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Instructional curriculum based on cooperative learning related to the structure of matter and its properties: Learning achievement, motivation and attitude

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In this study we aimed to analyse the effects of the Instructional Curriculum based on Cooperative Learning (ICBCL) prepared for the subjects, the orders of electrons and chemical properties, chemical bonds, compounds and their formulas, and mixtures on 7th grade learners' learning achievements, motivations to learn science, and their attitudes towards learning science. Pre- and post-test quasi experimental design was used in this study in which the participants, 89 7th grade learners were attending a public secondary school in Istanbul, Turkey during the 2013–2014 academic year. The Diagnostic Test for the Structure of Matter and its Properties (DTSMP), developed by the researchers, the Motivation Scale to Learning Science (MSTLS), developed by Dede and Yaman (2008), and the Attitude Scale Towards Science Lesson (ASTSL), developed by Biçer (2011) were used as data collection instruments. SPSS 16 and Lertap 5 were used for data analysis. As a result of the post-tests, learners from the experimental group achieved significantly higher mean scores than learners from the control group. This reflected that ICBCL was highly effective on increasing learners' achievement levels by preventing possible misconceptions, developing motivation, and positive attitudes compared to the current Science Teaching Curriculum (STC).

Keywords: attitudes towards science; cooperative learning; instructional curriculum; motivation to learn science; science education

Introduction

In the information age, education plays a major role in the economic development of any country. To ensure economic growth, especially in developing countries such as South Africa, Turkey, Cuba, and Algeria, instructional curriculums are being updated to address skills required of learners in the 21st century, namely knowledgeability about science, ability to use scientific processes, ability to communicate well with others, ability to dream big, being good at problem solving, caring about the environment, and respecting people's views (Partnership for 21st Century Skills, 2008).

The quality of education is closely related to the instructional design model used and how it is implemented when preparing the instructional curriculum (Erden, 1993). In most sources the concepts of Instructional Design and Instructional Systems Design are used interchangeably with regard to the instructional design model. Reigeluth (1999) describes these concepts as separate concepts. The concept of Instructional Design defines the whole of the strategies, methods, and techniques used during the design of a lesson, while the concept of Instructional Systems Design is the sum of activities of analysis, design, development, implementation, and evaluation during the design of a curriculum. Over the last decades, practitioners have developed a number of models about instructional system design (Lee, J & Jang, 2014).

The ADDIE model, a guide for creating an effective design (Aldoobie, 2015), is one of the most widely used models in teaching design. Educators need tools to teach knowledge, skills, and attitudes. Using the ADDIE model helps educators to perform these tasks (Cheung, 2016). When the steps of the ADDIE model are followed, it can be applied easily in online or face-to-face environments (Aldoobie, 2015).

Steps of the model are analysis, design, development, implementation and evaluation. In the analysis, learners' learning needs, limitations and present knowledge and skills are determined. In the design phase, the most appropriate environment is selected for the acquisition of knowledge and skills, and the teaching method, learning activities, and evaluation process are designed. In the development phase, teaching materials (all the tools to be used in teaching and support materials) are prepared and an appropriate learning environment is created. The product is developed at this stage. During application the design is fully implemented with real learners. During the evaluation the design is checked to determine how well the learning needs have been met by the learning objectives (Kaminski, 2007). Evidence of many studies using the ADDIE model for instructional design can be found in the literature (Arkün, 2007; Özerbaş & Kaya, 2017; Peterson, 2003; Reinbold, 2013). In this study, the relevant learning environment was developed based on the ADDIE instructional design model.

New instructional methods, techniques, and strategies, which will encourage individuals to think, discuss, research, question, think critically, and participate actively in the learning process, should be used in classroom settings when applying new instructional curriculums. One of the instructional methods in which learners actively participated, is cooperative learning. Cooperative learning is a learning method based on the cognitive developmental theory, the behavioral learning theory, the social interdependence theory, and the cognitive elaboration theory (Jacobs, 1990; Johnson & Johnson, 1999; Kauchak & Eggen, 2003; Slavin, 1995). Cooperative learning involves learners working on learning activities in small groups, getting intrinsic or instrumental awards as a result of the group's success and aims (Siegel, 2005). For cooperative learning to be successful it depends on positive cooperation, dependency, personal responsibilities, face-to-face communication, social skills, and the evaluation of cooperative work (Johnson & Johnson, 1999). When learners work cooperatively, they show increased participation at group argument, connect in fewer interruptions when others speak, and provide more intellectually valuable contributions (Gillies, 2006). Studies have shown that cooperative learning enables the development of social skills (Genlott & Grönlund, 2013), motivation for the lessons (Saban, 2004), positive attitudes towards autonomous learning (Johnson, Johnson & Smith, 2007), developing teamwork skills (Johnson & Johnson, 1999), development of face-to-face information sharing, helping, ,discussing and sharing skills (Tran & Lewis, 2012; Veenman, Van Benthum, Bootsma, Van Dieren & Van der Kemp, 2002).

