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Facilitating conceptual change in students' understanding of concepts related to pressure

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Abstract

The aim of this research was to explore the effects of three different types of methods of learning physics (conceptual change-based, real life context-based and traditional learning) on high school physics students in the 11th grade in terms of conceptual change they achieved in learning about the various topics (pressure exerted by solids, pressure in stagnant liquids and gases, buoyancy, Bernoulli's principle). In this study, a pre-test/post-test quasi-experimental method with nonequivalent control group, involving a 3 (group) × 2 (time) factorial design was used. Study group 1 were given the conceptual change texts on the mentioned subjects, study group 2 were offered a teaching approach based on real life context-based learning, whereas the control group was taught in the traditional style. Data for the research were collected with the 'pressure conceptual test'. As a result of research, the number of misconceptions had been reduced or shifted altogether in all three groups. After the instruction, it was seen that none of the students formed new misconceptions. It was found that the most positive change could be seen in the conceptual change text group followed by context-based and lastly traditional. The fact that none of the students formed new misconceptions is important, particularly since research such as the following shows that conceptual change is tenuous and inconsistent, taking time to shift in a sustained manner.

S Online supplementary data available from stacks.iop.org/EJP/37/055702/mmedia

Keywords: conceptual change texts, conceptual change, real life context-based learning, pressure

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1. Introduction

Many studies have shown that students begin physics classes with many preconceived ideas. These preconceptions are often misconceptions in which students do not provide a correct description of the behavior of the physical world that is consistent with the laws of science. In a review of the literature many studies have observed that students enter the learning environment with many misconceptions about topics in physics such as mechanics, optics, electricity, and others (e.g. McDermott and Shaffer 1992, Beichner 1994, Eryilmaz 2002, Besson and Viennot 2004, Sharma and Ahluwalia 2012). The topic of pressure, too, is one that encompasses both invisible and abstract conceptions, and about which students have misconceptions (She 2002).

Students tend to be very determined not to change the misconceptions they have and do not in fact easily change these at all (Schmidt 1997). To shift misconceptions and achieve meaningful learning, the accuracy of existing knowledge must be reviewed and misinformation must be changed in order to pave the way for new knowledge. This is called the conceptual change process (Smith *et al* 1993).

Conceptual change has become a topic in recent years for science teachers and cognitive developers (Vosniadou 2007). The literature reveals that there are studies that have explored the effect of the conceptual change approach on shifting misconceptions in physics (Hynd *et al* 1994, Chambers and Andre 1997, Guzzetti *et al* 1997, Hynd *et al* 1997, Keogh and Naylor 1999, Diakidoy *et al* 2003, Kwon and Cifuentes 2009). These studies have led to the conclusion that a conceptual change approach is in fact effective in shifting students' misconceptions. It has been observed that there are different teaching strategies that are based on the conceptual change approach. For instance, there have been significant comparisons of conceptual change and traditional learning in physics (Muller *et al* 2007, 2008a, 2008b, Gokalp *et al* 2013). In addition, Hill *et al* (2015) investigated conceptual in comparison with representations. Georgiou and Sharma (2014) indicated that focusing on conceptual understanding does improve learning. These studies are specific to physics, but in the literature there are not enough works in physics.

The conceptual change approach has been developed by Posner *et al* (1982). This approach is based on four conditions. (1) Dissatisfaction: the student must be dissatisfied with the concept he knows; that is, he must realize that it is inadequate. (2) Intelligibility: the new concept must be understandable enough for the student. (3) Plausibility: the student must find the new view/concept logical and be able to picture it in his/her mind. (4) Fruitfulness: the new concept must be efficient; in other words, the student must be able to solve similar problems with this new concept.

Among the most commonly used are conceptual change texts, concept mapping, analogies, and extra materials (Stavy 1991). This study analyzes the strategy of using 'conceptual change texts', which are believed to be very efficient (e.g. She 2002, Başer and Geban 2007) in identifying and overcoming misconceptions. Conceptual change texts specify students' misconceptions, clarify their reasons, and explain why they are incorrect by using concrete examples (Guzzetti *et al* 1997).

Both conceptual change and context-based teaching are espoused to be student-centered and constructivist. Conceptual change approach has become the term indicating learning science from constructivist perspectives (Duit 1999). Another approach that has been introduced as an alternative to the traditional learning approach in recent years has been context-based learning (Taasoobshirazi and Carr 2008). This approach, whose theoretical framework is also based on constructivist learning theory, is student-centered. Since usually different approaches to teaching and learning address different aims, a problem with research on

conceptual change is that it is rather difficult to compare the success of conceptual change approaches and other approaches (Duit and Treagust 2003). As the conceptual change approach includes 'metaconceptual' awareness of the students (Vosniadou and Ioannides 1998), with context-based learning activities, students are able to see why they learn something and how they can use that knowledge (Glynn and Koballa 2005).

When the literature is examined, it can be seen that many studies that defend context-based physics learning or developing a context to study physics (e.g. Whitelegg and Parry 1999, Astin *et al* 2002, Colicchia 2005). In the Netherlands, USA, Germany, UK, Canada, Australia and other countries, context-based physics projects or programs have been effectively used in rendering physics more relevant to student experience.

A few works of research were encountered on context-based learning in physics instruction but these studies were conducted with a single group (Kaschalk 2002, Cooper *et al* 2003). At the same time, studies on the effects of context-based learning in physics, on learning outcomes (such as motivation, problem-solving and achievement) and studies that compare these effects with the effects of traditional instruction are considerably few (Wiersta and Wubbels 1994, Murphy *et al* 2006, Tural 2013).

