



Effects of storylines embedded within the context-based approach on pre-service primary school teachers' conceptions of matter and its states

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Abstract

In this study, the effect of the context-based approach on pre-service primary school teachers' understanding of matter and its states and their attitude towards chemistry was investigated. Using a simple experimental design, the study was conducted with 35 pre-service primary school teachers who were exposed to context-based material with storylines. Two instruments were used to collect data as pre-test, post-test, and delayed-test: the *States of Matter Achievement Test (SMAT)* and the *Chemistry Attitude Scale (CAS)*. Also, semi-structured interviews were conducted with the pre-service primary school teachers after the implementation. The results indicated that the use of storylines embedded within a context-based approach resulted in better understanding of the concepts of matter and its states. Furthermore, the approach helped pre-service teachers gain positive attitudes towards chemistry. This improved performance was also observed in the delayed test. Overall, the results showed that the intervention had considerable effects on remedying pre-service teachers' alternative conceptions. Some suggestions are made on the implications for practice and learning.

Keywords: Chemistry education, Storyline, Context-based approach

Introduction

The concept of matter and its transformations are essential to chemistry. Educators agree that the nature of matter is in the heart of theoretical chemistry and is a key component in several science education curricula from as early as upper primary school years to various stages of secondary school and to university (Tsai, 1999). Appropriate understanding of the particle theory is essential to learn the states of matter and the changes associated with heating or cooling of a substance (Valanides, 2000). In addition to particle theory, learning the structure of matter and phase changes, solution chemistry, chemical reactions, and gases are also important. However, research findings from the literature indicate that issues such as the nature and characteristics of particles, the nature of space between particles, behavior of particles in different states of matter, the size of molecules, and change in the arrangement of the particles during the phase change and chemical processes are problematic for students to understand (e.g., Griffiths & Preston, 1992; Tsai, 1999). The literature shows that students develop several alternative conceptions for these



concepts. For example, in a study related to change of states from solid or liquid to gas, Stavy (1990) reported that students have difficulty in conceptualizing gas to be matter and they believe that gases are weightless or lighter than solids and liquids. Similarly, Durmuş and Bayraktar (2010) and Eskilsson and Hellden (2003) showed that students think that gases are weightless. Studies conducted by Griffiths & Preston (1992), Özmen (2011), and Valanides (2000) reported that many students think particle size increase as it changes from a liquid state to a gas state. In addition, Gabel, Samuel and Hunn (1987) and Özmen (2011) found that students at all levels, and even teachers, think that the number of particles would change during phase and temperature changes. Osborne and Cosgrove (1983) and Valanides (2000) report that students have alternative conceptions related to the distance between particles during the change of states. As a number of students perceive that there are no gaps between the particles of a liquid or gas, most students think that there are no spaces between the particles of a solid. These results indicate that students have a tendency to use their perceptions of macroscopic changes of a substance to infer its phase change occurring at the microscopic level; the presence of the particles in three states of matter is counter-intuitive to their knowledge. Based on a review of the literature, Tsai (1999) summarized students' alternative conceptions of microscopic views on phase change using four major categories: size, distance, reorganization, and motionlessness.

The most important results emerging from the above literature are, that students have difficulties in answering the following two questions:

- What distinguishes solids, liquids, and gases – the so-called states of matter – from each other?
- What changes occur during the transformation of matters?

Because of these difficulties, students hold many alternative conceptions about the particulate nature of matter, including the boiling, condensation, evaporation, and changes in the states of matter.

In the present study, we worked with pre-service teachers because primary school teachers could be a resource of alternative conceptions in students. Gilbert & Zylbersztajn (1985) suggested that alternative conceptions may arise as a result of interaction with teachers, as many of the above mentioned concepts are firstly taught in primary schools. However, primary school teachers often avoid chemical themes due to a lack of knowledge, interest, and confidence (Harlen & Holroyd,



1997). They also hold views of science concepts that are not in accordance with generally accepted scientific viewpoint (Harlen & Holroyd, 1997). Teachers must first develop an understanding of the chemistry concepts that they are expected to teach their students. When both teachers and prospective teachers do not completely understand the basic science concepts they will not be able to teach them well (Abd-El-Khalick & Lederman, 2000) and they may cause their students to develop alternative conceptions (Quiles-Pardo & Solaz-Portoles, 1995).

Tsai (1999) has pointed out that traditional teaching strategies are ineffective in helping students to develop complete understanding of abstract scientific concepts, to build correct conceptions, to alleviate alternative conceptions, and to promote accurate conceptual change. Also, traditional lecture-based school science fails to sustain and develop student sense of wonder and curiosity.

To address the shortcomings of traditional teaching methods, researchers and educators have developed original and useful approaches to aid in teaching of science concepts. One of these approaches, the context-based approach, has become increasingly popular in many countries, including the UK (Barker & Millar, 2000; Bennett & Lubben, 2006), the USA (Schwartz, 2006), and Turkey (Demircioğlu, Demircioğlu & Ayas, 2006). This current study is based on the Salters Advanced Chemistry (SAC) unit that illustrates the context-based approach using thirteen theoretical units including *Storylines*, *Chemical ideas*, and *Activities* (Bennett & Lubben, 2006). The storylines in the context-based approach relate theoretical knowledge to the real world (Bennett & Lubben, 2006), to communicate ideas, to make ideas meaningful, and to present the content of the curriculum (Banister & Ryan, 2001; Millar & Osborne, 1998). They also engage the student, facilitate common experiences, foster consciousness, and enrich the learning environment with contradictory voices (Barry et al., 2002).

The context-based approach successfully addresses the age-old student question: *Why do I need to learn this topic or concept?* Furthermore, it is based on constructivist learning theory in that it links theoretical knowledge to daily life. When they are taught by this approach, students grasp theoretical knowledge and can apply it to new situations. In the literature, only a few studies (Banister & Ryan, 2001; Demircioğlu, 2008; Demircioğlu et al., 2009; Ramsden, 1997) have concentrated on context-based learning of key ideas (e.g., evaporation,



condensation, boiling, and periodic table). Therefore, further evidence is needed to convince teachers to implement context-based learning in their classes.