Cooperative learning techniques have been widely used in science education around the World. Aruna and Sumi (2010), Ebrahim (2012), Fernandez-Rio, Sanz, Fernandez-Cando and Santos (2017); Lazarowitz (1991), Liao (2006), Lowe (2004), Marzban and Akbernejad (2013), Nam and Zellner (2011), Sisovic and Bojovic (2000), Tran and Lewis (2012), and Zoghi (2013) found that the cooperative learning method influenced achievement, attitudes, motivation, and scientific process skills, particularly in countries such as South Korea, New Zeland, Yugoslavia, Spain, Israeli, Kuwait, Vietnam, Iran and Taiwan. Cooperative learning is preferred to traditional learning methods due to greater learner achievement and development of social skills and less material needs (Carpenter & McMillan, 2003; Tarhan & Sesen, 2012).

One of the main subjects of science education is the learning of concepts. For this reason, the main aim of science education is to develop learners' understandings of scientific concepts. Effective science teaching requires constructing the concepts which are the building blocks of knowledge in learners' minds (Tatar & Cansüngü Koray, 2005). For reasons like biased thoughts, non-scientific beliefs, conceptual misunderstanding stemming from learners' background knowledge, misconceptions resulting from different uses in science and in daily life, and course book-related misconceptions, may prevent learners from constructing new knowledge (Köseoğlu, Atasoy, Kavak, Akkuş, Budak, Tümay, Kadayıfçı & Taşdelen, 2003). If new knowledge is not constructed well, it affects learning negatively and causes learner misconceptions (Jonassen, 1991).

It is well known that it is difficult for learners to understand science and chemistry as both contain a good number of abstract concepts (Gilbert, Justi, Van Driel, De Jong & Treagust, 2004; Yang, Andre, Greenbowe & Tibell, 2003). For example, macroscopic, microscopic, and symbolic are three levels used to express events in chemistry (Johnstone, 1993). The symbolic level refers to symbols, numbers, and formulae, while the micro dimension cannot be seen with the naked eye and the macro dimension covers events that learners can observe (Okumuş, Çavdar, Alyar & Doymuş, 2017). Learners know the three levels of chemistry but cannot make connections between three levels (Merritt, Shwartz & Krajcik, 2007). Since learners do not sufficiently relate to the symbolic, macro, and micro dimensions, they find it difficult to understand the structure of matter and its properties. Numerous studies show that learners at different levels (primary and secondary school) struggle to understand the structure of matter (Harrison & Treagust, 2003; Merritt et al., 2007). Structure of matter and its properties is very important in many of the subjects underlying chemistry (The Orders of Electrons and Chemical Properties, Chemical Bonds, Compounds and Their Formulas, Mixtures). In middle school, learners encounter these issues that form the basis of chemistry for the first time. In order to achieve success and to ensure success in the progressive education processes, these issues should be learned completely and without misunderstanding. Studies show that learners have a lot of misconceptions about the orders of electrons and chemical properties (Griffiths & Preston, 1992; Harrison & Treagust, 2000; Kara & Ergül, 2012), chemical bonds (Butts & Smith, 1987; Coll & Taylor, 2001; Nicoll, 2001; Taber, 1998; Tan & Treagust, 1999), compounds and their formulas (Meşeci, Tekin & Karamustafaoğlu, 2013; Novick & Nussbaum, 1978) and mixtures (Ebenezer & Erickson, 1996; Ebenezer & Fraser, 2001; Lee, O, Eichinger, Anderson, Berkheimer & Blakeslee, 1993; Papageorgiou & Sakka; 2000; Şen & Yılmaz, 2012; Uluçinar Sağır, Tekin & Karamustafaoğlu, 2012; Valanides, 2000).

Cooperative learning has been used in a very limited number of studies to teach all identified science subjects and to overcome learners' misunderstandings (Acar & Tarhan, 2007; Birk & Kurtz, 1999).

