

Effects of Conceptual Change Texts and Laboratory Experiments on Fourth Grade Students' Understanding of Matter and Change Concepts

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Abstract The purpose of this study was to investigate whether conceptual change texts and laboratory experiments are effective in overcoming misconceptions and whether the concepts were acquired permanently when these methods were utilized. In this study, we addressed some topics from the “Matter and Change” unit in science and technology class of elementary 4th grade. Students from three classes of an elementary school participated in the study ($N = 104$). Students' misconceptions were determined by administering the “Matter Concept Test” before, immediately after and 13 weeks after the instructional period. The results of the study showed that both conceptual change texts and experiment method were more successful than traditional instruction in overcoming the misconceptions and acquiring permanent knowledge. However, there was not a significant difference between these two alternative approaches in terms of reducing the misconceptions.

Keywords Conceptual change texts · Laboratory instruction · Science achievement · Science teaching

Introduction

Misconceptions are defined as the knowledge that is generally obtained by personal experience and inconsistent

with the scientifically accepted ideas (Lawson 1995). Sometimes the knowledge hinders the student from accessing to information regarded as scientifically correct, and as a result, it becomes difficult and even impossible for the student to gain new information.

Since “Matter” subject constitutes the fundamentals of chemistry, significant amount of research has been conducted on how students understand the concepts related to it. The research literature shows that students develop many misconceptions on the subjects related to Matter concept. For example, the research conducted by Eskilsson and Helldén (2003) and Çakır (2005) shows that students think that gases are weightless. Kirikkaya and Güllü (2008) study with 300 grade-five students reveals that approximately half of the students think that heat is measured with a thermometer and two out of three students think that temperature is a type of energy. Research conducted by Lee et al. (1993) reveals that, students think that when something evaporates it ceases to exist and condensation is a kind of creation of a new substance. Some students believe that when a substance transforms into another state, it becomes a different substance. Students participated in this particular study explained the evaporation as “alcohol became air” and condensation “air changed into water”. Most students in Turkey think that water doesn't evaporate in every temperature; it is required to be boiled in order to evaporate (Kirikkaya and Güllü 2008; Özata 2003).

Students believe that solid state of a substance is heavier than its liquid state. According to them, mass of a substance changes during the change of state. For example, when we heat something, it's mass decreases (Çakır 2005). Lee and colleagues (1993) showed that students hold misconceptions about dissolution. In general, when considering the relationship between solvent and solute, students think that solute disappears. For example, students

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think that sugar disappears when it is put into water. Other studies (Çakır 2005; Demetgül 2003; Dincel 2005; Ersoy 2004; Prieto et al. 1989; Uzuntiryaki and Geban 2005) showed that students have the idea that dissolution is the same as melting.

Studies identifying students' misconceptions on a variety of science topics are abundant. Currently researchers turned their focus to find effective teaching methods in order to overcome these misconceptions. Conceptual change texts and hands-on laboratory experiments are among these methods. Hynd and Alverman define conceptual change texts as texts that present the conflicts between misconceptions and information that is scientifically correct (Pınarbaşı and Canpolat 2002). By means of these texts, students realize that the conceptions they have are useless in solution of a problem they encounter. When students feel the inadequacy of their current knowledge, conceptual change will be initialized.

Conceptual change texts are based on the conceptual change theory which put forward by Posner et al. (1982). According to the theory, particular conditions should be fulfilled for conceptual change to occur: (1) Learners must dissatisfy with their existing conceptions. That is, they should be encountered with such situations that their current conceptions will not work. (2) The new conception must be intelligible. Learners must be able to understand the new concept. (3) The new conception must appear plausible. With the new conception they should feel that they would be able to solve the problems they had with the older conception. (4) The new conception should be fruitful. It should have the potential to be extended. Conceptual change texts use in classroom is applied in the following steps: (1) Common misconceptions held by the students are identified. (2) Students are asked to make predictions about certain situations to present the inconsistency between alternative and the scientific conception. (3) Evidence is provided to show that their conceptions are wrong. (4) The explanatory phase of the text involves an explanation of the scientifically correct concepts (Chambers and Andre 1997).

Conceptual change text design has been used frequently in various science topics. In physics, Chambers and Andre (1997) investigated college students' understanding of direct current in electricity by using conceptual change texts. The researchers found that conceptual change text resulted in a better conceptual understanding of electricity concepts for college students. Dilber (2006) investigated the effects of analogies and conceptual change texts on students' understanding of physics concepts and attitudes towards physics. Results of the study indicated that conceptual change texts are successful in helping students understanding the concepts and reducing the misconceptions.