The science knowledge learned in schools can explain most of the events or situations in daily life (TPSI, 1991). Unfortunately, in the public schools of many countries this association of concepts with events in daily life is not emphasized (Millar & Osborne, 1998). This lack of association negatively affects students' attitude towards chemistry. Attitude is a significant factor affecting student achievement (Cheung, 2009). For example, Salta and Tzougraki (2004) found a meaningful correlation between student achievement in chemistry and their attitude towards chemistry. We also believe that the type and design of materials would increase students' positive attitude towards chemistry. There is a need to develop teaching materials that provide meaningful learning, link concepts in curriculum to daily life, and help students develop higher order thinking skills.

Research questions

The aim of this study is to investigate the effect of storylines embedded within a context-based approach on pre-service primary school teachers' conceptions of matter and its states. Within this aim, the following research questions are specifically explored:

1. Do the storylines embedded within a context-based approach cause a statistically significant improvement on pre-service teachers' learning of matter and its states?
2. How do the teaching activities based on the context-based approach influence pre-service teachers' long-term memory retention of new conceptions about matter and its states.
3. Are the storylines embedded within a context-based approach effective in overcoming pre-service teachers' alternative conceptions of matter and its states?
4. Do the storylines embedded within a context-based approach cause a statistically significant improvement in the students' attitudes towards chemistry?
5. Are correlations between the pre-service teachers' attitudes towards chemistry and their achievement on matter and its states statistically significant?



Method

Study Context

The General Chemistry course is a compulsory subject for the divisions of Primary School Teacher Education of Education Faculties at universities in Turkey. All pre-service primary school teachers take this course for two hours per week during their first year. The unit *Matter and Its States* is included in this course. The content of the unit includes general concepts related to matter and its states. These concepts include common and distinctive properties of matter, heat-matter interaction, pure matter, solution and mixture, melting point and freezing point, evaporation, condensation, boiling, freezing, states of matter, the particulate nature of matter, and phase changes. This content is prepared by Higher Education Council (YOK) and faculties have to teach this content to their pre-service teachers.

Research Design and Participants

A simple experimental design (one group pre-test/post-test design) was chosen for the study and this involved one group that is pre-tested, exposed to a treatment, post-tested and delayed-tested. There are several threats to the internal validity of this design (Robson, 1998); lack of random assignments and a control group limits confidence in assigning causality to an intervention (Trochim, 2001). In particular, because the experimental group is exposed to a specific teaching implementation within a significant amount of time, students in this group are expected to become more successful than the control on post-test (Sadler, 2009). Nonetheless, using only one experimental group without control is plausible and a number of studies employing only one experimental group have been reported in the literature (Çalık *et al.*, 2010; Karşlı and Çalık, 2011).

Another threat to validity is, as Trochim (2001) argues, the perception of being involved in an “experiment” (i.e., in this case a teaching intervention) and may result in an apparent improvement in students' conceptual understanding.

To decrease this validity threat, researchers advocate the use of a delayed-test (Çalık *et al.*, 2010; Karşlı and Çalık, 2012). According to them, if gains are due to students involved in an intervention, this cause will probably diminish by the time. Thus, gains after the implementation (in post- and delayed-test) are seen to be evidence of a genuine improvement in conceptual understanding. Because of these



reasons, for this study, we preferred using only one experimental group along with a delayed-test.

The study was conducted with 35 pre-service teachers in their first year in the Primary School Teacher Education program of Fatih Faculty of Education at Karadeniz Technical University in Turkey. The implementation lasted for 8 lesson hours (two lessons per week), and each lesson was fifty minutes. The study was conducted during the 2012-2013 spring semester, and the first author taught the students by using context-based approach.

Data Collection Instruments

It is used two instruments and an interview to collect data for the study. The instruments included The *States of Matter* Achievement Test (SMAT) and the *Chemistry Attitude Scale (CAS)*.

The *States of Matter* Achievement Test (SMAT) was composed of twenty multiple-choice (items 1-20) and five open-ended (items 21-25) items. Two steps were followed to develop the SMAT. First, the content boundaries were defined and instructional objectives were determined from the general chemistry curriculum. Second, a review of the literature related to students' was completed. Tests items were constructed by considering the objectives of the curriculum and alternative conceptions identified from the literature. Four of the multiple-choice questions in the test were adapted from the literature (Osborne & Freyberg, 1985), the others were prepared by the researchers. Examples of the items in the SMAT are given in Appendix A (translated from Turkish to English). Table 1 includes the content areas of all the test items.

Table 1. Content areas of the items in the test

Item number	Content area
1, 2, 7, 16, 18, 24	States of matter (solid, liquid, gas)
3, 4, 22	Evaporation
5, 6, 13, 8, 21	Condensation
9, 10, 11, 12, 14, 23	Particulate nature of matter
15, 19, 25	Boiling
17, 20	Temperature curves



The content of the test was validated by three experts in chemistry education. In addition, the test was piloted with fifty pre-service second grade teachers. After the pilot study, the reliability and validity studies of each section of the test were performed in different ways.

For the multiple-choice section (items 1-20), item analysis was conducted and then discrimination index of each question was computed. The discrimination indexes of the questions ranged from 0.76 to 0.35. The reliability coefficient for this section of the test (first 20 items) was found to be 0.83 by using KR-20 formula. In this section, each true response was marked with 3 points, and each wrong one was scored with a zero. Thus, for this section of the SMAT the maximum score was 60 points.

For the open-ended section (items 21-25), the questions were categorized and scored as given in the Table 2. Similar categories have been used in the literature (Abraham et al., 1994). The maximum score for this section was 15 points. To provide inter-rater reliability, the authors independently classified student responses to open-ended items the categories listed in Table 2. The kappa statistic (Fleiss, 1981) was used to assess the extent of agreement among the three raters. The authors coincided around 90% or more of the classifications. Finally, all differences or disagreements were resolved by discussion.