It is also very important to prevent learners from forming conceptual misconceptions (Ayas & Özmen, 2002; Bauma, Brant & Sutton, 1990; Griffiths, 1994; Nakhleh, 1992). However, the studies aimed at the prevention or elimination of misconceptions about these issues. In limited studies where extensive misconceptions exist, teaching methods and techniques, other than cooperative learning, are used extensively (Gökharman, 2013; Say, 2011; Uzun, 2010).

From studies carried out in Turkey the effect of cooperative learning on success, attitude, motivation, scientific process skills, self-efficacy, and persistence has been investigated (Bozdoğan, Taşdemir & Demirbaş 2006; Bozkurt, Orhan & Kaynar, 2008; Doğru & Ünlü, 2012; Gençosman, 2011; Tarhan & Sesen, 2012; Tortumluoğlu, 2014; Yapıcı, Hevedanlı & Oral, 2009).

Bozdoğan et al. (2006) examined the relationship between experimental and control group learners' final test scores. The final test scores of the learners in the experimental group were found to be higher than the post-test scores of the learners in the control group. Bozkurt et al. (2008) found that cooperative learning is more effective in increasing the learners' success than traditional learning methods. Doğru and Ünlü (2012) found that there was no relationship between cooperative learning methods and learners' motivation about science lessons. Gençosman (2011) found that cooperative learning has a more significant effect on self-efficacy, academic achievement, and persistence than the traditional teaching method and the current science and technology curriculum, which is based on constructivism. Tarhan and Sesen (2012) found that learners in the experimental group had less misconceptions than learners in the control group. From individual interviews it became clear that learners believed that jigsaw was an effective cooperative learning technique that provides positive attitudes. Tortumluoğlu (2014) determined that there was no significant difference in terms of academic achievement between the groups in which cooperative learning and traditional teaching methods were applied. Yapıcı et al. (2009) found that cooperative learning was more effective in increasing the success levels. When learners' attitudes towards the course were examined, no significant difference was found between the experimental and control groups.

Many studies on cooperative learning as a method with focus on its effects on learners' achievement and attitudes exist in the literature (Ebrahim, 2012; Marzban & Akbernejad, 2013; Nam & Zellner, 2011; Sisovic & Bojovic, 2000; Tarhan & Sesen, 2012; Tran & Lewis, 2012; Zoghi, 2013), while few studies dealing with the effects of cooperative learning on learners' motivation exist (Doğru & Ünlü, 2012; Fernandez-Rio et al., 2017).

Purpose of the Study

The aim of this study was to analyse the effects of instructional curriculum based on cooperative learning (ICBCL) on 7th grade learners' academic achievements, motivations to learn science and their attitudes towards learning science in the subjects, the orders of electrons and chemical properties, chemical bonds, compounds and their formulas, and mixtures. To achieve this purpose the following sub-questions were investigated:

1. What is the effect of ICBCL on learners' achievements about the aforementioned subjects?
2. What is the effect of ICBCL on learners' conceptual misunderstandings?
3. What is the effect of ICBCL on learners' motivation to learn science?
4. What is the effect of ICBCL on learners' attitudes towards learning science?

Methodology

Design

A comparison group pre- and post-test quasi experimental design was used in this study. Participants in the experimental group were taught the instructional curriculum using cooperative learning (ICBCL) while the control group was taught the current Science Teaching Curriculum (STC) used in the relevant academic year. The experimental pattern of the study is presented in Table 1.

Table 1 Design of the study

	Pre-test	Curriculum	Post-test
Control group	DTSMP	STC	DTSMP
	MSTLS		MSTLS
	ASTSL		ASTSL
Experimental group	DTSMP	ICBCL	DTSMP
	MSTLS		MSTLS
	ASTSL		ASTSL

Note. DTSMP: Diagnostic Test for the Structure of Matter and its Properties, MSTLS: Motivation Scale to Learning Science, ASTSL: Attitude Scale towards Science Lesson, STC: Science Teaching Curriculum, ICBCL: Instructional Curriculum based on Cooperative Learning.

Participants

The participants in this study were 89 7th grade learners studying at a public secondary school in Istanbul during the 2013–2014 academic year. Two of the six 7th grade classes were chosen randomly for the implementation of this study. The experimental group was made up of 46 learners while 43 learners were in the control group.

Development of Instructional Curriculum based on Cooperative Learning (ICBCL)

Within the aim of this study, a literature review on the predefined subject matter was done and the learners' misconceptions relating to the aforementioned concepts were determined (Nicoll, 2001; Papageorgiou & Sakka, 2000). The objectives for these subjects were analysed in accordance with Bloom's taxonomy and it was found that the objectives were mainly based on recall and comprehension, which are cognitive stages in Bloom's taxonomies. The objectives were rearranged to also include the cognitive stages of application, analysis, and evaluation. Seven objectives of the Science Teaching Curriculum were not changed, while 14 were changed and nine more added. In order to decide whether these objectives were suitable or not, four science teachers were consulted and 30 objectives, which were analysed according to Bloom's revised taxonomy, were agreed upon.