There has been no research encountered in the literature that examines and compares the effects of context-based learning on the conceptual learning. Although the use of conceptual change texts in science instruction is very popular (e.g. Tsai 1999, Palmer 2003, Coştu *et al* 2007), its use in physics instruction (Hynd *et al* 1994, Chambers and Andre 1997, Guzzetti *et al* 1997, Hynd *et al* 1997, Diakidoy *et al* 2003) has as yet not been adequately reviewed.

This research took as its starting point these gaps and was conducted to study and compare the effects of three different types of approaches of learning physics (conceptual change-based, context-based and traditional learning) on high school physics students in the 11th grade in terms of their conceptual change of pressure (pressure exerted by solids, pressure in stagnant liquids and gases, buoyancy, Bernoulli's principle).

The problems of the study were the following.

1. What are the misconceptions students have in groups that practice conceptual change texts, context-based learning and traditional learning, before and after the instruction?
2. What is the conceptual change that students display in the conceptual change texts, context-based learning and traditional learning groups at the end of the instruction compared to the beginning?
3. Are there significant differences between changes (from pre-test to post-test) in the number of students on distribution into groups?

2. Method

2.1. Research design

This study used the pre-test/post-test quasi-experimental method with a nonequivalent control group, involving a 3 (group) $\times$ 2 (time) factorial design. The research was carried out with three groups—two study groups and one control group. In study group 1, the conceptual change text group (CCTG), the physics topics to be taught were introduced using conceptual change texts. Study group 2, the context-based learning group (CBLG), were taught the same topics in the manner recommended by the Turkish Ministry of National Education (2007), implementing the context-based learning approach to the activities and examples in the Physics 11 textbook. In the control group, traditional learning group (TLG), the topics were

Table 1. Distribution of students by gender and group.

Gender	CCTG	TLG	CBLG	Total
Female	16	15	8	39
Male	14	15	22	51
Total	30	30	30	90

Table 2. Example of a test item on the two-tier PCT.

Q.1. Which answer or answers refer to the reason you need wide-soled shoes in order to be able to walk without falling on ground covered with snow?

I. To use the wide sole to reduce friction.
II. To reduce the pressure as a result of a widened surface.
III. To stop from sinking by reducing the weight carried.

A. I only
B. II only
C. I and II
D. II and III
E. I, II and III
F. Other…

Please explain the reason for your answer
…

taught using traditional teaching methods (plain narrative, questions and answers). They all follow the same curriculum specification and learning outcomes, but they were taught using different teaching methods.

2.2. Research group

The research was conducted in three different 11th grade physics classes in an Anatolian high school located in the province of İzmir, Turkey. The three 11th grade classes of the school where the research took place were grouped into study and control groups without prejudice. Students from different primary schools in Turkey have to pass an entrance examination in order to pursue their schooling process in high school, which ensures that all students have almost the same success level. Therefore, these students in three groups were at almost the same level of success. Because education regulations in schools do not allow one to create new groups, it was decided that pre-test post-test quasi-experimental research (the requirements of the full experimental research design cannot be provided) was the most appropriate research design (Gay and Airasian 2000). Three 11th grade classes in the school were randomly assigned to control and study groups. The gender distribution of the groups is shown in table 1.

2.3. Dependent measure instrument

The two-tier pressure conceptual text (PCT) that was prepared on the subjects of pressure and buoyancy was developed to define the students' misconceptions. Treagust and Chandrasegaran (2007) have stated that students' conceptions of topics could be studied in depth if the second tier of the two-tier test was composed of open-ended questions.

Table 3. Distribution of activities by topic in the Physics 11 textbook.

Names of the activities	Content of the conceptual change texts
Which sunk's more?	Pressure in solids
Why are fluids flowing different?	Pressure in liquids
Why did shape of the plastic bottle change?	Pressure in liquids
Why did the bottle spill fast?	Pressure in liquids
What happened to the water?	Gas pressure
We are measuring the air pressure.	Gas pressure
Why did the injector alleviate?	Buoyancy in liquids
Is the weight change?	Buoyancy in gases
Is the object gush out the same height?	Pressure in fluids
Fluid speed	Pressure in fluids

The first version of the test prepared by the researchers consisted of 30 five-choice (one right answer and four distractors) test items and a justification section. To test the content and face validity, the test was reviewed by three physics teachers from two different high schools (with more than 10 years of experience) and three faculty members specializing in physics instruction. In line with the opinions of the specialists, a sixth choice of 'Other (state, if any)' was added to the two-tier test that was developed. The objective of this was to define the different misconceptions that the students may have had that were not offered in the distractors (that were not foreseen). There was only one right answer to each question on the test. Also, before testing for validity and reliability, a pilot run was implemented with 50 students to see whether there was anything the students could not understand.

The 30-item test was tested for reliability in the spring semester of the 2011–2012 academic year in İzmir, Turkey, at two Anatolian high school 11th grade classes, encompassing a total of 169 students. PCT was piloted with these students from different schools. These students had already been taught the concepts of pressure. The analysis of the two-tier pressure conceptual text was completed in two phases. The assessment criteria used in the analysis of the test are described in detail in the data analysis section. Students' scores on each test items were computed (based on the criteria, see table 3) and inputted into SPSS 10.0 to calculate Cronbach alpha estimates of internal consistency. For the reliability of the test, the Cronbach alpha value was found as 0.79 indicating the test as satisfactorily reliable (McMillan and Schumacher 2001). At the end of the calculations, the number of items on the test was brought down to 19. The score range possible on the two-tier test is 0–57. The question below is an example from the PCT (table 2).

2.4. Intervention

2.4.1. Conceptual change texts (*CCTs*). In this exercise, the topics of pressure in solids, liquids and gases and buoyancy, found in the 11th grade unit on 'Matter and its properties' were made the subjects of nine conceptual change texts designed to shift the misconceptions the students may have had. These texts, which were developed by the researcher, were devised to suit the 11th grade level and the curriculum.

