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THE EFFECT OF STORYLINES EMBEDDED WITHIN CONTEXT-BASED LEARNING APPROACH ON GRADE 6 STUDENTS' UNDERSTANDING OF 'PHYSICAL AND CHEMICAL CHANGE' CONCEPTS

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Abstract. *Alternative conceptions of 'physical and chemical change' concepts to minimize their effects on further learning should be handled at lower secondary school in that these concepts are formally introduced at grade 6. This study aimed to investigate the effect of storylines embedded within context-based learning approach on grade 6 students' understanding of 'physical and chemical change' concepts. To probe the students' conceptions, Chemical and Physical Change Concept Questionnaire (CPCCQ) was employed as pre- and post-test. The results indicated that most of the students tended to pay more attention to 'reversibility' criterion in distinguishing 'chemical change' concept from 'physical change' one. Finally, it can be deduced that the storylines embedded within the context-based learning approach not only resulted in a better meaningful learning but also increased student achievement level. To give an opportunity for the students to grasp the relevance of chemistry/science to their lives, the meaning of each daily life concept should be bridged with that in a chemistry context.*

Key words: *alternative conception, context-based learning approach, chemical change, physical change, science education, storylines.*

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Introduction

Because students are introduced with some abstract concepts in early ages, they find such concepts difficult to learn and visualize (i.e. Çalık, Kolomuç & Karagölge, 2010; Gökdere & Çalık, 2010). For example, in Turkish context, the students formally learn particulate nature of matter, chemical change and physical change at grade 6 (aged 11 and 12 years). This means that such concepts require the students to possess abstract reasoning competency. If not, the students may construct various alternative conceptions, which are different from the scientifically accepted one (e.g. Bakırcı & Çalık, 2013; Ben-Zvi, Eylon & Silberstein, 1987; Johnson, 2000). For example, a few studies report that students at different grades have difficulty in understanding 'physical and chemical change' concepts (Ayas & Demirbaş, 1997; Çalık & Ayas, 2005a; Gabel, 1996; Johnstone, 1991; Johnson, 2002; Robinson, 2003; Stavridou & Solomonidou, 1989; Tsaparlis, 1997). In fact, 'physical and chemical change' concepts play a significant role in making sense of further chemical phenomena, i.e. equilibrium, redox, radioactivity, chemical reactions. For this reason, an intervention study that facilitates lower-secondary students' conceptions of these concepts can be seen as a cornerstone for further learning.

Theoretical Framework

Because school science fails to get most students to sustain curiosity of the real world, science educators have attempted to find alternative ways. Of these alternative ways, the context-based learning approach links theoretical knowledge (school science) with daily (real) life. Thereby, it yields a 'need to know' basis and increases their enthusiasm towards science (e.g. Pilot & Bulte, 2006; Ültay & Çalık, 2012). For this reason, several context-based learning approaches have been developed in various countries: e.g. Salters Advanced Chemistry in the UK (Barker & Millar, 2000; Bennett & Lubben, 2006), *Chemistry in Context* in the USA (Schwartz, 2006), Industrial Chemistry in Israel (Hofstein & Kesner, 2006), Chemie im Kontext in Germany (Parchmann, Gräsel, Baer, Nentwig, Demuth, Ralle & the Chik Project Group, 2006), Context-concept Approach in the Netherlands (Bulte, Westbroek, de Jong & Pilot, 2006). Of these context-based learning approaches, The Salters Advanced Chemistryinvolves "Storyline", "Chemical ideas" and "Activities" (Barker & Millar, 1999, 2000; Hughes, 2000; Pilling, Holman & Waddington, 2001; Demircioğlu, Demircioğlu & Ayas, 2006b; Demircioğlu, Demircioğlu & Çalık, 2009**;** Bennett & Lubben, 2006). However, the storylines to create the 'need to know' basis could be viewed as the "backbone" of the Salters Advanced Chemistry (Bennett & Lubben, 2006). By doing this, the Salters Advanced Chemistry gives an opportunity for the student to analyze some phenomena that they encountered in daily life and to perceive how science is relevant with daily life (as a context) (TPSI, 1991). Also, finding pathways through known and unknown territories of knowledge, the storylines improve student cognitive processing and narrative structures (Barry, Berry, Cunningham, Newton, Schweppe, Spalter, Whiteley & Williams, 2006). Further, the storylines enhance the students' enthusiasm towards science and their understanding of science concepts in that they are effective in such targeted features as communicating ideas, making ideas meaningful, increasing student engagement, generating a dynamic-organic "game" for learning, and enriching the learning environment with contradictory voices (Banister & Ryan, 2001; Barry et. al., 2006; Millar & Osborne, 1998). Given these advantages of the storylines, the authors employed the storylines in the current study.