Cooperative learning tasks were designed in accordance with the objectives of the subjects chosen for this study. Firstly, a literature review on related subjects was done in the task developing process. Current tasks for the different subjects in the 7th grade science book were analysed. The aim of designing new tasks was to allow learners to relate new concepts to the previous ones and engage with these in their daily lives. The results of the analysis done on the related subjects in 7th grade science book show that the tasks did not make it possible for the learners to concretise some of the abstract concepts. For instance, there were no tasks or activities to concretise the concept of the structure of the atom and its particles in the learners' minds. All the activities on the topic of the structure of atoms were to be completed on the paper and none of them required three dimensional work. As a result, within the scope of this study, three dimensional models of atoms were designed in activities like "Let's make an atom model," "Shall we do shopping?," "How do these atoms stand together?" Such activities provided students with opportunities to concretise the concepts of the orders of electrons and chemical properties and chemical bonds.

To determine whether these activities were suitable for the learners' level or not, and to prove that they had content validity, one science teacher and three lecturers were consulted. After making necessary changes based on the experts' opinions, an Activity Book for the Students and an Activity Book for the Teachers were written using compiling all the activities. Each of the activities in the Students' Activity Book was designed in a way that included the required time, safety measures, tools, process steps and evaluation parts. Besides these, the Teachers' Activity Book was designed in a way to include learner objectives, scientific process skills, background information to help the teacher and teacher planning steps needed for the activities. In Table 2, one can see the names of the cooperative learning activities developed for this study and the ICBCL objectives for each activity.

Implementation Process of ICBCL in the Experimental Group

The learning together model which is one of the cooperative learning methods was used in this study. The most important characteristic of this method which was designed by Johnson and Johnson (1999) are that it has an aim, thoughts and materials are shared, there is cooperation and group awards (Açıkgöz, 1992).

The experimental group is made up of 46 learners. Teaching the determined subjects to the experimental group took 4.5 weeks - four lessons per week (one lesson time = 40 minutes) - in accordance with ICBCL. The time used for using the evaluation tests was not included in the implementation process of lessons. One week before the subjects were taught, learners were given DTSMP, MSTLS and ASTSL tests as pre-tests.

Before the learners begin the process of applying the method; the responsibilities of each group member are explained by explaining how to create groups, how to make the task distribution, which responsibilities will be given to the members of the group, which subject will be taught, the rules that the learners and the teacher have to comply within the implementation of the method and the necessary concepts related to the subject.

It is important in the cooperative learning method that small groups of learners should be heterogeneous and the average grades of the groups should be similar or the same (Foyle, Lyman, Morehead & Foyle, 1989). Groups consisting of many learners will be composed of people with different characteristics due to their heterogeneity. For this reason, in groups of few people, learners have the opportunity to encounter a few different ideas, while in the group of many learners, learners will be able to have more different opinions (Köseoğlu & Tümay, 2013).

For this reason, four heterogeneous cooperative groups made up of seven learners and three heterogeneous cooperative groups made up of six learners were formed with the technique of bedded random sampling by using learners' DTSMP test results. After that, the groups were located in a way that allowed the learners in the same group to work together easily and each group works freely and separately from the other groups. Each group was asked to choose a group name to make it possible to have a positive attachment in the group and each learner was given a role as summarizer, reporter, comprehension checker, researcher and encourager and these roles were swapped. For the last thing before the start of the process, the learners were told that they should speak silently and call their friends by their names while working together.

Each group was given an activity set before the activities were started to be done. In this way, the learners were made to share the materials. While the learners were doing the activities, the teacher was going around the classroom, explaining unclear parts and giving leading answers to learners. At the end of the implementation process, randomly chosen learners were asked to summarize the information that they needed to learn. As a result of the feedback gotten from the learners, the teacher diagnosed the information gaps and informed learners about the subject. After the implementation of ICBCL; DTSMP, MSTLS and ASTSL tests were given again as post-tests. A certificate of Participation in Cooperative Learning Activities was given to the learners of the experimental group as an award at the end of the implementation process.