In chemistry, Yürük (2007) investigated the effects of conceptual change text supplemented instruction on 11th

grade students' conceptual understanding in some chemistry topics. The results of the study showed that conceptual change supplemented instruction was more successful than the traditional instruction. Uzuntiryaki and Geban (2005) determined that instruction utilizing conceptual change texts accompanied with concept maps was more effective than traditional instruction in the understanding of solubility concepts of 8th grade students. Özmen (2007) concluded that conceptual change texts were efficient in overcoming 10th grade students' misconceptions related to chemical equilibrium topics. The results of the study by Sevim (2007) showed that conceptual change texts are more effective in reducing the misconceptions and retention of chemistry concepts in pre-service teachers.

Regarding biological concepts, Mikkila-Erdmann (2001), Sungur et al. (2001), Tekkaya (2003), and Yenilmez and Tekkaya (2006) demonstrated the effectiveness of conceptual change text instruction on 8th, 9th and 10th grade high school students' understanding of the human circulatory system, diffusion/osmosis, and plant respiration and photosynthesis. In chemistry, Cakir et al. (2002) reported the effectiveness of conceptual change texts in creating conceptual change and promoting meaningful learning in 10th grade high school students regarding acids and bases.

The studies cited here investigated the effectiveness of conceptual change texts for high school or college students. Whether this strategy is appropriate for younger students is questionable. One of the objectives of the present research is to investigate this question.

Laboratory experiments are regarded a must for science classes. Experiments appear to be effective in acquiring some skills that laboratory instruction intended for. However, their effect on cognitive outcomes is inconclusive (Hofstein and Lunetta 2004). For example, in her cross-age study, Weaver (1998) investigated the successes of hands-on activities and experiments with fourth, eighth grade, and tenth grade students. Weaver reports that the students found hands-on activities very valuable and suggested that hands-on science activities and experiments can promote conceptual change, when combined with discussion and reflection. On the other hand, Bell et al. (2003) found that, "while the students did show some gain in the process of scientific inquiry, their conceptions of key scientific concepts remained virtually unchanged".

Ersoy (2004) compared the effectiveness of laboratory instruction and concept maps on students misconceptions. The researcher found that laboratory instruction was more effective than the concept maps in 7th grade matter and change topics. Dincel (2005) compared the effectiveness of laboratory instruction and story writing technique in overcoming students' misconceptions in some chemistry topics such as "Separating mixtures by physical method", "Separating compounds by chemical methods" and

“Forming compounds from elements” and found that laboratory was more effective than the story writing. Similarly Güler (2005) revealed that laboratory experiments are effective in overcoming misconceptions of high school students related to heat and temperature concepts.

“Matter and Change” teaching unit contains fundamental concepts about matter and constitutes the fundamentals of chemistry. Students’ unrevealed misconceptions about the topic influence their current understanding of the concepts as well as understanding of chemistry topics they will study in the future. Therefore, it is important to identify students’ misconceptions about the subject and the best methods to overcome them.

Purpose of the Study

The purpose of this study is to identify elementary 4th grade students’ misconceptions about topics related to teaching unit “Matter and Change” and to investigate the relative effectiveness of conceptual change texts and laboratory instruction on these misconceptions.

Method

This research is based on Pretest–Posttest control group design. A total of 104 students from three classes of an elementary school in Kars city center, which is located at Northeastern Turkey, participated in this study. All students were 4th graders and their age ranged between 9 and 11 years. Two of the classes assigned as experimental groups and one class assigned as control group. One of the experimental groups was instructed by utilizing conceptual change texts. Conceptual change text group consisted of 34 children (18 girls and 16 boys). The other experimental group performed experiments. Laboratory instruction group consisted of 35 children (18 girls and 17 boys). Control group received traditional instruction. Control group consisted of 35 children (13 girls and 22 boys).

Students’ misconceptions were identified by administering “Matter Concept Test”. Matter concept test, which was developed as a result of examination of the related literature, consisted of eight open ended questions. The following are the examples of open ended-questions.

Question 2: What can you say about the mass of a liquid when it becomes solid (e.g. ice and water). Explain your answer.

Question 3: Can we convert water vapor into water? Explain your answer.

Question 5: Ali put his new ball in his closet before he went to sleep. When he got up he saw that the ball was flat. What do you think about the mass of the ball? Did it change? Why?