Overview of 'Physical and Chemical Change' Concepts

Relevant literature indicates a number of alternative conceptions of 'physical and chemical change' concepts. These are: (1) a chemical reaction occurs during phase change (Ahtee & Varjola, 1998; BouJaoude, 1992; Novak & Musonda, 1991; Stavridou & Solomonidou, 1998), (2) a chemical reaction happens when a substance dissolves (Abraham, Williamson & Westbrook, 1994; Ahtee & Varjola, 1998; BouJaoude, 1992; Eilks, Moellering & Valanides, 2007; Novak & Musonda, 1991; Stavridou & Solomonidou, 1998; Valanides, 2000), (3) a chemical change is always irreversible (Cavallo, McNeely & Marek, 2003; Çalık & Ayas, 2005a), (4) any change at sub-microscopic level is the same as that at macroscopic one (Andersson, 1990; Lee, Eichinger, Anderson, Berkheimer & Blaskeslee, 1993), (5) a chemical reaction always require two reactants (Cavallo et al., 2003; Eilks et al., 2007), (6) a chemical reaction transforms reactants' particles into different ones (Andersson, 1986), (7) total amount of the matter is not conserved during phase change (Lee et al., 1993; Stavy, 1990), (8) total mass is not conserved in a chemical change in which gases give off (Hesse & Anderson, 1992; Özmen & Ayas, 2003), (9) a chemical reaction make atoms disappear (Andersson, 1986; Mitchell & Gunstone, 1984). Furthermore, these alternative conceptions have been elicited at varied samples: grade 6 students (Mitchell & Gunstone, 1984), grade 7 students (Ahtee & Varjola, 1998; Eilks, Moellering & Valanides, 2007), grade 8 students (Ahtee & Varjola, 1998; Çalık & Ayas, 2005a), grade 9 students (Cavallo, McNeely & Marek, 2003), grade 10 students (Özmen & Ayas, 2003), grade 1 to grade 12 students (Novak & Musonda, 1991), high school students (BouJaoude, 1992; Hesse & Andersson, 1992), student teachers (Valanides, 2000; Çalık & Ayas, 2005a), 9-15 year-old students (Stavy, 1990), 12 to 18 year-old students (Stavridou & Solomonidou, 1998), and 12-16 year old students (Andersson, 1990). Taking the samples in the aforementioned studies into account, it can be inferred that an increase in educational level (grade) does not remedy the alternative conceptions. For this reason, the alternative conceptions of the 'physical and chemical change' concepts to minimize their effects on further learning should be handled at lower secondary school in that these concepts are formally introduced at grade 6. Overall, the foregoing studies call for a need to facilitate the grade 6 students' conceptual understanding and to overcome their alternative conceptions. By doing this, the authors hypothesize to eliminate conventional instruction driven alternative conceptions.

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The Aim of the Study

The aim of this study was to investigate the effect of the storylines embedded within context-based learning approach on grade 6 students' alternative conceptions of the 'physical and chemical change' concepts. Within this aim, the following research question is specifically explored: Do the storylines embedded within the context-based learning approach cause a statistically significant change in students' understanding of the 'physical and chemical change' concepts?