Teaching Process in the Control Group

The control group is made up of 43 learners. In the course of the lessons in the control group, the teacher made a presentation of the same content and similar considering the same learning objectives. In Table 2, one can see the names of activities for this study. Teaching the determined subjects to the control group was done by using the learner textbook and the Teacher's Activity Book. While the teacher explained the issues, the learners listened to her and wrote notes about the issue of the lesson. At the end of the lesson, the teacher had the activities done by the learners in the book. Some activities were given as homework. One week before the subjects were taught, learners were given DTSMP, MSTLS and ASTSL tests as pre-tests. Teaching the subjects synchronously took 4.5 weeks - four lessons per week (one lesson time = 40 minutes). The time used for using the evaluation tests was not included in the implementation process of lessons. At the end of the process, the control group was given DTSMP, MSTLS and ASTSL tests.

At the end of the Application Process of ICBCL in the Experimental Group and the STC in the control group, additional lesson was made by the course teacher to bring the control group to the experimental group level.

Data Collection

Diagnostic test for the structure of matter and its properties (DTSMP)

Within the scope of this study, a two-tier diagnostic test DTSMP which was designed by the researchers was implemented so as to diagnose the experimental and control group learners' level in terms of academic knowledge for the determined subjects. Right after the subject matter was decided on, a literature review was done during the process of test development. An item pool of 53 items was prepared in accordance with the objectives of ICBCL which was designed for this study. A table of specifications was prepared according to Bloom's revised Taxonomy in order to test the construct and content validity of the test. So as to make the test valid in terms of content, experts were consulted and the test was finally decided on 32 items. It was implemented to 225 7th grade learners. The reliability coefficiency of the test was defined as 0.91. The top score that could be gotten from the test was defined as 32.

Motivation scale to learning science (MSTLS)

A Likert type scale MSTLS of 23 items with five choices which was designed by Dede and Yaman (2008) was used before and after the implementation of the study in order to evaluate the motivation of the learners in both experimental and control groups for learning science. Scale: is made up of five dimensions as motivation for searching, motivation for performance, motivation for communication, motivation for cooperative work and motivation for participation. The reliability coefficient of this motivation scale was found to be 0.80 as a result of the reliability analysis done. Answer options for the items of the scale were defined as "5 = Totally Agree," "4 = Agree," "3 = Neutral," "2 = Disagree," "1 = Totally Disagree." The top score that could be gotten from the test was defined as 115.

Table 2 ICBCL objectives and experiment-control group activities

Activity number	The name of the activity		Objectives
	Experiment group	Control group	
1	Let's make an atomic model	Atom models Thinking, let's write	He can assume that atoms are charged positively (+) when they lose electrons and charged negatively (-) when they receive electrons. O_8, He can explain the principles of Octet and Doublet. He can make atomic models of some elements. He can prepare and present a material made up of anions and cations in the class.
2	Identity (ID) card of atom	Find, let's fun Find the exit	He can give examples for some of the anions and cations. He can distinguish ions, anions and cations from the given symbols or formulas.
3	Shall we do shopping?	Bonds	He can conclude that the concept of ionic bonds only includes ions.
4	How do these atoms stand together?	Find, let's fun	He can relate the affinity that holds the atoms together and the notion of chemical bonds. He can conclude that the concept of chemical bonds includes ionic and covalent bonds. He can infer that structures with covalent bonds form molecules. He can draw the models of H2, O2, N2 molecules that are formed by the cooperation of electrons.
5	Who is right?	Fill in the blanks	He realizes that electron cooperation can be with both the same kinds of atoms and different kinds of them. He can differentiate the similarities and differences between ionic and covalent bonds. He can explain why noble gases do not make bonds.
6	Can we stand together?	Thinking, let's write	He can differentiate between ions with a single atom and the ones with multiple atoms.
7	Ionic structure or molecule structure?	Compounds	He can define that atoms of different types of elements can form new matters. He can give examples for compounds. He can differentiate between the compounds of molecular structure and the ones of ionic structure. He can infer that every compound is made up of at least two elements. He can point to the molecule and atom on a crystal model of molecule structured solid element or on the picture of that model. He can say atom numbers of each element and the ratio of atom numbers of elements for the lattice structures. He can formularize a molecule whose model is given. He can prepare and present material about the models of some atoms that form chemical bonds in the class.
8	Whose mixture is more beautiful?	Mixing types	He can differentiate between heterogeneous mixtures and homogenous. He can give examples for the solutions of solid, liquid and gas matters in liquids. He can explain the interactions between solvent molecules and the ions or molecules of the dissolved matter in solutions.
9	Which one is faster?	Solutions	He can test the relationship between temperature and solution by experimenting. He can test that the solute is dissolved faster when the grain size gets smaller by experimenting.
10	I like Lemonade sugary	Concentrated and diluted solutions	He can differentiate between concentrated and diluted solutions.
11	Who conducts electricity?	When the bulb shines	He can explain the reasons why some solutions can conduct electricity and why the surface water is partially conductive.