Table 2. Classification of students' responses to open-ended questions

Categories	Criteria for the classification of student responses	Score
Sound understanding (SU)	Responses that included all components of the validated response.	3 points
Partial understanding (PU)	Responses that included at least one of the components of validated response, but not all the components	2 points
Alternative conception (AC)	Responses that included an alternative conception	1 points
No Answer (NA)	Repeated the question; contained irrelevant information or an unclear response; left the response blank	0 points

To examine the effect of different question types on students' understanding and whether students' achievement differed in subtopics, we computed and compared the means and standard deviations of students' scores for each section of SMAT and for each subtopic in Table 1.



To identify students' conceptual understanding on the states of matter, the SMAT was given as a pre-test to the sample population six weeks before and two weeks after the treatment (post-test). Then, the SMAT was administered four months after the treatment (delayed-test) to the sample. Enough time elapsed among the three administrations in order to allow the students to forget the test items and to help avoid bias; the post-test was administered 14 weeks after pre-test, and the delayed test was administered 16 weeks after post-test.

The second instrument used in the study was the Chemistry Attitude Scale (CAS), a 15-item chemistry attitude scale (with 10 positive and 5 negative statements) was adapted from Geban et al. (1994). The main adaptation was to use the word "chemistry" instead of "science." Positive statements in the attitude scale, a five point Likert-type, were marked from Strongly Agree (5 points) to Strongly Disagree (1 point). In contrast, negative statements were scored from Strongly Agree (1 point) to Strongly Disagree (5 points). The total score of the CAS ranged from minimum of 15 points to maximum of 75 points. Its alpha reliability coefficient was found by Geban et al. (1994) was 0.83. For the analysis of the CAS, firstly the total score of each student was computed and then mean score of the entire group was calculated.

The last data collection instrument was interviews with students. Semi-structured interviews were conducted after the intervention with three female and three male pre-service teachers. The students were randomly selected from a pool of male and female participants. The interviews aimed to determine pre-service teachers' views on teaching based on context-based approach. Each interview lasted 10-15 minutes. All the interviews were audiotaped and transcribed by the researchers. The results of interviews were presented by using direct quotations from the interviews.

Development of Context-Based Teaching Material (CBTM)

The *Context-Based Teaching Material* (CBTM) was prepared by the researchers and used to teach the states of matter. To develop the CBTM and to determine the coverage and time-schedule, we examined a number of relevant resources, such as the Turkish chemistry textbooks, publications of Salters' Advanced Chemistry Course, and the general chemistry curriculum of Higher Education Council (YOK). In addition, all the authors are chemists and they have been teaching chemistry at the university level for many years; consequently, this study benefitted from their experiences and teaching materials that they have been using to teach the concepts.



The CBTM included the same number of lessons about the nature of matter and its changes that are in the national curriculum, but with a different teaching approach. A group of experts, three experienced chemistry teachers and three chemistry educators, reviewed and validated the content of the CBTM.

The material for eight teaching sessions (8x50 minutes) was designed to engage the students actively in context-based learning. All the eight lesson plans consisted of a storyline and related activities (e.g., pictures, images taken from real events, laboratory work, worksheets, animations, power-point presentations, group and class discussion). Each of the plans started with a storyline and followed with related activities based on the storyline. The lesson plans for the first two lessons are given in Table 3 as an example.

The other plans were prepared in a similar way. The *storylines Matter from Empedocles to Dalton (Story 1)* were retrieved from Carpi (2005), *State of Life and A Difficult Decision (Story 2)* was written by the first author, *The Ozone Hole (Story 3)*, *Science or Magic? (Story 4)* and *Flood in the Library (Story 5)* were retrieved from LeMay et. al. (1996), *Falling and Flashing Plasma (Story 6)* was retrieved from URL-1 (2005), and *Control of Nature: Cooling the Lava (Story 7)* was retrieved from URL-2 (2005). All of the other activities such as worksheets, power-point presentations, were prepared by the researchers. One of the activities (Activity 1) is given in Appendix B.

Table 3. An outline of the teaching design

Lesson Plan	Teacher's role	Students' role
First class time	The teacher initially told the story (<i>Matter from Empedocles to Dalton</i>) to enable students to capture the related concepts they needed to make sense.	(S)he tried to capture and find out the related key concepts they needed to make sense by listening the story carefully.
	After completing the storyline, (s)he asked the students to find the key concepts.	(S)he explained the concepts (S)he found.
	The teacher asked the questions " <i>what is the solid, liquid and gas states of matter made of?</i> " and " <i>why can we not see the particles forming matter?</i> " to the students and started a class discussion. Then she asked the students to perform the Activity 1.	They performed the Activity 1 (see Appendix B), entitled "What are all substances mainly made of?". For this, they work in the groups of 5 to 6 members. They discussed the questions at the end of the worksheet within their group. Then each group presented its results to entire class.



	PowerPoint presentation, entitled “What are substances made of?”, was explained by the teacher to the students. The teacher asked a few questions to students about the presentation. She tried to relate the presentation with the results of Activity 1.	(S)he try to answer the teacher’ questions.
Second class time	The teacher initially told the story 2 (State of Life and A Difficult Decision) to enable students to capture the related concepts needed.	(S)he tried to capture and find out the related key concepts they needed to make sense by listening to the storylines carefully.
	After completing the storyline, (s)he asked the students to find the key concepts.	They discussed the concepts covered in the story.
	The teacher encouraged the students to participate the discussion. Then, she asked them to perform Activity 2 (Is each substance compressible?)	They performed Activity 2 in groups and discussed their results.
	The data in the tables created by the groups was combined in one table by the teacher. Then the table was presented with a projection to the entire class. She asked the students to perform Activity 3.	Each group created a table of physical properties (solid, liquid and gas) of substances and presented its table to entire class.
	After Activity 3, she asked the question “what are the differences between solid and liquid and gas particles?”	They carried out Activity 3 in the groups (Do molecules move?)
	She summarized the properties of solids and liquids by using power-point presentation involving daily-life pictures and molecular-level images.	They participated in all class-discussion.