Methodology of Research

The present study followed a pre-experimental research design (one group pre-test/post-test design) (Ohlund & Yu, 2009). That is, the experimental group in the present study did not have a comparison (control) group. This issue may be seen as a pitfall of the study. Indeed, Trochim (2001) views such a research design as validity threat in that its lack of random assignments and control group, limits confidence in assigning causality to an intervention. But he also discusses such design is worthwhile in particular circumstances, i.e. use of complex intervention. For the present study, the main validity threat is viewed as being involved in 'a teaching intervention' which may of itself result in an apparent improvement in conceptual understanding (e.g. Trochim, 2001; Çalık, Ayas & Coll, 2010; Çalık, 2013). However, the inclusion of a pretest within the pre-experimental design to determine baseline scores may reduce this validity threat (Heffner, 2004). Also, using the underlying science content of the 'physical and chemical change' concepts (instead of directly aligning with the curriculum) in *Chemical and Physical Change Concept Questionnaire (CPCCQ)* indicates effect of independent variable (the storylines embedded within the context-based learning approach) on dependent variable (student understanding) and decreases the pre-experimental research design's validity threat (Sadler, 2009).

Sample of Research

This study was conducted with 35 (18 girls and 17 boys) grade 6 students in a primary school in the city of Trabzon, Turkey.

Instrument and Procedures

To decide the CPCCQ's content, the authors examined grade 6 science and technology curriculum and studies of 'physical and chemical change' concepts (e.g. Cavallo, McNeely & Marek, 2003; Çalık & Ayas, 2005a; Stavridou & Solomonidou, 1989). Then, they devised *Chemical and Physical Change Concept Questionnaire (CPCCQ)* with ten multiple-choice items (5 items for discriminating physical change from chemical change--, 5 items for identifying change(s) in inner or outer structure (composition) of the matter in physical and chemical change) Also, a group of experts, i.e. three chemistry educators and two science teachers went over the questionnaire and confirmed its content validity. In addition, the questionnaire was pilot-tested with forty grade 7 students who had already attended the concepts under investigation. Its Cronbach alpha reliability coefficient was found to be 0.82 which is quite higher than the acceptable value (0.70) suggested by Hair, Black, Babin, Anderson, & Tatham (2006). Two of items in the CPCCQ is displayed in the following:

Item 3: Which of the following is a chemical change example?

a) melting of ice
b) corrosion of zinc*
c) telephone wires sag
d) dissolving of salt into water

Item 4: Which of the following does not change with an increase in temperature of oxygen gas in an elastic balloon?

e) Volume
f) Distance between particles
g) Mass*
h) Physical properties

The CPCCQ was administered as a pre-test two weeks before the teaching intervention and re-administered as a post-test two weeks after the teaching intervention. This was deliberate in that the authors planned to allow at least some time distance from the intervention as a means of addressing a Hawthorne type effect (e.g. Çalık, Ayas & Coll, 2007, 2009; Guba & Lincoln, 1994). This time gap means that straight memory recall should be less influential in improved performance.

Teaching Intervention

To develop the context-based learning material (CBLM), the authors examined a number of related resources, such as grade 6 science textbooks, publications of Salters Advanced Chemistry, and grade 6 science and technology curriculum. Given the student active engagement within the context based approach, a two-class hour- teaching intervention (2x45 minutes) was designed. A group of experts, three experienced chemistry teachers (6 to 15-year teaching background) and three chemistry educators (who held PhD in chemistry education), looked over and ensured the content of the CBLM. An outline of the teaching design is represented in Table 1.

Table 1. An outline of the teaching design.

Lesson Plan	Teacher's role	Student's role
First class time	• Teacher began the course with '*The Changes in Our Life*' storyline (Appendix 1). Then, she asked the following questions to stimulate their notions through class-discussion: "*What do you think about the story? What changes happened in this storyline? What do you think about type of change (physical or chemical change)? Please defend your reason*" • After reading the storyline, she asked the students to find the key concepts/events about physical and chemical changes. • She required the students to perform Activity 'Is it a physical or chemical Change?' (Appendix 2) in their small groups of 5-6 students. • She encouraged them to share their views with peers through the class-discussion.	• They found and discussed the related key concepts by carefully reading the storyline. • They performed the Activity *"Is it a physical or chemical change?"* in their small groups of 5-6 students.
Second class time	• She discussed the 'physical and chemical change' concepts via power-point presentation. • She fostered the students to link their results with the scientific ones by asking some related questions. • She called the students to create their own data tables and to presentto the entire class. • She summarized properties of physical and chemical change and presented relevant daily-life pictures and molecular-level images.	• In their small groups, they responded the question prompted by the teacher. • Spokesman of each group presented the results to the entire class. • Each group created their data tables of the properties of physical and chemical change and presented them to the entire class. • They participated in the class-discussion moderated by the teacher.