The conceptual change texts were developed according to the conceptual change approach introduced by Posner *et al* (1982) which is based on the conditions of dissatisfaction, intelligibility, plausibility and fruitfulness.

After the texts were prepared, two physics instructors with more than 10 years of professional experience and two faculty members specializing in physics education were

enlisted to offer their views. In line with the opinions of the specialists, it was established that the prepared texts were appropriate to the academic level of the students and their knowledge. A pilot study was then launched. During the pilot study, the students were asked if there was anything in the texts that they could not understand; no questions were raised during the implementation of the texts. A sample conceptual change text can be found in the supporting information.

2.4.2. Physics 11 textbook. The 11th grade physics curriculum emphasizes that students should be active learners if what is taught is to be meaningful and retained. The reason the Physics 11 textbook, prepared on the basis of the curriculum, was made the center of the activity is so that students could be prompted into active participation in class. In study group 2, instruction was carried out with a context-based teaching approach in a way that complied with the activities recommended by the Turkish Ministry of National Education (2007). The goal was to have students learn by experiencing and the result of the teaching was reviewed in terms of effectiveness.

The Physics 11 textbook contains ten activities on the topics of pressure and buoyancy. The tools and equipment used in these activities are easily found and usable. In study group 2 in the research (CBLG), each activity was conducted when the related topic was first brought up. In addition, the students were asked to read the texts in the unit and to discuss the activities in class, providing an opportunity for effective participation.

2.5. Procedure

The research was conducted in the fall semester of the 2012–2013 academic year and involved the unit of 'Matter and its properties' in the 11th grade physics course. The pilot study occurred for CCG and CBLG in the spring semester of the 2011–2012 academic year in İzmir, Turkey, at two Anatolian high school 11th grade classes. The duration of the study was a total of seven weeks. In all three groups, a pressure conceptual text (PCT) pre-test and post-test was administered before and after the implementation. The study experiment was initiated immediately after the pre-testing. The same researcher (the first researcher), an instructor that was experienced in high school physics, taught all of the groups. To avoid bias the implementer's (researcher's) every step was planned beforehand and the students' teacher just watched the researcher and gave feedback on whether or not biased. Both groups were instructed for an equal length of time.

2.5.1. Treatment in the conceptual change group. The instruction using the conceptual change texts started by handing out to students the worksheets which contained the first tier of the conceptual change texts. Once the worksheets were distributed, the students were told that they were to follow the instructions on the sheets. After each student received a sheet, a volunteer was called upon to read the text out loud. The objective of this was to encourage participation of the students in the class. The researcher acted as a guide throughout the process and, instead of correcting the students' mistakes, led the students to finding the right answers by themselves. After the topic was covered, the researcher collected the students' worksheets for a review. At the end of every topic, the sample questions prepared by the researcher were answered together with the students.

2.5.2. Treatment in the context-based learning group. In the context-based learning group, the first lesson started out with an intriguing text taken from the Physics 11 textbook. All of the questions for discussions in the textbook were discussed in the classroom as an

Table 4. The criteria for the classification of students' responses in the test question.

Understanding level (UL)	Criteria for the classification of student response
Sound understanding (SU)	Responses that include all components of the scientifically accepted ideas
Partial understanding (PU)	Responses that include at least one of the components of theacceptable ideas and that show understanding of concepts butthat may also contain a kind of misconception
Miscellaneus understanding (MU)	Inappropriate or unidentified responses

introduction to the lesson. In this, the goal was to incite the curiosity and motivation of the students. In this group, the teaching remained loyal to what was offered in the Physics 11 textbook. The activities in the book were conducted in the order they were provided in the book. The students carried out the activities under the guidance of their teacher. Care was taken to have different students perform the different activities. The students were each asked to write down the measurement results in their books. The discussions in the 'Let's conclude' section at the end of the activities were again carried out in a discussion involving the whole class and each student was encouraged to participate actively. At the end of every topic, the sample questions prepared by the researcher were answered together with the students.

2.5.3. Treatment in the traditional learning group. In the control group, before each class started, the students were asked a question to motivate them. The researcher conducted the lessons here in this group, but only by using the method of lecturing. It was the teacher who played an active role over the course of the session. At the end of every topic, the sample questions prepared by the researcher were answered together with the students.

2.6. Data analysis

The classification of categories set forth by Sujarittham *et al* (2016) in table 4 was used to analyze the data obtained from the pressure conceptual text. The scoring of the text was achieved by the evaluation of the data in both the first and second tiers.

3. Results

The results obtained from the sub-problems of the research are given below. Table 5 summarizes the two-tier results of the application of the pressure conceptual text pre-test.

Rows 15 and 16 show that the students had serious misconceptions about the topics these questions covered. Looking at questions 2, 4, 15 and 17, it can be seen that 90% or more of the TLG either had deficient knowledge or misconceptions about the topics. Again, the percentage of deficient conceptualization in the responses of the CBLG to question 15 is over 90%. In the light of these results, it may be said that the students had deficient knowledge or misconceptions prior to the instruction.

Table 6 summarizes the two-tier results of the application of the pressure conceptual text post-test.

When examining table 5, before teaching the distribution of students involved in different groups into the level of understanding showed many differences from each other. The examination of changes in the distribution from pre-test to post-test was thought to be more

Table 5. Pre-test percentages of student responses to the two-tier test items by category of understanding.

