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An Analogy Activity for Teaching Chemical Reaction and Collision Theory from Perspectives of Pre-Service Science Teachers

Sevil Kurt [1*]

[1] *Recep Tayyip Erdogan University, Rize, TURKEY*

* CORRESPONDENCE: sevilkurt@erdogan.edu.tr

ABSTRACT

In chemistry, events are explained in three dimensions: microscopic, macroscopic, and symbolic. Achieving a complete understanding of a chemical event requires integrating these three dimensions. Research on the comprehension of chemistry concepts shows that students sometimes fail to use them correctly in explaining chemical events. Students especially have difficulty in understanding and explaining some chemistry topics because of their abstract structures like chemical reactions. This study aims to evaluate an analogy activity developed for teaching chemical reaction and collision theory from the perspectives of pre-service science teachers. To this end, the analogy activity developed on chemical reaction and collision theory was carried out with the 1st grade 42 science students (i.e. pre-service teachers) attending a state university, and their opinions were received. The observation notes taken and the analogy tables filled in by the students were used to evaluate the analogy. In general, the pre-service teachers considered the analogy distinctive, interesting, and amusing relative to other methods and thought that the analogy helped them concretize the concept of chemical reaction, see the events taking place in the reaction process in detail, and provided them with an insight into developing activities and materials of this sort in the future.

Keywords: analogy, chemical reaction, collision theory, evaluation, pre-service science teachers

INTRODUCTION

It is difficult for students to understand the distinctive language of chemistry, which is an important branch of physical science, at any education level (Ben-Zivi & Gai, 1994; Nakhleh, 1992; Schmidt, Kaufmann, & Treagust, 2009). Many chemistry topics are abstract, and students mostly cannot understand them with a single example. Students usually find it easier and more amusing to learn concepts which they can see, feel, or picture in their minds. In chemistry, events are explained in three dimensions: microscopic, macroscopic, and symbolic (Johnstone, 1993). Macroscopic level deals with the concrete aspects of chemical phenomena that are visible to the naked eye (e.g. evaporation of water, gas discharge as a result of a chemical reaction). Symbolic level involves the explanation of the events observable at macroscopic level through certain formulas and equations (Barak & Dori, 2004; Gabel, 2003). Trying to determine the kind and amount of the gas coming out through reaction is an example of making an explanation at symbolic level. Microscopic level deals with those aspects of chemistry which are not directly observable such as atoms, molecules, ions, and the spatial structures of these particles (e.g. trying to explain how a chemical reaction takes place in atomic level). Achieving a complete understanding of a chemical event requires integrating these three dimensions (Gabel,

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2003; Wu, 2003). However, research on the comprehension of chemistry concepts shows that students sometimes fail to use them correctly in explaining chemical events (Ben-Zivi & Gai, 1994; Coştu & Ayas, 2002; Eilks, Moellering, & Valanides, 2007; Karaer, 2007; Osborne & Cosgrove, 1983; Schmidt, Kaufmann, & Treagust, 2009; Solsona, Izquierdo, & Dejong, 2003). Research also indicates that students have difficulty in understanding some chemistry topics and try to explain events by use of non-scientific ideas.