Attitude scale towards science lesson (ASTSL)

An ASTSL which was designed by Biçer (2011) was used before and after the implementation of the study in order to evaluate the attitudes of the learners in both experimental and control groups about science lessons. The reliability coefficient was 0.898 as a result of the reliability analysis done. The attitude scale is a likert type scale with five choices made up of 11 positive and 15 negative items - 26 items in total. Answer options for the positive items of the scale were defined as "5 = Totally Agree," "4 = Agree," "3 = Partially Agree," "2 = Disagree," "1 = Totally Disagree"; and answer options for the negative items of the scale were defined as "1 = Totally Agree," "2 = Agree," "3 = Partially Agree," "4 = Disagree," "5 = Totally Disagree." The top score that could be gotten from the ASTSL was defined as 130.

Data Analysis

Shapiro-Wilks test was used while analysing the data of this study to decide whether gathered data were ranged equally in both groups because the sample was less than 50 in number (Büyüköztürk, 2007). As a result of the tests, it was considered appropriate to use nonparametric methods of statistics. Programs of SPSS 16 and Lertap 5 were used for data analysis.

Findings

According to the results of the Shapiro-Wilks test, it was seen that the pre-test and post-test points of experimental and control groups from DTSMP, MSTLS and ASTSL tests were not ranged normally ($p > 0.05$).

The test of DTSMP aiming to answer the question of "What is the effect of ICBCL on learners' achievements about the aforementioned subjects?" was given to the experimental and control groups as pre-test and post-test.

According to the supplementary statistical data of DTSMP, while the average pre-test point of the experimental group was 6.41 for this test, it was 5.88 for the control group. According to the findings of Mann Whitney *U*-Test, there was not a meaningful difference between the pre-test points of DTSMP of the experimental group and the points of the control group (Table 3). Findings showed that these two groups were equal in the beginning ($U = 941.00$, $p > 0.05$).

According to the supplementary statistical data of DTSMP, while the average post-test point of the experimental group was 18.35 for this test, it was 12.67 for the control group. As can be seen in Table 3, according to the findings of Mann Whitney *U*-Test, there was a meaningful difference between the post-test points of DTSMP of the experimental group and the points of the control group ($U = 571.00$, $p < 0.05$).

Table 3 Mann Whitney-*U* results of the DTSMP pre-test and post-test

	Group	*N*	Mean rank	Sum of ranks	*U*	*z*	*p*
Pre-test	Experimental	46	43.96	2022.00	941.00	-0.397	0.691
	Control	43	46.12	1983.00			
Post-test	Experimental	46	54.09	2488.00	571.00	-3.43	0.001
	Control	43	35.28	1517.00			

The test of DTSMP aiming to answer the question of "What is the effect of ICBCL on learners' conceptual misunderstandings?" was given to the experimental and control groups as a post-test.

According to the results of the DTSMP, it was showed that learners' in the experimental and control groups have misconceptions. While four of these misconceptions were identified for the first time in this study, 10 of them could be found in the literature. Misconceptions which were identified for the first time: "Atoms containing only eight electrons in the last layer may participate information of links," "When an electron is disconnected from any atom, an electron is disconnected, loses its energy," "A single Cl atom makes only ionic bond with a different atom" and "Salt dissolves homogeneously both in water and oil."

According to the results, while misconceptions ratio of experimental group about "Electron Sequence and Chemical Properties" was between 6–12%, it was 19–26% for the control group, about "Chemical Bonds" was between 4–8%, it was 19–26% for the control group, about "Compounds and Formulas" was between 6–8%, it was 24–26% for the control group and about "Mixtures" was between 4–12%, it was 19–24% for the control group.

The test of MSTLS aiming to answer the question of "What is the effect of ICBCL on learners' motivation to learn science?" was given to the experimental and control groups as pre-test and post-test. According to the supplementary statistical data of MSTLS, while the average pre-test point of the experimental group was 82.78 for this test, it was 80.83 for the control group. According to the findings of Mann Whitney *U*-Test, there was not a meaningful difference between the pre-test points of MSTLS of the experimental group and the points of the control group (Table 4). Findings showed that these two groups were equal in the beginning ($U = 806.500$, $p > 0.05$).