	Conceptual change text group (CCTG)			Traditional learning group (TLG)			Context-based learning group (CBLG)		
I	SU f (%)	PU f (%)	MU f (%)	SU f (%)	PU f (%)	MU f (%)	SU f (%)	PU f (%)	MU f (%)
1	4(13.3)	22(73.4)	4(13.3)	1(3.3)	8(26.7)	21(70.0)	5(16.7)	14(46.7)	11(36.7)
2	2(6.7)	7(23.3)	21(70.0)	1(3.3)	2(6.7)	27(90.0)	1(3.3)	5(16.7)	24(80.0)
3	15(50.0)	4(13.3)	11(36.7)	3(10.0)	18(60.0)	9(30.0)	8(26.7)	2(6.7)	20(66.7)
4	1(3.3)	3(10.0)	26(86.7)	0(.0)	3(10.0)	27(90.0)	3(10.0)	1(3.3)	26(86.7)
5	7(23.3)	7(23.3)	16(53.3)	2(6.7)	18(60.0)	10(33.3)	2(6.7)	6(20.0)	22(73.3)
6	4(13.3)	7(23.3)	19(63.3)	0(.0)	17(56.7)	13(43.3)	4(13.3)	8(26.7)	18(60.0)
7	5(16.7)	8(26.6)	17(56.7)	0(.0)	2(6.7)	28(93.3)	4(13.3)	5(16.7)	21(70.0)
8	2(6.7)	15(50.0)	13(43.3)	0(.0)	8(26.7)	22(73.3)	3(10.0)	13(43.3)	14(46.7)
9	4(13.3)	17(56.7)	9(30.0)	0(.0)	19(63.3)	11(36.7)	3(10.0)	14(46.7)	13(43.3)
10	6(20.0)	13(43.3)	11(36.7)	3(10.0)	17(56.7)	10(33.3)	3(10.0)	7(23.3)	20(66.7)
11	2(6.7)	5(16.7)	23(76.7)	1(3.3)	10(33.3)	19(63.7)	2(6.7)	8(26.7)	20(66.7)
12	5(16.7)	13(43.3)	12(40.0)	0(.0)	7(23.3)	23(76.7)	5(16.7)	7(23.3)	18(60.0)
13	0(.0)	2(6.7)	28(93.3)	0(.0)	6(20.0)	24(80.0)	1(3.3)	4(13.3)	25(83.3)
14	0(.0)	2(6.7)	28(93.3)	0(.0)	5(16.7)	25(83.3)	0(.0)	9(30.0)	21(70.0)
15	0(.0)	2(6.7)	28(93.3)	0(.0)	3(10.0)	27(90.0)	0(.0)	2(6.7)	28(93.3)
16	0(.0)	2(6.7)	28(93.3)	0(.0)	5(16.7)	25(83.3)	1(3.3)	4(13.3)	25(83.3)
17	0(.0)	4(13.3)	26(86.7)	0(.0)	2(6.7)	28(93.3)	1(3.3)	7(23.3)	22(73.3)
18	2(6.7)	5(16.7)	23(76.7)	0(.0)	13(43.3)	17(56.7)	0(.0)	6(20.0)	24(80.0)
19	0(.0)	4(30.0)	21(70.0)	0(.0)	4(13.3)	26(86.7)	0(.0)	6(20.0)	24(80.0)

Note. f: frequency. Values in parantheses are the percentage of students within groups.
I = item number; SU = sound understanding; PU = partial understanding; MU = miscellaneus understanding. Figures have been rounded off.

Table 6. Post-test percentages of student responses to the two-tier test items by category of understanding.

	Conceptual change text group (CCTG)			Traditional learning group (TLG)			Context-based learning group (CBLG)		
I	SU f (%)	PU f (%)	MU f (%)	SU f (%)	PU f (%)	MU f (%)	SU f (%)	PU f (%)	MU f (%)
1	19(63.3)	7(23.3)	4(13.3)	12(40.0)	8(26.6)	10(33.3)	22(73.3)	3(10.0)	5(16.7)
2	23(76.7)	3(10.0)	4(13.3)	17(56.7)	1(3.3)	12(40.0)	18(60.0)	2(6.7)	10(33.3)
3	23(76.7)	3(10.0)	4(13.3)	15 (50.0)	13(43.3)	2(6.7)	17(56.7)	2(6.7)	11(36.7)
4	16(53.3)	3(10.0)	11(36.7)	15 (50.0)	3(10.0)	12(40.0)	11(36.7)	1(3.3)	18(60.0)
5	26(86.7)	1(3.3)	3(10.0)	22(73.3)	5(16.7)	3(10.0)	20(66.7)	2(6.7)	8(26.6)
6	26(86.7)	3(10.0)	1(3.3)	18(60.0)	3(10.0)	9(30.0)	22(73.3)	1(3.3)	7(23.3)
7	24(80.0)	5(16.7)	1(3.3)	10(33.3)	2(6.7)	18(60.0)	19(63.3)	5(16.7)	6(20.0)
8	24(80.0)	5(16.7)	1(3.3)	8(26.6)	8(26.6)	14(46.7)	20(66.7)	8(26.6)	2(6.7)
9	26(86.7)	0(.0)	4(13.3)	13(43.3)	11(36.7)	6(20.0)	18(60.0)	9(30.0)	33(10.0)
10	25(83.3)	5(16.7)	0(.0)	21(70.0)	2(6.7)	7(23.3)	18(60.0)	2(6.7)	10(33.3)
11	23(76.7)	3(10.0)	4(13.3)	12(40.0)	3(10.0)	15(50.0)	15(50.0)	0(.0)	15(50.0)
12	28(93.3)	2(6.7)	0(.0)	24(80.0)	2(6.7)	4(13.3)	24(80.0)	1(3.3)	5(16.7)
13	14(46.7)	2(6.7)	14(46.7)	13(43.3)	5(16.7)	12(40.0)	8(26.6)	4(13.3)	18(60.0)
14	20(66.7)	2(6.7)	8(26.6)	3(10.0)	5(16.7)	22(73.3)	5(16.7)	8(26.6)	17(56.7)
15	22(73.3)	2(6.7)	6(20.0)	7(23.3)	1(3.3)	22(73.3)	12(40.0)	2(6.7)	16(53.3)
16	21(70.0)	1(3.3)	8(26.6)	8(26.6)	4(13.3)	18(60.0)	13(43.3)	3(10.0)	14(46.7)
17	18(60.0)	4(13.3)	8(26.6)	8(26.6)	2(6.7)	20(66.7)	19(63.3)	3(10.0)	8(26.6)
18	21(70.0)	4(13.3)	5(16.7)	15(50.0)	2(6.7)	13(43.3)	17(56.7)	4(13.3)	9(30.0)
19	19(63.3)	6(20.0)	5(16.7)	10(33.3)	2(6.7)	18(60.0)	13(43.3)	2(6.7)	15(50.0)

Note. f: frequency. Values in parantheses are percentage of students within groups. I = item number; SU = sound understanding; PU = partial understanding; MU = miscellaneus understanding. Figures have been rounded off.