Chemical reaction is one of the chemistry concepts in understanding which students have difficulty (Ahtee & Varjola, 1998). Students may observe macro changes such as gas discharge, color change, and precipitation in a chemical reaction. Chemical change process is also explained with chemical equations and symbols in terms of substances at the beginning and at the end of the reaction. In addition, in a chemical reaction, students are expected to understand and interpret certain events and things in micro level that cannot be directly observed such as atoms, molecules, collisions, and the breaking of chemical bonds and the formation of new ones. However, research reveals that students even fail to achieve an absolute understanding of those concepts which involve concrete examples they can observe (Hesse & Anderson, 1992; Johnson, 2000; Tsaparlis, 2003). In this sense, it may be really difficult for students to comprehend what a chemical reaction is and how it takes place. As a matter of fact, previous studies report that students have a lot of misconceptions about the particle structure of matter and the events occurring in the chemical change process. These studies indicate that students regard reaction only as a change in the external appearance of a matter (Johnson, 2000); they think a chemical change takes place during change of state (Ahtee & Varjola, 1998); they think substances cannot transform into other substances (Johnson, 2000); they think a substance disappears when a chemical reaction takes place (Driver, Squires, Rushworth and Wood-Robinson, 1994); and they define chemical reaction as the formation of a new substance out of two substances, think that chemical reactions are irreversible, and describe some physical events as chemical events (İcik, 2003; Kurt, 2010). It is very likely that these results derive from the fact that students fail to achieve a complete understanding of the chemical change process. It is stated in many studies that difficulties in understanding this process are due to the particle structure of matter, deficiencies in understanding the concepts of element, compound, atom, ion, and so on, and problems experienced in associating the macroscopic properties of substances with particle properties (Ayas, 1995; Ahtee & Varjola, 1998; Eilks et al., 2007; Lee, 1999; Özmen, 2004; Papageorgiou, Grammaticopoulou, & Johnson, 2009; Solsona et al., 2003; Tsaparlis, 2003).

The main purpose of chemistry teaching is to ensure that concepts are learned effectively. The teaching of topics such as atom, ion, molecule, and reaction requires special attention. This is because; these concepts are the basic concepts which are used in explaining almost all chemistry topics. Concretizing these concepts which students cannot observe directly as much as possible, trying to teach them in different ways, and testing the effectiveness of these ways will help accomplish the objectives of chemistry teaching. A lot of modern teaching methods, techniques, and materials are developed by educational researchers to be used for concretizing abstract science concepts or teaching the concepts which students have difficulty in understanding, and their effectiveness is tested through various methods. Some of them are computer animations, simulations, laboratory activities, and analogies (Aydoğdu, 2000; Bilgin & Geban, 2001; Greenbowe, 1994; Pekdağ, 2010; Williamson & Abraham, 1995; Yang, Andre, Greenbowe, & Tibell, 2003).

Analogies have been frequently used by educators in teaching from past to present because they are appropriate to many chemistry topics, mostly do not require a high-level technological infrastructure, are easy to access, can be developed by students and teachers, and can be used in any environment (e.g. classroom, laboratory). Apart from that, we frequently use analogies, intentionally or unintentionally, to describe an unknown thing better in the daily life.

Analogies help individuals establish a connection between their current knowledge and new knowledge. Prior knowledge which is more familiar to an individual is defined as source while new situation or knowledge to be learned is defined as target. Analogies, on the other hand, build a bridge between these two kinds of knowledge (Brown, 1993). In this way, individuals use knowledge which is more familiar to them to make sense of and understand those concepts which are new or less familiar to them (Gentner & HolYoak, 1997; Glynn, 1991).

Analogies used in teaching environments have been classified by researchers in terms of content, usage, creator, the number of steps, and so on. Some are as follows: the structure mapping theory (smt), the general model of analogy teaching (gmat), teaching with analogies, bridging analogies, multiple analogies model, narrative analogies model, analogies in the form of games, verbal and pictorial analogies, and individual analogies (Glynn, 1991; Thiele & Treagust, 1991). However, there are some principles to taken into account in developing and using an analogy regardless of is type. These principles can be summarized as follows;

- Content and target have to be determined well;
- A similar (familiar) analog has to be used for a new unknown concept;
- A concrete analog has to be used for a new abstract target concept;
- Connections that can be associated with the nature of the new concept have to be selected; and
- Students' prior knowledge has to be considered (Kesercioğlu, Yılmaz, Cavaş, & Cavaş, 2004).