Experimentation Process

The SMAT and the CAS were administered to the sample as a pre-test six weeks before the intervention. Pre-service primary school teachers spent eight teaching periods (8 x 50 minutes) to learn about matter and its changes. The first author of this study taught the students. In the implementation process, the teacher initially told the story to enable students to convey the related concepts needed to understand the topic. After completing the storylines, she asked the pre-service teachers to find the key concepts and to perform different activities such as completing worksheets and creating diagrams. At the end of the lessons, she summarized the concepts through power-point presentations.

The experimentation process was completed in eight hours that lasted for four weeks. Two weeks after the intervention, the SMAT and the CAS were re-administered to the study population as a post-test. To measure how the



intervention affected primary pre-service teachers' long-term memory (retention), the same instruments were given as a delayed-test four months after the intervention.

Results and Discussion

a. Results from the SMAT

The first research question for this study was to determine whether the storylines embedded within a context-based approach caused a statistically significant improvement in the levels of pre-service teachers' understanding of matter and its states, or not. After the sections (multiple-choice and open-ended) of the SMAT were examined in detail, mean scores and standard deviations for each of the test applications (pre-, post-, and delayed-test) were computed. The results are presented in Table 4.

Table 4. Mean scores and standard deviations of pre-, post- and delayed-tests

Tests	N	Multiple-Choice Section		Open-Ended Section	
		Mean	SD	Mean	SD
Pre-test	35	28.89	7.17	8.2	2.89
Post-test	35	46.03	8.39	12.17	2.06
Delayed test	35	45.38	8.58	12.75	1.94

The students gained 17.14 (22.85 out of 100) points on average in the multiple-choice section and 3.97 (24.46 out of 100) points on average in the open-ended section from pre-test to post-test (Table 4). These differences are quite high when compared with the results of other experimental studies in the science education literature (e.g., Demircioğlu et al., 2005; Özmen et al., 2009). After examining mean changes from post-test to delayed test, a decrease of 0.65 points was found in the multiple-choice section, as there was an increase of 0.58 points for the open-ended section. To statistically test the retention and knowledge development of matter and its change, we conducted a one-way ANOVA for repeated measures analysis and LSD test for post hoc comparisons on the scores of pre-, post-, and delayed-tests. The results are summarized in Table 5.



Table 5. The results of one-way ANOVA for repeated measures on the scores of pre-, post-and delayed-test

Sections of SMAT	Source	Sum of square	df	Mean square	F	p	Difference(LSD test)
Multiple-Choice Section	Intervention	6531.43	2	3265.21	239.67	.000	2-1; 3-1*
	Error	926.57	68	13.63			
Open-Ended Section	Intervention	428.59	2	214.29	74.32	.002	2-1; 3-1*
	Error	196.07	68	2.88			

* 1: pre-test, 2: post-test, 3: delayed-test

As seen from Table 5, the effect of the intervention on pre-service teachers' achievement is statistically significant in both the multiple choice section ($F(2;68) = 239.67$; $p < 0.05$) and the open-ended section ($F(2;68) = 74.32$; $p < 0.05$). The LSD post hoc test results showed that while there were statistically significant differences between pre-test and post-test and between the pre-test and delayed-test, there is no significant difference between the post-test and delayed-test in both sections of the survey (Table 5). Since the only independent variable was the intervention, it could be concluded that this difference likely resulted from the context-based learning materials.

To determine if the pre-service teachers' achievement differed in subtopics, the results of the questions related to each content area listed in Table 1 were computed independently. Means and standard deviations identified from each set of questions are given in Table 6. The results are given out of 100.

Table 6. Student teachers' performances in subtopics

Content areas (Item no)	Pre-test		Post-test		Delayed-test	
	Mean	SD	Mean	SD	Mean	SD
	%	%	%	%	%	%
States of matter (1,2,7,16,18,24)	44.44	15.83	74.44	22.39	76.98	22.35
Evaporation (3,4,22)	55.24	30.55	46.03	18.09	86.03	18.35
Condensation (5,6,8,13,21)	67.81	26.35	45.38	21.78	80.38	23.82
Particulate nature of matter (9,10,11,12,14, 23)	43.65	15.07	78.73	22.40	74.29	18.67



Boiling(15,19,25)	45.71	39.05	67.14	34.18	65.71	33.81
Temperature curves (17,20)	41.43	41.10	72.86	40.84	72.86	42.60

As seen in Table 6, pre-service teachers' performance in each subtopic had notable increases from the pre-test to the post-test, ranging from 13.33 (condensation) to 35.08 (particulate nature of matter). The pre-test means for condensation ($M=67.81$) and evaporation ($M=55.24$) are higher than others (Table 6). It should be noted that pre-service teachers were more familiar with these two concepts (condensation and evaporation) than others. The reason for this could be that students are faced with these two concepts in their daily life more often. Mean changes of each subtopic in Table 6 were compared by using Wilcoxon signed ranks test. The results obtained from the analysis showed that the mean change of each subtopic from pre-test to post-test was statistically significant at the 0.05 level.

As seen from Table 6, while the mean for the states of matter subtopic increased 2.54 points, the others decreased or remained unchanged from post-test to delayed-test. According to Wilcoxon signed ranks test, the mean change from the post-test (74.44%) to delayed-test (76.98%) for states of matter subtopic was found to be significant at the 0.05 level.

These are similar findings reported in the literature that point to positive effects of context-based approach on student achievement in chemistry (Barker & Millar, 1999; 2000; Belt et al., 2005; Demircioğlu et al., 2009). Teaching materials used in these studies were more useful than the traditional approaches in teaching complex chemistry concepts.