As treatment, one experimental group utilized conceptual change texts and the other experimental group performed several laboratory experiments during instructional period. Control group received traditional instruction. The intervention period lasted 32-class hour. “Matter Concept Test” was administered again after the treatment period ended in order to examine the impact of the two methods on students’ misconceptions. Using the same test as pre-test at the beginning of experiments can produce effects other than those due to the experimental treatments. Familiarity with the measurement tools can produce higher scores on post test measures (Cohen and Manion 1998). This testing effect might have threatened the internal validity of the present experiment. However, such a threat was controlled because a control group was already included. Johnson and Christensen (2004) propose that any testing effect that might occur in the experimental groups would also occur in the control groups. Moreover, following controls should have the reduced the threats of testing effect in the present study (a) The participants received no feedback about pre-test responses prior to the treatment and the post-test (b) Twelve weeks passed between the pre-test and post test.

Thirteen weeks after the intervention period, the test was used again as a retention test. Three different teachers taught the three classes. Teachers who were to teach the experimental classes were trained on how to implement the conceptual change text strategy and laboratory instruction and they were provided with the experiments plans and conceptual change texts which were designed specifically for this instructional unit before the instructional period started. The traditional class used traditional lecture method in teaching of the content. The same content was covered by each teacher. The implementation stage was monitored by the first author at various times. The monitoring and the conversations with teachers confirmed that the intervention period proceeded as planned.

The researchers designed the conceptual change texts and the laboratory experiments themselves by specifically addressing the misconceptions which were determined from the pre-test results. Eight experiment- plans and eight conceptual change texts were designed for the whole instructional period. The conceptual change texts and the experiments addressed the topics of evaporation, boiling, changes of state, gases, solubility, and mixtures. A conceptual change text example was given below.

A Conceptual Change Text Example About Gases

By using your knowledge about gases, please explain the following situations.

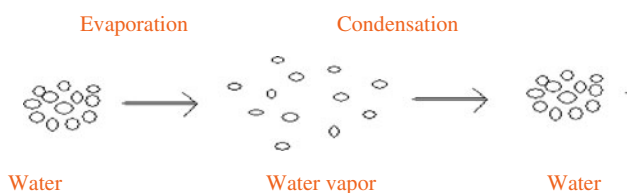
When you fan yourself with your hands, although your hands do not touch to your face, you feel that something hits your face. In your opinion, what might this be?

Ayşe noticed that her balloon gets heavier when she blows it up. How can you explain this increase in the balloon's weight?

We may think that gases do not exist since we cannot see them. Although we cannot see them, we can feel their existence. For example, we can feel air when we fan ourselves with hands. We can also observe that a wind wheel can rotate by means of air flow. These examples prove us that the air is around us. That is gases are matter. If we accept that gases are matter, then, we should also accept that they have mass, do not we?

Mass is amount of matter in an object. We know that all the objects (stone, flower, wood, iron, etc.) around us have mass. Air around us also has a mass although we cannot observe it directly. For example, mass of a blown-up balloon is greater than a balloon which was not blown up. The difference in mass comes from the air in the blown up balloon.

When we evaporate water, we cannot see the water vapor in the air around us. However, our not seeing the water vapor does not mean that the water does not exist any more and that it does not have a mass. When evaporation occurs, matter only changes its state and becomes a gas. That is why we cannot see it. We can condense water vapor (like what we see under a tea pot lid when we heat water) and we see that it conserves its mass. This means that when a substance evaporates, it does not cease to exist therefore, it does have a mass.



Experiments were performed in the laboratory. The experiments were introduced to the students, and they were asked to make predictions about the result of the experiments and record their predictions. After the experiment was completed students were asked to compare their predictions and the result of the experiment. Experiments were discussed by the students and the instructional period was concluded by the teacher's guidance. The students utilizing the conceptual change texts were first asked to make

predictions about particular situations related to the topic investigated in order to make them dissatisfied with their pre-conceptions. Then, they were explained why their conceptions are wrong giving real life examples. Finally they were introduced with the scientifically accepted conception.

Findings

Pre-test results showed that students held several misconceptions about the matter subject. Some examples of the misconceptions are: "Water is required to be boiled in order to evaporate", "When water evaporates, it ceases to exist", "Water becomes heavier when it freezes", "Gases are weightless", "Dissolving sugar melts", and "Solids are heavier than liquids". ANOVA test was utilized to see whether the three groups of students were homogeneous in terms of previous knowledge about the topics related to "Matter and Change". Table 1 shows the percentages of students' misconceptions as determined in pre-test and post-test. According to the results, there were no significant differences among the three groups in pre-test mean scores. Therefore, it can be said that all groups were equivalent with respect to their understanding of concepts related to "Matter and Change" topics before the treatment.