Otherwise, students might fail to distinguish the analogy from the content to be learned, remember only the analogy rather than the content to be learned, focus on only irrelevant aspects of the analogy, and produce false results (Ayas & Sözbilir, 2015). On the other hand, it is known that when analogies are used effectively, they make a lot of positive contributions to teaching environments. It is reported that when they are used for teaching abstract concepts that are difficult to understand, they make complicated topics simpler and clearer for students and thus facilitate learning, enhance permanence, eliminate misconceptions, and increase students' curiosity and motivation (Bilgin & Geban, 2001; Brown, 1992; Dagher, 1994; Heywood, 2002; Keller, 1983). Furthermore, analogies provide platforms where different ideas are put forward and discussed in learning environments and support the improvement of skills such as solving problems, making explanations, and collaborating (Gentner & HolYoak, 1997; Kesercioğlu et al., 2004).

Advancing technology and our incrementally increasing knowledge provide us with new ways of achieving better teaching and learning. The mission of a qualified educator is to develop methods and materials appropriate to the interests and needs of his/her students by using these opportunities and to use such methods and materials in his/her lessons (Cavaş, 2011). Therefore, pre-service teachers should be provided with not only theoretical but also practical opportunities to know different teaching methods throughout their undergraduate education. If these methods are covered in different courses given in faculties of education, pre-service teachers may be made to look at the concept of science teaching and learning from a broader perspective.

The present study involves an analogy activity for the teaching of chemical reaction and collision theory and aims to evaluate this activity based on the views of pre-service science teachers.

METHODOLOGY OF RESEARCH

42 first grade pre-service science teachers attending a state university in Turkey participated in the study.

Data Collection Tools

The researcher observed the activities and took written notes about the process. Moreover, semi-structured interviews were carried out with 7 students at the end of the study, and the views of the pre-service teachers were received in regard to the analogy used.

Though the primary aim of the study was not to make a quantitative evaluation of student understanding, the analogy tables included in the worksheets, which were used throughout the activities, and filled in by the students were also used as data collection tools to support interview and observation data.

Data Analysis

At the end of the activities, semi-structured interviews were carried out with 7 voluntary students about the activities they were engaged in. The data coming from the interview were subjected to descriptive analysis. Then the students' responses were grouped under two main categories about the activity process: positive and negative. The participating students were referred to as P1, P2, P3, P4, and so on, and their responses were showed in table by category. Furthermore, one or two quotations from the students' responses were included. The researcher took written notes about her observations throughout the process under certain titles. These titles are as follows: the willingness of the students to do activities, the functionality of group work, the halting sides of the activity, the functionality of worksheets, and the positive or negative reactions of the students about the activity. The observation data were arranged through reading and presented after simplification.

The analogy tables included in the worksheets and filled in by the students were analyzed and evaluated based on certain criteria. The below-mentioned criteria were used for comparison between properties involving analogy in the analogy table.

Completely correct comparison: Answers in which relationships between the properties which are likened and the properties to which they are likened are explained completely.

Partially correct comparison: Answers in which relationships between the properties which are likened and the properties to which they are likened are explained partially.

Incorrect comparison: Answers in which relationships between the properties which are likened and the properties to which they are likened are explained wrong.

Blank: Answers in which there is no explanation.

Introduction of the Activity and the Analogy

The researcher developed an analogy activity for the teaching of chemical reaction and collision theory. In addition, a worksheet was developed to be used during the implementation of activities. The analogy activity, the worksheet, and other materials were examined by three chemistry educators and one domain expert. Necessary arrangements were made based on their feedbacks. The first two parts of the worksheet used in the study are given in Appendix 1. The four-step model of the constructivist approach was taken as basis in the implementation process of the activity. The researcher divided the students into 7 groups of 6 people and distributed the worksheets, which they would fill in individually throughout the activity, to all students. The first part of the worksheet contains a question about how chemical reactions take place. The researcher asked the question to the entire class. By this means, she attempted to reveal the ideas (i.e. prior knowledge) of the students regarding the connections between chemical reactions and the events taking place in the micro dimension of these chemical reactions.