The intention of the second research question was to determine how the teaching activities based on the context-based approach influenced pre-service teachers' retention and long-term memory of new conceptions about matter. In other studies investigating the retention of knowledge, a decrease from post-test to delayed-test is generally observed. However, this study identified a 0.58 point increase in the open ended section (Table 4) and a 2.54 point increase in the states of matter subtopic (Table 6). This finding is promising for science education; it shows that the intervention caused a retentive change in pre-service teachers' knowledge structures (Banister & Ryan, 2001; Barker & Millar, 2000) and, more importantly, it reveals that some students continued to configure the concepts in their mind even after the treatment (Çalık, 2006). These results contradict with the literature where



after an intervention minor decreases over time are often reported in student achievement (e.g., Coştu, 2006; Çalık et al., 2010).

These results are indicators for the effectiveness of such an approach on pre-service teachers' understanding and their retention of knowledge. The reason for this effectiveness is probably due to the storyline-based discussions, the detailed explanations found in materials, and the relation of daily-life to the materials. These results concur with other studies showing positive effects of both storylines and context-based approach on students' understanding of chemistry concepts (Barker & Millar, 1999; 2000; Belt et al., 2005; Demircioğlu et al., 2009).

The third research question for the study was to determine whether the storylines embedded within a context-based approach are effective in overcoming pre-service teachers' alternative conceptions of matter and change, or not. The alternative conceptions concerning the matter and its states were determined by the pre-service teachers' responses to questions in the SMAT. To focus on the major misconceptions held by students, only alternative conceptions held by 17% or more of the students (i.e., at least 6 students) in the pre-tests were analyzed. To consider each and every alternative conception would not show useful statistical evidence and would distract from the notable findings. The percentages of these alternative conceptions determined in the pre-, post-, and delayed-test are given in the Table 7.

Table 7. Pre-service teachers' alternative conceptions determined in the pre-test and post-test

Alternative conceptions	Pre-test	Post-test	Delayed-test
	%	%	%
Particle size would increase as it changed from liquid state to gas state.	44	5.7	5.7
Solid state of a substance is heavier than its liquid or gas state	48.6	17.1	11.4
Gas is the densest state of substance	22.9	5.7	0
Evaporation does not occur at all temperatures	40	14.3	8.6
The cold transforms the oxygen and hydrogen found in the air into the water	17.1	8.6	14.3
Gases are not fluid	25.7	14.3	5.7
There is water or air between two water molecules	54.3	25.7	31.4



Solid particles begin to vibrate in the melting point	22.9	0	14.3
The boiling point of a substance never changes	31.4	14.3	5.7
The boiling point of liquids decrease at high pressure	25.7	8.6	0
Gases do not have mass	17.1	0	0
Particles of a substance are solid in solid phase, liquid in liquid phase, and gas in gas phase	31.4	5.7	5.7
The cause of the smoke rising from an ice cube taken out of the freezer is evaporation	20	8.6	5.7

The results from the pre-test showed that pre-service teachers held a large number of alternative conceptions before receiving formal instruction on matter and change. After the intervention, they showed progress in eliminating their alternative conceptions and corrected two alternative conceptions completely (Table 7). In addition, the sample completely corrected one more alternative conception in the delayed-test. These results likely reflect the effectiveness of the materials. The ratios of alternative conceptions from pre-test to post-test and delayed test show that storylines embedded within a context-based approach contributed to an acquisition of the scientific conceptions and elimination of alternative conception.

From implementation of the SMAT as a pre-test, thirteen alternative conceptions were identified. While the percentages of students' alternative conceptions in pre-test ranged from 17.1% to 54.3%, these ratios in the post-test ranged from 0% to 25.7%. And also, these ratios in the delayed test ranged from 0% to 31.4% (Table 6). These results show that the teaching activities based on the context-based approach helped pre-service teachers to overcome their alternative conceptions.

The most common alternative conception encountered in this study is “*there is water or air between two water molecules*” (see Table 6). Similar alternative conceptions have been reported in the literature. For example, Lee et al. (1993), Novick and Nussbaum (1981), and Osborne and Freyberg (1985) studied with students of different ages (12, 13, 14 ages) and found the same alternative conception. To address this misconception, the CBTM developed for this study included *is each substance compressible?* (storyline 2), along with activities, discussions, and a power point presentation. While the teacher was telling storyline 2, she showed the presentation consisting of movement and arrangement of solid,



liquid and gas particles and discussed differences as the occasion arose. As could be seen in Table 7, such applications were effective in overcoming the alternative conception to a certain extent (54.3% in pre-test, 25.7% in post-test). Although storyline 2 and activity 2 aimed to overcome the pre-service teachers' alternative conceptions, 25.7% of the pre-service teachers continued to retain the same alternative conceptions. The microscopic nature of the content might have made it difficult for pre-service teachers' to understand the concept; some might have failed to transfer their macroscopic-level knowledge learned from the materials to the microscopic-level.

Another common alternative conception encountered in the study is that the *“solid state of a substance is heavier than its liquid or gas state”* (see Table 7). For this belief, pre-service teachers provided different explanations such as *“...gap between molecules in gas is more.”* *“...molecules in the solid are more tightly packed,”* and *“...number of the particles in gas is lower.”* None of the reasons is scientifically acceptable and similar alternative conceptions are also reported in the literature (Coştu, 2006; Demircioğlu, 2008; Lee et al., 1993; Osborne & Cosgrove, 1983; Stavy, 1990). For example, Stavy (1990) reported that students (age 9-15) believed that gas is lighter than the same material in its liquid or solid state or that gas has no weight. Durmuş and Bayraktar (2010) reported the latter alternative conception, as well. The teachers in Turkish schools generally use the following pictures (Figure 2) to visualize the particles in their students' minds and some textbooks contain the same pictures. Such images may cause students to think that solid phase is heavier.