Table 7. Frequency distribution of changes in the number of students from pre-test to post-test for sound understanding level (SU) and chi-squared test results.

Item	Conceptual change text group (CCTG) f (% within group)	Traditional learning group (TLG) f (% within group)	Context-based learning group (CBLG) f (% within group)	χ^2	sd	p
1	15(50.0)	11(36.7)	17(56.7)	2.494	2	0.287
2	21(70.0)	16(53.3)	17(56.7)	1.944	2	0.378
3	8(26.7)	12(40.0)	9(30.0)	1.323	2	0.516
4	15(50.0)	15(50.0)	8(26.7)	4.464	2	0.107
5	19(63.3)	20(66.7)	18(60.0)	0.287	2	0.866
6	22(73.3)	18(60.0)	18(60.0)	1.552	2	0.460
7	19(63.3)	10(33.3)	15(50.0)	5.425	2	0.660
8	22(73.3)	8(26.7)	17(56.7)	13.449	2	0.001*
9	22(73.3)	13(43.3)	15(50.0)	6.030	2	0.049*
10	19(63.3)	18(60.0)	15(50.0)	1.944	2	0.378
11	21(70.0)	11(36.7)	13(43.3)	7.467	2	0.024*
12	26(86.7)	24(80.0)	19(63.3)	4.845	2	0.089
13	14(46.7)	13(43.3)	7(23.3)	4.065	2	0.131
14	20(66.7)	3(10.0)	5(16.7)	26.855	2	0.000*
15	22(73.3)	7(23.3)	12(40.0)	15.679	2	0.000*
16	21(70.0)	8(26.7)	12(40.0)	11.916	2	0.003*
17	18(60.0)	8(26.7)	18(60.0)	8.893	2	0.012*
18	19(63.3)	15(50.0)	17(56.7)	1.086	2	0.581
19	19(63.3)	10(33.3)	13(43.3)	5.625	2	0.060

Note. f: frequency. Values in parantheses are percentage of students within groups.
*$p < 0.05$ (differences are statistically significant).

useful but instead reveals the difference in value of the distribution of groups to interpret table 6 alone. Based on this table 7 were formed. To obtain the values in table 7, for each group changes in the number of students who showed sound understanding from pre-test to post-test were provided. This change was performed by taking difference the number of students who had sound understanding pre-test with post-test and this procedure was repeated for each question. The direction of changes in the number of students who had sound understanding (SU) in each group for each question was positive (increase), other understanding levels (PU and MU) were decreased. Because the number of changes in some other understanding level was below 5, not sound understanding level (not SU) was described by combined PU and SU levels. In order to determine whether the changes in the number of students having sound understanding (SU) and not having sound understanding (not SU) on the basis of the group differed or not, the chi-squared test for each question was applied.

According to the chi-squared test, there were statistically significant differences between the distribution of changes in the number of students in seven items (9, 11, 14, 15, 16 and 17) into groups. When examining the group percentages for items 8, 9, 11, 14, 15 and 16, the highest positive change of number of students who had sound understanding was in the group that was taught with conceptual change texts, with this group followed by the context-based learning group. In item 19, in both CCTG and CBLG who had sound understanding level changes from pre-test to post-test occured equally and changes in TLG were lower than both.

Table 8. Changing of students' level of understanding.