Data Analysis

In analyzing the CPCCQ data, maximum score was 50 points (5 points for each correct response and zero point for incorrect one). The results of the pre- and post-test's scores were compared using paired-samples t test

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Results of Research

Table 2 indicates frequencies and percentages of the grade 6 students' responses to the CPCCQ for the pre-test and the post-test.

Table 2. Frequencies and percentages of the grade 6 students' responses to the CPCCQ for the pre-test and the post-test.

Principal Theme	Item Number	Incorrect Choices				Correct Choices			
		Pre-test		Post-test		Pre-test		Post-test	
		f	%	f	%	f	%	f	%
Discriminating physical change from chemical change	3	8	23	2	6	27	77	33	94
	5	22	63	5	14	13	37	30	86
	8	8	23	1	3	27	77	34	97
	9	9	26	-	-	26	74	35	100
	6	11	31	1	3	24	69	34	97
Identifying change(s) in inner or outer structure (composition) of the matter in physical and chemical change	2	15	43	4	11	20	57	31	89
	4	28	80	3	9	7	20	32	91
	7	17	49	6	17	18	51	29	83
	1	32	91	2	6	3	9	33	94
	10	12	34	3	9	23	66	32	91

As can be seen in Table 2, percentages of the students who gave correct responses in the pre-test were between 9% and 77%, whereas those in the post-test were between 83% and 100%. Further, as seen in Table 3, the results of the paired samples *t* test showed a significant difference between the pre- and post-test mean scores in favor of the post-test scores ($t= 13.943$, $p<0.05$).

Table 3. The results of the paired samples *t*-test on the pre- and post-test mean scores of the CPCCQ.

Tests	N	Mean	SD	Mean difference	t	df	Sig. (2-tailed)
Pretest	35	32.00	6.09	14.14	13.943	34	0.000
Posttest	35	46.14	3.45				

The grade 6 students' responses to the CPCCQ for the pre-test and the post-test were also analyzed to portray the extent to which conceptual change attained (see Table 4).

Table 4. Percentages of the students' alternative conceptions in the pre-test and the post-test.

Alternative conceptions	PrT	PoT	CC	R
A chemical change only modifies inner structure (composition) of the matter but not change outer structure (composition) of the matter	70	-	+70	R
A chemical change is always irreversible	9	94	-85	NR
Any heating process results only in the physical change	63	14	+49	R
A chemical change does not change chemical composition of the matter	34	9	+25	R

Alternative conceptions	PrT	PoT	CC	R
Phase change of ice into water is a chemical change	23	3	+20	R
Dissolving process is always a physical change	91	6	+85	R
Rusting process is a physical change example	60	9	+51	R
Phase change of matter increases or decreases sizes of particles	80	9	+71	R
Phase change of matter yields a new (different) matter	49	17	+28	R

PrT*: Pre-test,* **PoT***: Post-test,* **CC***: Conceptual change,* **R***: Retention;* **NR***: Not retain;* **+***, positive conceptual change;* **-***, negative conceptual change*