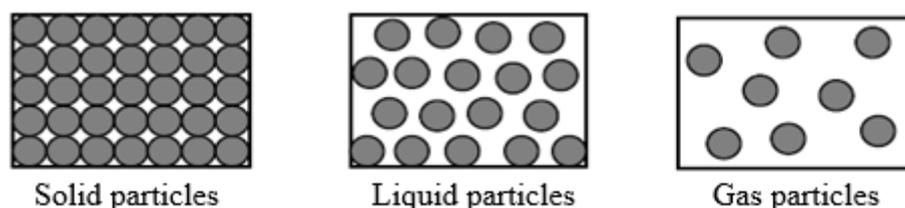


Figure 2. The particle pictures used by Turkish teachers and some textbooks

To overcome this alternative conception, Storyline 1 and Activity 1 were used. When the teacher told Storyline 1, she asked students to find and discuss key concepts in it. She used questions such as “what does matter mean for you?” and “what is matter made of?” Then, pre-service teachers performed Activity 1 (see



Appendix B). In this activity, they had the chance to observe that the weight of a piece of ice did not change by its phase. Whole-class discussion followed the activity and Figure 3 was shown to the pre-service teachers to summarize the concept.

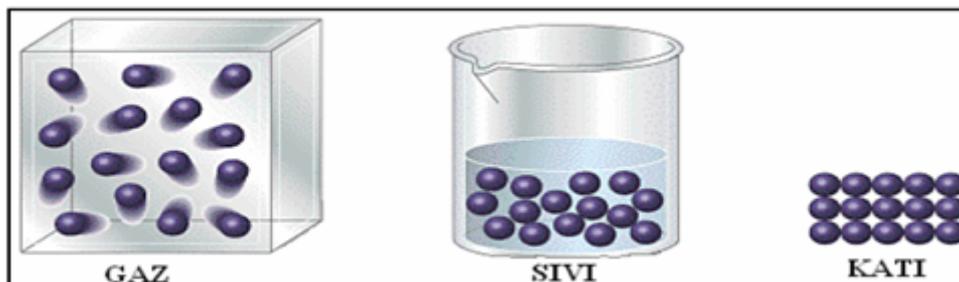


Figure 3. The particle pictures used in the present study

As can be seen in Table 7, such applications became effective in overcoming the alternative conception to a certain extent (48.6% in pre-test, 17.1% in post-test). However, this ratio decreased to 11.4% in delayed test showing that some of the sample population reverted to their earlier conception.

When table 7 is examined, it is seen that ratios of the alternative conceptions decreases from pre-test to post-test and delayed test. In some cases, however, there is an increase from post-test to delayed test. Because we used a new teaching approach in the experimental group based on storylines and activities, we can easily say that this approach is effective in addressing understandings and alternative conceptions. This conclusion is supported by a comparison of the pre-test and post-test results.

Given that student alternative conceptions are specially addressed during instruction, the decreasing the ratios from the pre-test to post-test are not surprising. And we cannot ignore that the post-test shows that a high ratio of students still have some alternative conceptions. For instance, the ratios of some alternative conceptions, “*the cold transforms the oxygen and hydrogen found in the air into the water,*” “*there is water or air between two water molecules,*” and “*solid particles begin to vibrate in the melting point,*” increased from the post-test to delayed test.



One reason for this can be that some pre-service teachers who were taught through traditional teaching methods were unwilling to participate in different teaching methods presented in the current study. Therefore, such students might not attend to the applications sufficiently. Those learning habits might have caused them to retain their alternative conception in post-test or to revert back to them before the delayed test.

The likely reason for this was that some students moved back to previous ideas. It has been argued that students' original beliefs are probably changing in the long run, even though they may give correct answers to the test (Rutherford & Ahlgren, 1991). These results show us the well-known reality that alternative conceptions are pervasive, stable, and resistant to change and often held even after the completion of years of formal science instruction (Guzzetti, 2000).

Despite evidence that supports strong commitment to alternative conceptions, our study revealed a change that gives hope to the ability promoting conceptual change. We found it remarkable that the ratios of some alternative conceptions decreased from the post-test to delayed test. These results reveal that the new teaching approach and materials may help students to continue constructing knowledge even after formal instruction. Furthermore, the decreasing ratios from the post-test to delayed test may indicate that the construction of knowledge takes time, continues beyond the time of instruction, and becomes more meaningful for students as time passes. In another words, consolidation of some learning continues over many months.

b. Results from the CAS and the Interviews

Another factor under investigation in the present study was pre-service teachers' attitudes towards chemistry. The statistical significance of the difference between pre- and post-CAS means was determined by using paired-samples t test. The results and descriptive statistics of analysis are given in Table 8. As can be seen from Table 8, mean and standard deviation of attitude scores were 51.09 ± 9.53 before the intervention as they were 57.94 ± 8.74 after the intervention. The pre-service teachers' mean scores showed an increase of almost 7 points and the effect of the intervention on attitude scores is statistically significant ($t(34)=6,93$; $p<0,05$).

Table 8. Summary of the paired-samples t test on scores of pre- and post-CAS



	N	Mean	SD	Mean Difference	df	t	p
Pre-CAS	35	51.09	9.53	6.85	34	6.93	.000
Post-CAS	35	57.94	8.74				

The results showed that the context-based approach had a strong effect on attitudes towards chemistry; the pre-service teachers were more motivated to participate in chemistry classes. Context-based courses inform students why they need to know scientific ideas; therefore, this result is expected. The results are consistent with related literature that indicates context-based approaches produced significantly better understanding of science ideas and more positive attitudes (Bennett, 2005; Tsai, 2000; Winther & Volk, 1994; Yager & Weld, 1999). Also, Bennett et al. (2003) reported that context-based approaches motivated students to learn science lessons and stimulated their interest in science. In addition, we observed that pre-service teachers were very willing to discover key concepts in the storylines and to complete the worksheets.