Pre-test percentages show the misconceptions held by students before the intervention, post test results show the misconceptions held after the instructional period which utilized particular teaching strategies (namely laboratory experiments, Conceptual change texts and traditional instruction) and retention test results show the misconceptions held by students after a period of 13 weeks. When we look at the percentages of students' misconceptions before the treatment, it is seen that students were approximately equivalent in all groups. Table 1 shows that there are significant differences between the groups regarding the percentages of misconceptions, after the intervention period. The conceptual change text and the laboratory instruction groups reduced the misconceptions in a considerably low level, although students' misconceptions in the control group remained the same at a large extent.

The percentage differences in the students' misconceptions determined in the post test and the retention test showed that most students in the control group reverted back to the misconceptions they had before the instructional period, while this situation occurred with a very few students in the conceptual change texts and laboratory instruction group (Table 2). The retention test results indicate that conceptual change texts and laboratory experiments are also more effective than the traditional teaching method in terms of helping students to maintaining the conceptions.

Table 1 The percentages of students' alternative conceptions as determined in pretest and posttest

| Alternative conceptions | LI (N = 34) | | CCT (N = 35) | | T.I. (N = 35) | |
|--|----------------|------|-----------------|------|------------------|------|
| | Pre | Post | Pre | Post | Pre | Post |
| | % | % | % | % | % | % |
| Evaporation occurs at a very high temperature | 29.4 | 5.9 | 8.6 | 0 | 8.6 | 5.7 |
| Boiling has to take place for the occurrence of evaporation | 14.7 | 0 | 11.4 | 0 | 22.9 | 20.0 |
| A specific amount of ice is heavier than its liquid state | 82.4 | 5.9 | 57.1 | 5.7 | 68.6 | 17.1 |
| Mixtures cannot be separated into substances that compose them. | 32.4 | 2.9 | 40 | 8.6 | 28.6 | 17.1 |
| A substance in gas state cannot be returned back to its liquid state | 44.1 | 8.8 | 8.6 | 5.7 | 44.2 | 32.3 |
| Gases do not have weight | 67.7 | 8.8 | 77.7 | 5.7 | 61.8 | 26.5 |
| Gases are not matters | 14.7 | 0.0 | 37.1 | 0 | 29.4 | 26.5 |
| When gases spread into a different environment, mass does not change with regard to its original condition | 14.7 | 0.0 | 20.0 | 0.0 | 23.5 | 0.0 |
| Solute melts in solvent | 50.0 | 5.9 | 45.7 | 14.3 | 37.1 | 22.9 |
| Substances composing mixtures loose their original characteristics | 35.3 | 5.9 | 34.3 | 8.6 | 22.9 | 11.4 |

LI Laboratory instruction,
CCT Conceptual change texts,
TI Traditional instruction

Table 2 The percentages of students' alternative conceptions as determined in posttest and retention test

| Alternative conceptions | LI (N = 34) | | CCT (N = 35) | | T.I. (N = 35) | |
|--|----------------|-------|-----------------|-------|------------------|-------|
| | Post | Retn. | Post | Retn. | Post | Retn. |
| | % | % | % | % | % | % |
| Evaporation occurs at a very high temperature | 5.9 | 8.8 | 0 | 2.9 | 5.7 | 2.9 |
| Boiling has to take place for the occurrence of evaporation | 0 | 0 | 0 | 2.9 | 20.0 | 22.9 |
| A specific amount of ice is heavier than its liquid state | 5.9 | 5.9 | 5.7 | 5.7 | 17.1 | 51.4 |
| Mixtures cannot be separated into substances that compose them. | 2.9 | 2.9 | 8.6 | 11.4 | 17.1 | 28.6 |
| A substance in gas state cannot be returned back to its liquid state | 8.8 | 11.6 | 5.7 | 8.6 | 32.3 | 32.3 |
| Gases do not have weight | 8.8 | 11.8 | 5.7 | 5.7 | 26.5 | 29.4 |
| Gases are not matters | 0.0 | 0.0 | 0.0 | 0.0 | 26.5 | 29.4 |
| When gases spread into a different environment, mass does not change with regard to its original condition | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.6 |
| Solute melts in solvent | 5.9 | 5.9 | 14.3 | 14.3 | 22.9 | 31.4 |
| Substances composing mixtures loose their original characteristics | 5.9 | 5.9 | 8.6 | 8.6 | 11.4 | 17.1 |

LI Laboratory instruction,
CCT Conceptual change texts,
TI Traditional instruction

Discussion

The main purpose of this study was to identify elementary 4th grade students' misconceptions about topics related to teaching unit "Matter and Change" and to investigate the relative effectiveness of conceptual change texts and laboratory instruction on reducing these misconceptions. The results of the pre-test showed that the misconceptions held by these particular students are similar to that of found in other research.(e.g. Eskilsson and Helldén 2003; Çakır 2005; Kirikkaya and Güllü 2008; Özata 2003) The most frequent misconceptions were "A specific amount of ice is heavier than its liquid state" and "Gases are weightless" for all groups.