	Conceptual change text group (CCTG)				Traditional learning group (TLG)				Context-based learning group (CBLG)			
Item	From SU to SU	From PU to SU	From MU to SU	Total	From SU to SU	From PU to SU	From MU to SU	Total	From SU to SU	From PU to SU	From MU to SU	Total
	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
1	4(13.3)	15(50.0)	0(.0)	19(63.3)	1(3.3)	0(.0)	11(36.7)	12(40.0)	5(16.7)	11(36.7)	6(20.0)	17(56.7)
2	2(6.7)	4(13.3)	17(56.7)	23(76.7)	1(3.3)	1(3.3)	15(50.0)	17(56.7)	1(3.3)	3(10.0)	14(46.7)	18(60.0)
3	15(50.0)	1(3.3)	7(23.3)	23(76.7)	3(10.0)	5(16.7)	7(23.3)	15(50.0)	8(26.6)	0(.0)	9(30.0)	17(56.7)
4	1(3.3)	0(.0)	15(50.0)	16(53.3)	0(.0)	0(.0)	15(50.0)	15(50.0)	3(10.0)	0(.0)	8(26.6)	11(36.7)
5	7(23.3)	6(20.0)	13(43.3)	26(86.7)	2(6.7)	13(43.3)	7(23.3)	22(73.3)	2(6.7)	4(13.3)	14(46.7)	20(66.7)
6	4(13.3)	4(13.3)	18(60.0)	26(86.7)	0(.0)	12(40.0)	4(13.3)	16(53.3)	4(13.3)	7(23.3)	11(36.7)	22(73.3)
7	5(16.7)	3(10.0)	16(53.3)	24(80.0)	0(.0)	0(.0)	10(33.3)	10(33.3)	4(13.3)	0(.0)	15(50.0)	19(63.3)
8	2(6.7)	10(33.3)	12(40.0)	24(80.0)	0(.0)	0(.0)	8(26.6)	8 (26.6)	4(13.3)	5(16.7)	11(36.7)	20(66.7)
9	4(13.3)	17(56.7)	5(16.7)	26(86.7)	0(.0)	8(26.6)	5(16.7)	13(43.3)	3(10.0)	5(16.7)	10(33.3)	18(60.0)
10	6(20.0)	8(26.6)	11(36.7)	25(83.3)	3(10.0)	15(50.0)	3(10.0)	21(70.0)	3(10.0)	5(16.7)	10(33.3)	18(60.0)
11	2(6.7)	2(6.7)	19(63.3)	23(76.7)	1(3.3)	7(23.3)	4(13.3)	12(40.0)	2(6.7)	8(26.6)	5(16.7)	15(50.0)
12	5(16.7)	11(36.7)	12(40.0)	28(93.3)	0(.0)	5(16.7)	19(63.3)	24(80.0)	5(16.7)	6(20.0)	13(43.3)	24(80.0)
13	0(.0)	0(.0)	14(46.7)	14(46.7)	0(.0)	1(3.3)	12(40.0)	13(43.3)	1(3.3)	0(.0)	7(23.3)	8(26.6)
14	0(.0)	0(.0)	20(66.7)	20(66.7)	0(.0)	0(.0)	3(10.0)	3 (10.0)	0(.0)	1(3.3)	4(13.3)	5(16.7)
15	0(.0)	0(.0)	22(73.3)	22(73.3)	0(.0)	2(6.7)	5(16.7)	7 (23.3)	0(.0)	0(.0)	12(40.0)	12(40.0)
16	0(.0)	1(3.3)	20(66.7)	21(70.0)	0(.0)	1(3.3)	7(23.3)	8 (26.6)	1(3.3)	1(3.3)	11(36.7)	13(43.3)
17	0(.0)	0(.0)	18(60.0)	18(60.0)	0(.0)	0(.0)	8(26.6)	8 (26.6)	1(3.3)	4(13.3)	14(46.7)	19(63.3)
18	2(6.7)	1(3.3)	18(60.0)	21(70.0)	0(.0)	11(36.7)	4(13.3)	15(50.0)	0(.0)	2(6.7)	15(50.0)	17(56.7)
19	0(.0)	3(10.0)	16(53.3)	19(63.3)	0(.0)	2(6.7)	8(26.6)	10(33.3)	0(.0)	4(13.3)	9(30.0)	13(43.3)

Note. f: frequency. Values in parantheses are percentage of students within groups.
I = item number; SU = sound understanding; PU = partial understanding; MU = miscellaneus understanding. Figures have been rounded off.

To shown gains we used the levels of understanding shown in table 8 as in the study of Sujarittham *et al* (2016). Table 8 shows the numbers who shifted into the sound understanding tendency in groups.

It can be said that a larger percentage of students shifted into sound understanding in CCTG. The misconceptions, which were obtained from the second tier of the PCT, found in the document analysis and the conceptual change that could see in a comparison of the pre- and post-tests are summarized in table 9.

When the conceptual change percentages of the students from before the instruction to after the instruction are considered in table 9, it is seen that the biggest change was in study group 1, followed by study group 2. The misconceptions that displayed more than 10% of a change were more in study group 1. The changes that remained below 10% were considered negligible. It was observed that some of the misconceptions did not change. The number of misconceptions that did not change were more in the control group. During the discussions in the classrooms, teacher observations are similar to table 9.

In addition to the misconceptions shown in the table, it was seen that the students found the following points in the pressure conceptual text challenging.

Besides the students' misconceptions, it was also observed that they had difficulties with understanding. The points they had difficulty with were deficiencies that fall into the category of understanding. The partial understanding that they had about these difficult points exhibited a great percentage change from before the instruction to after the instruction. Students' partial understandings are given in table 10. The answers to questions 7, 13, 19 and 18 are dependent on having the necessary conceptual knowledge. For example, when we look at the responses the students gave to question 13, which were about the examples in daily life of the concept of pressure in fluids, it is seen that they had trouble determining which of the examples was about fluid pressure. While some students were not able to make an association with any of the examples, some made the association but were not able to provide the exactly correct answer. In addition, a look into the results of the post-test shows that the group that had the greatest change was the conceptual change text group.

4. Discussion and conclusion

The pre-test results of the research showed that all of the students had some specific misconceptions or difficulty with understanding (partial understanding). In addition, it was also found that all three groups displayed similar misconceptions. After the instruction, it was seen that some of the misconceptions the students had were still present. It was however observed that the number of misconceptions had been reduced or shifted altogether in all three groups. After the instruction, it was seen that none of the students formed new misconceptions.

In looking at the percentages of the change in the students' misconceptions from the pre-test to the post-test, it was observed that the highest positive change was in the group that was taught with conceptual change texts, with this group followed by the context-based learning group. In addition, a look into the students' post-test scores showed that for all three groups, there had been a positive change in their misconceptions by topic.

When examining the group percentages for items 8, 9, 11, 14, 15 and 16, the highest positive change of number of students who had sound understanding was in the group that was taught with conceptual change texts, with this group followed by the context-based learning group. Although there is no statistically significant difference in other questions when looking at table 8, changing of the students' level of understanding has emerged most in the CCTG group.

Table 9. Percentages of students' specific misconceptions (SM) in pre-test and post-test.