The pre-service teachers participating in the interview said that they have never encountered chemistry teaching based on storylines; therefore, they found this application remarkable and different. Also, the pre-service teachers found concepts presented in a story format more interesting than those presented in expository text. Graesser et al. (1994) also reported that teachers found stories easier to comprehend and remember than other forms of text such as expository text. The following excerpts support this claim:

-“...teaching style of a teacher is very important to love and be interested in lesson. ...I learned the states of matter concepts a few years ago, but now I do not remember. ...I will remember the concepts you taught with the context-based approach even after 4-5 years (a female pre-service teacher).

-“I think that stories increase the retention. When the concepts are taught through stories, I find myself in the story and would like to participate in class. I do not forget the concepts. ...the story and its heroes are easier to remember than concepts or formula. A person do not easily forgets it, but s(he) forgets a formula or a concept a week after an exam” (a male pre-service teacher).

-“...I loved the stories...”, I wish other chemistry topics also were taught by using this method...” (a female pre-service teacher).



It is understood from interviews that the courses based on context-based approach are more enjoyable and understandable than previous chemistry courses and the stories used in the study make a significant contribution to this process. The following excerpts support this assertion:

-“I start to love chemistry. With this course, everything starts to become more understandable. In the previous way, everything was more abstract and more difficult to understand. In this way, I learned more... (a male pre-service teacher).

-...Stories made concepts more understandable...”(a female pre-service teacher).

-...”In this way, I learned better by seeing and doing experiments...”(a female pre-service teacher).

The twenty-week time period between the post-test and the delayed-test is considered to be adequate to test the retention of knowledge. Despite the elapsed time from the post-test to the delayed-test, most teacher candidates did not forget the concepts they learned during the intervention and did not revert to earlier alternative conceptions. This showed that the storylines, activities, class and group discussions, power-point presentations, and the pictures and animations used in the study were effective for the retention of pre-service teachers' understanding and for addressing their alternative conceptions.

c. Correlations between the CAS and the SMAT

The final research question for the study was to determine whether correlations between the pre-service teachers' attitudes towards chemistry and their achievement on the matter and its states were statistically significant. Correlations between scores of the pre- and post-CAS and scores of each section of the SMAT pre- and post-tests are given in Table 9. As seen in Table 9, there were significant correlations levels between pre- and post-test scores for the following:

- multiple choice section of SMAT and pre- and post-test scores of CAS (at 0.01 level);
- pre-test scores of the open-ended section of the SMAT and post-CAS scores (at 0.01 level);
- post-test scores of the open-ended section of SMAT and post-CAS scores (at 0.05 level).

However, there was no significant correlation between pre- and post-test scores of open-ended section of SMAT and pre-CAS scores. From this, it can be said that



there was a meaningful correlation between students' attitudes towards the concepts under investigation and their achievement.

Table 9. Correlations between scores of pre- and post-CAS and scores of each section of pre- and post-SMAT

Tests	Multiple Choice Section of SMAT		Open-Ended Section of SMAT	
	Pre	Post	Pre	Post
Pre-CAS	0.46**	0.52**	0.24	0.12
Post-CAS	0.53**	0.66**	0,55**	0,34*

** Correlation is significant at 0.01 level

* Correlation is significant at 0.05 level

It is already known that as attitude scores increase, learner achievement increases and that there is a significant correlation between attitude and achievement (Coleman, 2009). In the present study, the context-based materials contributed to a significant improvement on pre-service teachers' attitudes towards chemistry and a meaningful correlation was found between attitude and achievement.

Conclusions and Implications

A primary purpose of this study was to investigate the effect of storylines embedded within the context-based approach on pre-service primary school teachers' understanding of matter and phase change concepts. The research findings reported here show that the teaching intervention improved conceptual understanding and significantly corrected alternative conceptions. Another important purpose was to help pre-service teachers add new knowledge to their long-term memory. The results obtained for this purpose indicated that the teaching intervention used in this study helped students to retain correct conceptions about the states of matter. The teaching intervention facilitated meaningful learning by improving the ability of pre-service teachers to link theoretical knowledge with real life.

Furthermore, the storylines embedded within the context-based learning positively affected attitudes towards chemistry. Pre-service primary school teachers listened to the related story carefully and were very willing to discover the key concepts in the storylines, to ask questions, and to complete the worksheets. Throughout the



intervention, students were kept both physically and mentally active; therefore, these positive effects likely stemmed from teaching based on the context-based approach.

Typically, pre-service teachers receive teacher-centered instruction at the university level. Consequently, many of them are prejudiced against the storylines embedded within the context-based approach. However, studies have shown that completing storylines and participating in discussions enable students to see how their peers think and to share ideas by investigating, analyzing, and explaining the phenomena presented or contradictory theories (e.g., Erduran, 2007; Yan & Erduran, 2008). Since the context-based approach enhances interactions among learners, their attitudes changes day-by-day and improves significantly.

The storylines based on the context-based approach used in this study facilitated pre-service teachers' meaningful learning and helped overcome alternative conceptions. Therefore, we suggest that the storylines and other activities used in this study, as well as in other studies, should be placed in chemistry textbooks for better learning. Also, teachers should be trained in the preparation and use of storylines. There is a need for regular and substantial in-service teacher training programs to improve teaching approaches. Within these programs, teachers should be informed about storylines and the context-based approach and be persuaded to adopt them in preference to their theoretical frameworks. This should involve giving teachers practical experience in the design and implementation of new approaches (e.g. Stolk *et al.*, 2009a; 2009b). By doing this, the teachers may create an enriched learning environment where students can actively participate in the tasks in context of their learning process. Furthermore, such context-based activities should be incorporated in both the student textbooks and the teacher guide books.

Although the one group pre-test/post-test designed for this study does not allow for comparison between different groups, this limitation should not compromise the effect of the adopted teaching approach. Studies have shown that most teaching approaches that differ from traditional instruction promote better students' understanding and achievement in matter and its states chemistry (e. g., Chang, Quintana & Krajcik, 2010; Durmuş & Bayraktar, 2010; Özmen, 2011). For this reason and based on the results of this study, we feel confident that the teaching



approach in the study was effective on improving pre-service teachers' understanding and alternative conceptions.

