bulunmuştur. Bununla birlikte maddenin halleri konusundaki mikro seviyede olmayan (makro ve sembolik seviyede) anlamalar bakımından araştırma grupları arasında anlamlı bir farklılık olmadığı tespit edilmiştir. Elde edilen bulgular hem bilgisayar animasyonlarının hem de işbirlikli öğrenmenin mikro seviyede anlamalar üzerinde önemli etkisinin olduğunu göstermiştir.

Araştırmanın Sonuçları ve Öneriler: Bu araştırma mikro seviyede gösterimler içeren bilgisayar animasyonları ile öğretimin öğretmen sunumuna dayalı geleneksel öğretime göre öğrencilerin kimya konularını mikro seviyede anlamalarını sağlamada daha etkili olduğu sonucuna varılmıştır. Bununla birlikte bu çalışma, küçük grup çalışmalarına dayalı işbirlikli öğrenme yönteminin de öğrencilerin maddenin halleri konusunu mikro seviyede anlamalarını ve zihinsel modeller oluşturmalarını sağladığını ortaya koymuştur. Ayrıca öğretmen sunumuna dayalı geleneksel öğretim yönteminin öğrencilerin maddenin halleri konusunu makro ve sembolik seviyede anlamalarını sağlamada işbirlikli öğrenme ve bilgisayar animasyonları ile öğretim kadar etkili olduğu sonucuna varılmıştır. Öğretmenler işbirlikli öğrenme aktivitelerini destekler ve kullanır iseler, öğrencilerin mikro seviyede anlama güçlüklerini önleyebilirler. Bu sayede etkili ve anlamlı öğrenme sağlanabilir. Sonuç olarak bizler doğru ve uygun öğrenme stratejisi kullanıldığında mikro seviyedeki anlamaların sağlanabileceğini düşünüyoruz.

***Anahtar Sözcükler*:** Bilgisayar animasyonları, işbirlikli öğrenme, mikro seviye, maddenin halleri