Specific misconceptions (SM)	CCTG			TLG			CBLG		
	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)
1. Wearing wide-soled shoes stops you from sinking by reducing friction. (I1)	6.7	—	+6.7	13.3	6.7	+6.6	3.3	3.3	—
2. Wearing wide-soled shoes stops you from sinking because your weight is reduced. (I1)	33.3	26.7	+6.6	23.3	20.0	+3.3	20.0	10.0	+10.0
3. The buoyancy of objects in the same liquid is the same. (I2)	6.7	—	+6.7	13.3	6.7	+6.6	20.0	10.0	+10.0
4. The buoyant force exerted on sinking and floating objects is equal to the weight of the object. (I2)	13.3	10.0	+3.3	3.3	3.3	—	13.3	13.3	—
5. Buoyant force in sinking objects is less than the buoyant force in floating objects because the weight of a sinking object is greater. (I2)	33.3	3.3	+30.0	13.3	6.7	+6.6	43.3	16.7	+26.6
6. Nothing can be said about buoyant force without knowing the weight of objects. (I2)	6.7	3.3	+3.4	3.3	—	+3.3	3.3	3.3	—
7. To say something about buoyant force, you need to know the mass of the object. (I2)	6.7	—	+6.7	—	—	—	3.3	—	+3.3
8. When the density of a liquid is reduced, the floating object will sink less. (I3)	33.3	16.7	+16.6	13.3	6.7	+6.6	20.0	16.7	+3.3
9. The buoyant force exerted on floating and suspended objects is the same and greater than the buoyant force applied to sinking objects. (I4)	6.7	6.7	—	16.7	6.7	+10.0	16.7	3.3	+13.4
10. The buoyant force exerted on floating and suspended objects is the same and less than the buoyant force applied to sinking objects. (I4)	6.7	3.3	+3.4	10.0	6.7	+3.3	13.3	6.7	+6.6
11. The buoyant force applied to objects in a liquid is greatest on the object on top, growing lesser down the line. (I4)	23.3	13.3	+10.0	20.0	6.7	+13.3	33.3	20.0	+13.3
12. The least buoyant force is exerted on the lowest object in a liquid.	33.3	13.3	+20.0	23.3	13.3	+10.0	13.3	6.7	+6.6

Table 9. (Continued.)

Specific misconceptions (SM)	CCTG			TLG			CBLG		
	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)
13. When an object that has sunk is the heaviest, it is because the greatest buoyant force has been applied to it. (I4)	26.7	20.0	+6.7	20.0	10.0	+10.0	16.7	10.0	+6.7
14. As the depth of the container of liquid increases, the object sinks even further. (I5)	13.3	3.3	+10.3	23.3	16.7	+6.6	43.3	23.3	+20.0
15. As the depth of the container of liquid increases, the object is suspended. (I5)	6.7	—	+6.7	20.0	13.3	+6.7	33.3	20.0	+13.3
16. As in the oceans, objects sink less when there is more water. (I5)	13.3	3.3	+10.0	6.7	3.3	+3.4	6.7	—	+6.7
17. An object will sink more if it is left in a container with a wider base. (I6)	10.0	3.3	+6.7	33.3	13.3	+20.0	16.7	10.0	+6.7
18. An object will be suspended if it is left in a container with a wider base. (I6)	6.7	3.3	+3.4	20.0	13.3	+6.7	10.0	3.3	+6.7
19. Since the surface area will broaden and pressure will fall, it will sink less. (I6)	3.3	—	+3.3	6.7	3.3	+3.4	6.7	—	+6.7
20. Atmospheric pressure will not affect an open-ended manometer. (I8)	13.3	—	+13.3	10.0	3.3	+6.7	6.7	—	+6.7
21. A glass full of water turned upside down with its mouth closed off with paper is not affected by atmospheric pressure. (I8)	10.0	3.3	+6.7	6.7	3.3	+3.4	10.0	—	+10.0
22. A thermometer is affected by atmospheric pressure. (I8)	13.3	10.0	+3.3	10.0	—	+10.0	10.0	6.7	+3.3
23. The reason water does not spill out of a glass full of water turned upside down with its mouth closed off with paper is due to buoyant force. (I9)	6.7	—	+6.7	23.3	13.3	+10.0	13.3	—	+13.3
24. Buoyant force does not affect ships floating.	10.0	—	+10.0	13.3	6.7	+6.6	10.0	3.3	+6.7
25. The reason balloons fly cannot be explained by buoyancy. (Gases do not exert a buoyant force.) (I9)	10.0	6.7	+3.3	13.3	13.3	—	13.3	10.0	+3.3
	13.3	10.0	+3.3	6.7	6.7	—	13.3	10.0	+3.3

Table 9. (Continued.)

Specific misconceptions (SM)	CCTG			TLG			CBLG		
	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)
26. Jumping off an airplane with a parachute can be explained by buoyant force. (I9)									
27. The total pressure on each surface of a container full of water is equal. (I10)	13.3	10.0	+3.3	13.3	6.7	+6.6	26.7	13.3	+13.4
28. The pressure of water toward the surface of the container increases. (I10)	20.0	3.3	+16.7	30.0	13.3	+16.7	13.3	6.7	+6.6
29. The pressure on the top of a liquid is the greatest. (I10)	10.0	6.7	+3.3	6.7	3.3	+3.4	16.7	6.7	+10.0
30. Buoyant force depends on the shape of an object. (I11)	10.0	3.3	+6.7	6.7	3.3	+3.4	13.3	6.7	+6.6
31. The directions of buoyant force and gravity are different. (I11)	36.7	23.3	+13.4	30.0	20.0	+10.0	16.7	6.7	+10.0
32. The point of exertion of buoyant force is not the center of volume of a sinking object. (I11)	3.3	—	+3.3	3.3	3.3	—	6.7	3.3	+3.4
33. Buoyant force is exerted in the direction of gravity. (I11)	10.0	6.7	+3.3	20.0	13.3	+6.7	10.0	6.7	+3.3
34. To increase buoyant force, a little bit of more water has to be added to a container filled with water. (I12)	3.3	—	+3.3	3.3	3.3	—	10.0	3.3	+6.7
35. To increase buoyant force, a little bit of a denser liquid may be added to a container filled with water. (I12)	10.0	—	+10.0	33.3	26.7	+6.6	20.0	13.3	+6.7
36. To increase buoyant force, a little bit of a liquid that doesn't mix with water may be added to a container filled with water. (I12)	16.7	—	+16.7	26.7	13.3	+13.4	16.7	10.0	+6.7
37. Shaking a bottle of cologne before pouring it out has nothing to do with atmospheric pressure. (I14)	13.3	6.7	+6.6	13.3	13.3	—	16.7	13.3	+3.4
38. Suction pumps have nothing to do with atmospheric pressure. (I14)	20.0	13.3	+6.7	6.7	3.3	+3.4	6.7	3.3	+3.4
39. Vacuum bags have nothing to do with atmospheric pressure. (I14)	33.3	10.0	+23.3	53.3	40.0	+13.3	26.7	13.3	+13.4
40. Taking a liquid into an injector has nothing to do with atmospheric pressure. (I14)	3.3	—	+3.3	10.0	6.7	+3.3	10.0	6.7	+3.3