The second part of the worksheet includes the analogy activity. This part corresponds to focused exploration, which is the second step of the four-step model. This part contains two interconnected activities. In this part, every group played a competitive game by using a transparent reaction box and hook balls made of play dough of different colors and saved their scores. The goal and the rules of the game were announced in the beginning. The goal was to put the biggest number of clamped ball pairs in the other section of the transparent box within the given period. The winner of the game would be the group that put the biggest number of clamped ball pairs in the other section of the box within 5 minutes. Clamped ball pairs containing balls with the same color and ball pairs containing poorly clamped balls would not be counted. When the timekeeper was started, the students would begin to shake the box. In this way, they would try to make the balls be clamped together by colliding with one another. During shaking, the students would get the clamped ball pairs out of the first section of the box, strengthen the links between the balls, and put them in the other section of the box. The total number of the ball pairs put in the other section of the box would be written in the table. The winner of the game would be determined based on those total numbers written in the table.

In this game, the color balls are likened to two particles like A and B that participate in a chemical reaction. That the balls are clamped together by colliding with one another is analogous to that the particles participating in a reaction collide and generate a product. The students playing the game would notice that not all balls colliding with one another were clamped together. In this game, only those balls which collide with one another in hooks and at a certain speed are clamped together. Slowly colliding balls are not clamped together. In addition, the balls going on the same side are not clamped together even if they collide with each other. That is similar to the case of a chemical reaction in which a product is formed only when particles collide on a particular side and at a certain speed (non-elastic). The transparent box used in the game has a barrier in the middle. This barrier prevents the colliding balls from passing to the other section. This barrier in the game corresponds to the energy barrier that has to be overcome for a chemical reaction to take place. An important point of this game is that it shows the links between the clamping balls. There are two possibilities about these links. Either poorly clamped balls fall apart and revert back or perfectly clamped balls are counted. These links in the game correspond to new chemical bonds emerging in a chemical reaction. Collision theory uses activated complex (non-steady-state) in the formation of chemical bonds. Activated complex (non-steady-state) is formed as a result of the collisions taking place. This activated complex either generates products or transforms into reactants again.

In the second activity, the students were asked to create different ball combinations and collisions by using the available balls of different colors and connecting pieces.

By this means, an attempt was made for the students to see that more than two kinds of particles may simultaneously collide and generate a product, and the particles that participate in a chemical reaction and generate a product may have different structures.

In both activities, questions that would direct the students to the results were asked to them in the worksheet. They were requested to discuss these questions in group and write their ideas in the blank spaces given. In addition, a partly-filled analogy table was included in the worksheet. The researcher made an explanation about analogy and how to fill in the table during the activity. The researcher told all groups to share their answers and the analogy tables they filled in with the entire class through the medium of group spokespeople after they finished their works. Various explanations provided by the groups were discussed, and the way chemical reactions could be explained based on collision theory was formally explained through association with the analogy used. At this point, it was tried to ensure that the students could distinguish between similar and dissimilar aspects of the game they played to those of chemical reaction and they could associate properties with one another accurately. In addition, the correctly completed version of the analogy table was reflected on the board via projector, and unclear points were clarified.

RESULTS

Findings Obtained from the Interview Data

Table 1 concerning the findings obtained from the interviews with 7 students about the activity carried out is given below.

Table 1. The views of the pre-service teachers about the activity process and the analogy