According to the supplementary statistical data of MSTLS, while the average post-test point of the experimental group was 93.13 for this test, it was 75.09 for the control group. As can be seen in Table 4, according to the findings of Mann Whitney *U*-Test, there was a meaningful difference between the post-test points of MSTLS of the experimental group and the points of the control group ($U = 344.50$, $p < 0.05$).

Table 4 Mann Whitney-*U* results of the MSTLS pre-test and post-test

	Group	*N*	Mean rank	Sum of ranks	*U*	*z*	*p*
Pre-test	Experimental	46	48.97	2252.50			
	Control	43	40.76	1752.50	806.50	-1.499	0.134
Post-test	Experimental	46	59.01	2714.50			
	Control	43	30.01	1290.50	344.50	-5.30	0.000

The test of ASTSL aiming to answer the question of "What is the effect of ICBCL on learners' attitudes towards learning science?" was given to the experimental and control groups as pre-test and post-test.

According to the supplementary statistical data of ASTSL, while the average pre-test point of the experimental group was 103.09 for this test, it was 99.51 for the control group. According to the findings of Mann Whitney *U*-Test, there was not a meaningful difference between the pre-test points of ASTSL of the experimental group and the points of the control group (Table 5). Findings showed that these two groups were equal in the beginning ($U = 895.00$, $p > 0.05$).

According to the supplementary statistical data of ASTSL, while the average post-test point of the experimental group was 109.17 for this test, it was 105.51 for the control group. As can be seen in Table 5, according to the findings of Mann Whitney *U*-Test, there was not a meaningful difference between the post-test points of ASTSL of the experimental group and the points of the control group ($U = 871.50$, $p > 0.05$).

Table 5 Mann Whitney-*U* results of the ASTSL pre-test and post-test

	Group	*N*	Mean rank	Sum of ranks	*U*	*z*	*p*
Pre-test	Experimental	46	47.04	2164.00			
	Control	43	42.81	1841.00	895.00	-0.97	0.440
Post-test	Experimental	46	47.55	2187.50	871.50	-0.97	0.334
	Control	43	42.27	1817.50			

Discussion and Conclusion

In this study, the effects of ICBCL prepared for the subjects of "the Orders of Electrons and Chemical Properties," "Chemical Bonds," "Compounds and Their Formulas," "Mixtures" of 7th Grade Science class on the learners' academic achievement, motivation to learn science and their attitudes towards learning science were analysed. For this aim, the lessons were done by using ICBCL in the experimental group and lessons were done with STC of related academic year in the control group.

As a result of the DTSMP post-test, the experimental group was found to be more successful when compared to the control group at the end of the implementation process. This means that ICBCL is more efficient in teaching the determined subjects when compared to STC. Local and international studies also show that teaching subjects by using cooperative learning method increase the success rate of the learners as in the results of this study. Ebrahim (2012) and Ergün (2006) also proved that teaching subjects by using the cooperative learning method increased the success rate of their 8th grade learners. Besides, it shows the results of different researchers' cooperative learning method is highly influential on the success of learners (Zoghi, 2013). Improved classroom learning environments should encourage improved academic scientific achievement (Schulze & Van Heerden, 2015).

According to the results of the DTSMP, learners in the experimental group had significantly fewer misconceptions than learners in the control group. These difficulties were categorized as misconceptions related to electron sequence and chemical properties (Stable Atom, Ion and Atom Model), Chemical Bonds (Cation and Anion, Ionic Bonds and Covalent Bonds), Compounds and Formulas (Compound, Ionic and Molecular Compound) and Mixtures (Mixture, Dissolution Event, Dissolution Rate and Conductivity Solution). It was determined that some learners in the control group had misconceptions related to Electron sequence and chemical properties concept such as "*Atoms containing only eight electrons in the last layer may participate information of links*" and "*When an electron is disconnected from any atom, an electron is disconnected, loses its energy*." These two misconceptions were first identified in the context of this study. Also learners had misconceptions about the "Atom Model" concept such as "*For an atom, to be chemically determined, it has to have two electrons in its outmost energy level*." Similar findings had been reported by Harrison and Treagust (2000) and Kara and Ergül (2012). It was determined that some learners in the control group had misconceptions related to Chemical Bonds concepts such as "*Atoms become anion by accepting proton, and become cation by giving proton*" and "*A single Cl atom makes only ionic bond with a* *different atom*.” This misconception was first identified in the context of this study. Learners also had misconceptions about “Covalent Bonds” concept such as “*Salt (NaCI) and water (H2O), both have covalent structure*.” The similar alternative conceptions had been reported before by Nicoll (2001). It was determined that some learners in the control group had misconceptions related to Compounds and Formulas concepts such as “*Compounds are divided into components physically*.” The results of different researchers also show similar results (Meşeci et al., 2013). It was determined that some learners in the control group had misconceptions related to Mixtures concepts such as “Salt dissolves homogeneously both in water and oil.” This misconception was firstly identified in the context of this study. Learners also had misconceptions about “*Salty water is a heterogeneous mixture*.” Similar findings had been reported by Milenković, Hrin, Segedinac and Horvat (2016). Some misconceptions are about “Dissolution Event” concept as “Salt, melts in water,” “Disappearing.” The results of different researchers also show similar results (Demirbaş & Ertuğrul, 2014; Lee, O et al., 1993; Uzun, 2010). The misconceptions determined in the result of this research are shown that learners could not establish relationships between concepts and had difficulty in structuring information as a result learners cannot perform effective learning. It is very important to the development and implementation of the curriculum in which learners are active in the learning process. The cooperative learning method based on the constructivist approach is applied in learning science topics (Ebrahim, 2012).