Table 9. (Continued.)

Specific misconceptions (SM)	CCTG			TLG			CBLG		
	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)
41. If ice (solid) melts in a system in which a solid is floating in water, the volume of the system increases. (I15)	33.3	23.3	+10.0	26.7	23.3	+3.3	30.0	23.3	+13.3
42. If a solid melts in a system in which a solid is floating in water, the mass of the system increases. (I15)	46.7	20.0	+26.7	43.3	40.0	+3.3	46.7	26.7	+20.0
43. If a solid melts in a system in which a solid is floating in water, the density of the system increases. (I15)	16.7	3.3	+13.4	16.7	6.7	+10.0	13.3	6.7	+6.6
44. When the speed of fluids increases, pressure increases too. (I16)	63.3	20.0	+43.3	43.3	16.7	+26.6	53.3	23.3	+30.0
45. Liquids do not flow from a place where pressure is high to a place where it is low. (I16)	33.3	23.3	+10.0	26.6	23.3	+3.3	30.0	23.3	+6.7
46. The pressure of the gas in the pipe in the Toricelli experiment depends upon the cross-section of the pipe. (I17)	16.7	3.3	+13.4	16.7	6.7	+10.0	13.3	6.7	+6.6
47. The pressure of the gas in the pipe in the Toricelli experiment depends upon the angle of the pipe in relation to the horizontal. (I17)	13.3	3.3	+10.0	13.3	6.7	+6.6	6.7	3.3	+3.4

Note. I: item number, CC: conceptual change.

Table 10. The points about which the students showed particular understanding.

	CCTG			TLG			CBLG		
Particular understanding (PU)	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)	Pre (%)	Post (%)	CC (%)
1. Not being able to use the concepts to calculate the pressure of gas in an open-ended mercury manometer (I7)	56.7	13.3	+43.4	63.3	26.7	+36.6	60.0	26.7	+33.3
2. Not being able to associate the pressure of fluids with everyday life (I13)	93.3	43.3	+50.0	70.0	26.7	+43.3	83.3	40.3	+50.0
3. Not being able to use the concepts in the topic about the hydraulic press (I19)	46.7	10.0	+36.7	66.7	46.7	+20.0	56.7	33.3	+23.4
4. Not being able to compare the weights of two objects with equal pressure but different surface areas (I18)	33.3	6.7	+26.6	13.3	6.7	+6.6	26.7	13.3	+13.4

Note. I: item number, CC: conceptual change.

When the effects of the conceptual change approach on conceptual change are compared with traditional learning methods, it has been found in many studies that this approach has more of a positive impact (e.g. Chambers and Andre 1997, Duit and Treagust 2003, Coştu *et al* 2007, Sendur and Toprak 2013).

From the conclusion drawn from the first sub-problem of the research, it was seen that teaching based on the context-based learning approach has a more positive effect on conceptual change than traditional instruction. A review of the literature without differentiating the disciplines has not revealed any research on the effects on conceptual change of teaching according to a context-based learning approach. On the other hand, there are studies that point to the fact that context-based learning is an effective learning approach for students (e.g. Whitelegg, 1996, Ramsden 1997, Whitelegg and Parry 1999, Wilkinson 1999, Campbell and Lubben 2000, Binnie 2004, Glynn and Koballa 2005, Murphy and Whitelegg 2006, Murphy *et al* 2006).

When the literature was reviewed, studies were encountered in which it was reported that the use of conceptual change texts had a positive impact on the learning of concepts (e.g. Chambers and Andre 1997, Guzetti 2000, Diakidoy *et al* 2003, Coştu *et al* 2007). When compared with the traditional learning environment, it may be said that students participate more actively in the activities presented to them in the context-based learning atmosphere and therefore their conceptual learning is positively affected.

Based on the findings of this study, it might be recommended that before starting to teach any subject, it should first be determined whether students have preconceptions or misconceptions about the subject and teaching activities should proceed on the basis of this information (to shift existing misconceptions). In the light of these results, the use of conceptual change texts in teaching may be considered as an alternative learning method.

The conceptual change texts prepared in this study on the subjects of pressure and buoyancy and the context-based learning approach activities were developed in line with the 11th grade syllabus on matter and its properties. In this context, the results obtained are limited to the mentioned topics in one particular unit. Conceptual change texts and the context-based learning approach may be attempted at various academic levels and on different subjects in science/physics education to examine the impact on the same variables. The effects of conceptual change and context-based learning approaches on learning should be researched at length.

If it is considered that the educational system today is transitioning from traditional instruction to contemporary teaching methods, more room should be made for these modern methods in the organization of teaching and education efforts. In this context, teachers should give up their accustomed traditional learning techniques and lean towards teaching activities that are based on these new methods.

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