Storylines should be used as a starting point for teaching chemistry concepts and they should take into account student difficulties in understanding certain concepts. The storylines should be relevant for students and should motivate them to study the chemistry concepts. Another important condition for improving context-based chemistry teaching is a careful selection of storylines.

Since the study was conducted with only 35 first-year pre-service teachers enrolled in the primary teacher education program and only with concepts related to the states of matter, further studies with a larger population and with different topics should be undertaken to generalize the findings. This study may be considered as a small step in developing effective teaching strategies in Turkish schools regarding the context-based approach.

In our country, there has been an ongoing transition from teacher-centered instruction to student-oriented approaches in most chemistry classes. During this transition, the storylines embedded within the context-based approach can be used to improve students' understanding of science concepts and dispel their alternative ideas.

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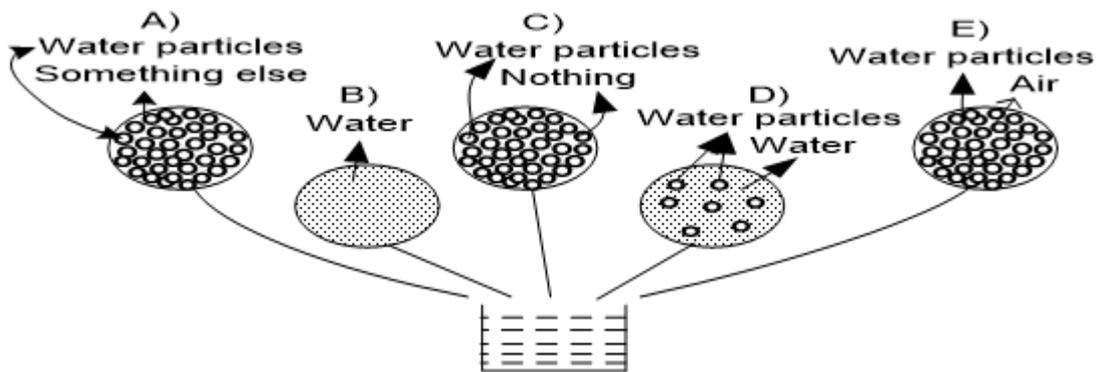
Appendix A

Examples of the items in SMAT

Item 3: Which of the followings is false about evaporation? (developed by the researchers)

- Evaporation begins after a substance is heated until its boiling point. *
- Evaporation occur at all temperatures.
- The vapor pressure of a liquid depends on its molecular structure and the temperature.
- The vapor pressure of a liquid has the lowest value at freezing point of liquid.
- If the attractive forces between molecules of a liquid are less, the liquid evaporates more easily.

Item 10: Your picture of pure water in its finest detail, would be most like which of the following drawings? (adapted from Osborne and Freyberg, 1985).



Item 22: In the summer, smokes rises from the soil after rain. What is the reason of this event occurring? Please explain.

Item 24: When you compare the states of matter (solid, liquid and gas) in terms of weight what would you say? (in a closed container). Please explain.



Appendix B

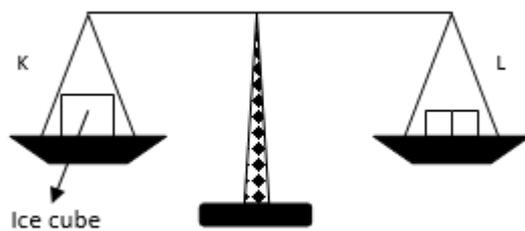
Activity 1: What are all substances mainly made of? (Translated from Turkish)

Name and Surname:

Group name:

In the following figure, an ice cube is in pan K, balanced by weights in the other pan. After a period of time, the ice melted completely. When the ice in the pan K melts, what happens to the balance?

Write your answer



.....
.....
.....
.....
.....



Now, let's perform the following activity.

Materials:

One small balloon, one small flask, one ice cube, a match, a piece of string, hot plate, balance, oven mitt.

Procedure:

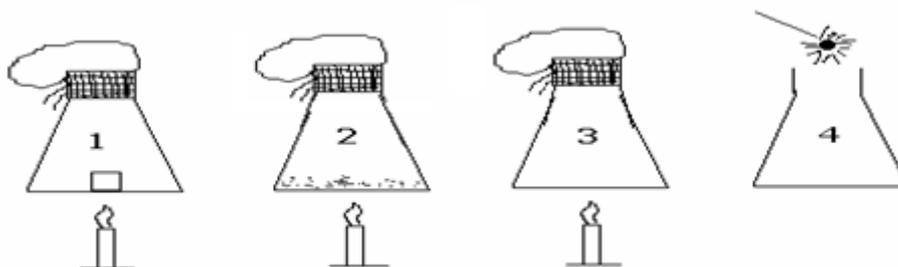
1. Weigh the flask, ice cube, and balloon using the balance. Record the weight on the following data table.
2. Stretch the open balloon over the top of the flask and tie it with a string.
3. Heat the flask until the ice cube melts. Write down your observations of the ice cube and the balloon on the data table.
4. Using an oven mitt, place the bottle with balloon on the balance; record the weight on the data table.
5. Heat the flask until the water evaporates completely. Write down your observations of the water and the balloon on the data table.





- Using an oven mitt, place the flask with balloon on the balance; record the weight on the data table.
- Quickly hold the *burning* match *into* the mouth of the flask.

Write down your observations of the burning match on the data table.



Data table

	Weight (gram)	Observations
Flask, balloon, ice cube		
Flask, liquid, balloon		
Flash, water vapor, balloon		
Experience of the burning match		



Questions:

- What do you think caused the balloon to expand?
- If water changes states from liquid to gas to solid, how does its mass change?
- If water changes states from liquid to gas to solid, how does the size of its molecules change?
- If water changes states from liquid to gas to solid, how do interactions between molecules change?

Congratulations !