MSTLS which was given as a post-test at the end of the implementation process showed that the motivation level of the experimental group towards science dramatically increased when compared to the control group. This means that ICBCL is effective in increasing learners’ interest in Science lessons and their motivation. Local and international studies also have similar results with the results of this study. It was found that using cooperative learning method increased the interest and motivation of the learners in their related studies of “Science Lesson” by Oh and Shin (2005), “Biology” by Keraro, Wachanga and Orora (2007); “Power and Motion” by Doğan, Uygur, Doymuş and Karaçöp (2010). Along with this, it was seen that there were a few studies concluding that the cooperative learning method had nothing to do with the learners’ motivation. Doğru and Ünlü (2012) found that there was no relationship between the cooperative learning method and learners’ motivation about Science lessons.

ASTSL which was given to experimental and control groups as a post-test at the end of the implementation process showed that although there was an increase in the attitude level of experimental group towards Science lesson, the difference was not found to be meaningful. The results which were gotten from the studies named “A Journey to the Inner Structure of Matter” by Demiral (2007), and “Mixtures” by Genç (2007) are in parallel with the results of this study. Besides, it shows the results of different researchers cooperative learning method did not significantly change the attitudes of learners (Umdu Topsakal, 2010). However, in their related studies, Ballıel (2014) and Lowe (2004) found that there was a meaningful difference between the learners’ attitudes towards Science lessons as opposed to the results of this study.

In addition to the teaching methods used in the effective realization of learning, affective field features also play an important role. One of the affective field characteristics is attitude. In the measurement of the affective field characteristics, it is not possible to observe these features directly and thus indirect measurement is used. For this reason, either long-term observation is made or the learner is interacted with artificial situations to determine how he tends to behave in these situations (Genç & Şahin, 2015). Zacharia and Barton (2004) stated that the attitude from affective field behaviors is resistant to time, that it is a phenomenon that can change with personal beliefs, and that it can be learned over time in the process (Zacharia & Barton, 2004). It has also been shown in different studies in the literature that the attitude changed over time (Baykul, 2004).

The reason why there was not a meaningful difference between the experimental group and the control group can be that the time used to apply ICBCL was limited, the learners were not used to work as a group while doing a task, they needed more time to get used to the method, they were used to get information readily by their teachers and that they found it difficult to work individually.

Suggestions as a result of the findings of this study: Further ICBCL for the other topics of Science lessons can be developed. Further curriculums for the other subjects can be developed by taking ICBCL as an example. The efficiency and practicality of this curriculum can be researched by doing similar studies about ICBCL for the other grades. The dependent variables whose effects on the experimental group who were taught with ICBCL were analysed on academic achievement, motivation and the learners’ level of attitude towards Science lesson. Apart from these variables; further studies on the variables like critical thinking, creative thinking, empathetic thinking, logical thinking and self sufficiency can also be done.

Advanced economies, innovative industries and firms, and high-growth jobs require more educated workers with the ability to respond flexibly to complex problems, communicate effectively, manage information, work in teams and produce new knowledge. For this reason, individuals especially in developing countries such as India, Philippines, Thailand, Turkey, South Africa, Brazil must have 21st century skills. As shown in the results of this study, cooperative learning has the potential to train individuals who have those skills.

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Authors' Contributions

FA was responsible for data collection and the first draft manuscript; FGK and BAS contributed to the conceptualisation of the study, the analysis and writing of the manuscript. All authors reviewed the final manuscript.

Notes

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