The results of the present study showed that laboratory experiments are more effective than traditional instruction in reducing the misconceptions in 4th grade matter and change topics. This result consistent with those obtained from previous studies by Dincel (2005), Ebert and Eliot (2002), Ersoy (2004), McConnell et al. (2003), and Weaver (1998). It might be said that laboratory experiments are effective due to the fact that they make the abstract concepts more concrete by engaging students in active learning. For example students in the laboratory instruction group tested their idea that matter in different states might differ in mass, by measuring the mass of a certain amount of ice cubes and water (by melting the ice cubes) themselves. Students did the same experiment for water and the ice (by freezing the

water). Doing this experiment, rather than just hearing the right explanation from the teacher, was shown to be more effective in helping students to change their existing misconception. The mean score of laboratory experiments group was also significantly higher than the traditional instruction group at the retention test. The new conception was gained permanently due to the fact that the students learned by doing experiments which required them to use more senses. These results suggest that, laboratory experiments should be emphasized to promote conceptual understanding and retention of the concepts in science teaching. By performing experiments in laboratory, students are introduced with the models of real phenomena they encounter in real life and can use these models to explain daily events. Laboratory instruction should be given more importance especially in the primary education in which students are at the concrete operational level.

The results of the present study also showed that conceptual change texts are more effective than traditional instruction in reducing the misconceptions in 4th grade matter and change topics. The results are consistent with those obtained in previous studies conducted by Tekkaya and Dođru (2002), Güler (2005), Köse et al. (2006), Dilber (2006), and Sevim (2007). These particular studies were conducted with grade 8 and upper level students. Although the present study conducted with students at a considerably younger age, the results are similar. This result suggests that conceptual change texts might be effective for young students' learning science as well as older students. First of all, conceptual change texts help students to recognize that they have something wrong with their preconceptions. For example, students were asked that whether a substance changes its state when its mass increased. If no change occurs, then why to believe the reverse, why should the mass change when a substance change its' state? Students' preconceptions challenged this way. They were helped to dissatisfy with their preconceptions with questions like these. Then the concepts such as mass and change of state were explained to students. Examples showing that mass of a substance does not change with the state change were presented. As a result of these activities students come to realize that state change does not affect the mass of a substance.

Several researchers have noted that students may change their misconceptions for a while following intervention but may revert to the original misconceptions after some time (Trundle et al. 2002). The retention test was administered to address these concerns. It was held 13 weeks after the post-test. The results of the retention test showed that the change occurred in students' minds as a result of instructional period in both experimental groups have been largely retained after 13 weeks which is a considerably long period. However, a considerably large proportion of the control group students reverted back to their original conceptions.

The results of the retention test suggest that conceptual change texts and the laboratory instruction are both more effective than the traditional instruction regarding the retention of the concepts. This result is consistent with the results of Sevim (2007), and Dincel (2005) studies. Using strategies which make students both mentally and physically active is important in construction of new knowledge and retention of the concepts. The retention of this understanding probably indicates that conceptual exchange have take place and that the old misconceptions have been superseded by new scientific conceptions. In other words, accommodation of new conceptions has occurred. However, students in the control group were not exposed to instructional methods that would help them realize the presence of certain misconceptions in their minds and overcome these misconceptions.

Conclusion

In summary, this research showed that laboratory experiments and conceptual change texts were more effective than the traditional instruction in reducing the misconceptions which were held by students related to "Matter and Change" topics. The results of this study support the inclusion of more hands-on science laboratory activities and conceptual change texts in science classrooms. However, it is not satisfactory to merely increase the frequency of hands-on laboratory activities. Their quality and how they are used are equally important if the desired goals are to be achieved. In order to implement hands on science effectively in science classes, all teachers need to recognize the importance of hands-on laboratory activities. Furthermore, teachers need to be trained in how to include hands-on laboratory activities in science classes at the primary grades. In addition to training, supplying materials and time in the teaching schedule should be considered.

This study revealed that conceptual change texts are as effective as hands on laboratory experiments. The result suggests that well designed conceptual change texts are also appropriate in teaching science to primary school children. This strategy could be benefited especially in large class sizes where the hands on activities are problematic to perform.

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