Discussion

As seen in Table 4, a significant proportion of the grade 6 students' alternative conceptions was replaced with the scientific ones. This means that the storylines embedded within the context-based learning approach were effective in remedying their alternative conceptions and achieving conceptual change (Ayvacı & Çoruhlu, 2009; Banister & Ryan, 2001; Demircioğlu et al., 2009; Demircioğlu, 2012). In fact, a conceptual improvement is always an expected issue after any teaching intervention. For the current teaching intervention, given a 'need to know' basis linking theoretical knowledge with practical one seems to have improved their meaningful learning abilities (Banks, 1997; Bennett, 2005; Demircioğlu et al., 2009; Tsai, 2000; Ültay & Çalık, 2012; Winther & Volk, 1994; Yager & Weld, 1999). Moreover, the authors informally observed the grade 6 students' interest to find the key concepts in the storylines and to share their gained experiences with peers through their small groups and class discussion. Such an effect may stem from the nature of the context-based learning approach that stimulates their interests towards science (Bennett, Lubben, & Hogarth, 2003; Ültay & Çalık, 2012). This reveals that the grade 6 students much more willing to engage with the context-based chemistry materials. This is in a harmony with Sutman and Bruce's (1992) claim that North-American high school students were much more willing to engage with context-based chemistry materials than traditional materials.

Unfortunately the context-based learning approach seems to have fully only one out of the nine alternative conceptions (see Table 4). This arises a new hypothesis *'all alternative conceptions cannot be fully diminished with only one learning approach'*. In fact, even though some authors assumed that using a combination of conceptual change methods would fully eliminate all alternative conceptions probed by their samples, they reported that the hypothesis seems to have run only for some alternative conceptions (i.e. Çalık, Ayas & Coll, 2010; Çalık, Okur & Taylor, 2011; Çoruhlu-Şenel, Çalık & Çepni, 2012; Karslı & Çalık, 2012). This appears that hard-core alternative conceptions are resistant to change even if instruction (or intervention) is directly designed to address them (Ayas, Özmen & Çalık, 2010; Demircioglu, 2009; Tanel, 2013; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). In other words, this also advocates that several factors, rather than one factor, may engender to various alternative conceptions (e.g. Çalık & Ayas, 2005a; Kolomuç & Çalık, 2012).

An increase on the alternative conception *'A chemical change is always irreversible'* may be explained with some reasons. That is, due to Piagetian term at this grade (i.e. concrete operational term), the 'physical and chemical change' concepts are taught by means of only irreversibility criterion. However, such an instruction seems to have triggered insidious alternative conceptions to some extent. In fact, our cognitive system contains competitive knowledge types, i.e. alternative conception and scientific conception (e.g. Çalık & Ayas, 2005b; Karslı & Çalık, 2012). Also, dominant knowledge in the cognitive system is initially retrieved from the cognitive mind (e.g. Çalık & Ayas, 2005b). To sum up, the present teaching intervention somewhat seems to have changed this competitive environment in the cognitive system in favor of the scientific conception (see Table 4).

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Conclusions and Recommendations

Even though pre-service education gives an opportunity for pre-service teachers to keep up with contemporary trends in science education , in-service teachers still possess little chance to catch these trends as compared their total numbers, for instance, 400,000 teachers have been employing in nearly 35,000 primary schools in Turkey. In other words, whatever approach is used to improve science education, teachers should be persuaded to its efficacy and benefits. This then indicates a need for regular and substantial in-service teacher training program (Çalık & Ayas, 2008). Therefore, the teachers should be practically informed about the storylines and the context based learning approach. By doing this, the teachers will be able to grasp how to design (or create) a student-centered learning environment (e.g. Çalık & Ayas, 2008; Demircioğlu et al., 2009).

Because textbooks are still seen as one of the main sources in the learning process (e.g. Erdemir & Topçu, 2012), the textbook authors should be informed on contemporary educational trends/approaches. Hence, they may pay more attention on how to adapt these trends into the textbooks. Further, to give an opportunity for the students to grasp the relevance of chemistry/science to their lives, the meaning of each daily life concept should be bridged with that in a chemistry context (De Jong, 2008). Thereby, students' applied knowledge and skills should be paralleled to their theoretical knowledge in order for accomplishing meaningful learning. In a similar vein, they will be able to consider that science and chemistry are everywhere around them. Such an attempt may replace negative attitudes towards science/science courses with positive ones.

Appendices: Please visit the link at http://www.academia.edu/3642652/JBSE_Appendices

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