Categories (positive)	**Students**	**Q1**	**Q2**
Interesting	P1, P2, P3, P4, P5, P6, P7	It was very different from our other lessons. I think it attracted our attention more because it was like a competition, and we learned amusedly. It was not boring (P2).	In my opinion, it made the activity more amusing and exciting that it was competitive and had a particular duration and specific rules. I think it would have been boring and non-interesting if we had just shaken and combined them. We were excited because we wondered which group would put the biggest number of the balls in the given period (P6).
Amusing	P1, P2, P3, P4, P5, P6, P7		
Exciting	P3, P4, P7	.	
Helpful for concretization	P1, P3, P4, P5	For example, threshold energy is mostly showed in graphs in textbooks. Thanks to the activity in which it was hard for the balls to pass to the other section when the barrier between two sections was high, we could concretely see that when the threshold energy is higher, it is more difficult for reactions to take place (P4).	We treated the balls like atoms and made them collide with one another. Then we assumed that the clamped balls established bonds. In fact, atoms and molecules collide with one another, which brings about chemical reactions. We demonstrated that in a concrete way (P5).
Helpful for the comprehension of concepts	P4, P5, P6, P7	This lesson was about just one chemistry topic, but it was quite effective, I think. In my opinion, students can understand topics more easily if activities of this sort are carried out for teaching other topics (P4).	To be honest, I already knew this topic very well because I had memorized it while studying for the exam (university entrance exam). However, it seems that I comprehended the topic better in this way (P6).
Suggestive	P1, P7	I would like to develop similar activities and analogies for some difficult topics, though not for all topics, when I become a teacher (P1).	It was useful in that it showed us that chemistry can be made interesting not only through experiments but also by use of different methods (P7).
Increasing communication with classmates	P1, P3, P4	People who did not have much communication with one another leagued together, shared their ideas with one another, and made discussions together (P1).	There were some shy people in our group. In the beginning, they did not want to participate, but we did it together because everyone had a task within the framework of the game (P3).
Demonstrating the process	P5	In the past, I thought that when there is a chemical reaction, something happens and ends. I would think about just its beginning and end or I would say its internal structure changes, but I would not understand what happens actually. In this game, it seemed as if we had been going through a reaction. We tried to see what happened (P5).	
Permanent	P1, P2, P4, P5, P6, P7	I had watched the collision of particles and the formation of a product as a result in an animation on the computer before. Our teacher had showed it. However, I do not remember its details. It was too short. In this game, however, everything was more detailed. We did everything ourselves. We did not just watch. I think it was permanent and easier to remember (P6).	

Q1, Q2: Quotation 1, Quotation 2

Table 1 (continued). The views of the pre-service teachers about the activity process and the analogy

Categories (positive)	**Students**	**Q1**	**Q2**
One-to-one experience	P2, P3, P5,	We experimentally learned that not a reaction takes place as a result of every collision. That is, the balls were not clamped together every time. They were clamped together when they collided under certain conditions (P2).	Chemistry is always associated with experiments, but I cannot say that we have frequently conducted experiments in our lessons. Our teacher either carried out demonstration experiments and did not allow us to touch the materials or had us carry out very simple experiments. Though we did not carry out an experiment in this activity, there were materials which we could use and touch. That is, we did it ourselves (P3).
Different and authentic	P1, P3, P5, P6	While our textbooks or teachers were demonstrating this topic, we would see figures in which arrows indicated round particles colliding with one another. There used to be only two particles. In this activity, we saw that there could be more than two colliding particles, too (P3).	Filling in the analogy table was like a puzzle. It was something different and distinctive. We had not used similar things to the worksheet and the analogy in our lessons before. Our teachers would distribute worksheets, but they would mostly have questions on them (P5).
Categories (negative)	**Students**	**Q1**	**Q2**
Three-dimensional materials	P4, P7	The connecting pieces and the balls were not completely mounted. That caused us to lose time during the game (P4).	
Activity duration and arrangement	P2	The number of the balls could have been bigger, and the duration of the activity could have been longer (P2).	
Group work	P1, P7	As we are 1st grade students, we do not know each other enough. I could have worked better if I had been in the same group as the people I knew better (P1).	Group work was good in general, but some of our friends were not willing to participate. The same people took the floor in discussions in particular (P7).

Q1, Q2: Quotation 1, Quotation 2

All of the pre-service teachers found the activity interesting and amusing. Most of the pre-service teachers participating in the interviews stated that the activity helped them understand and concretize the concepts. P4 told the contribution of the activity to concretization as follows:

"For example, threshold energy is mostly showed in graphs in textbooks. Thanks to the activity in which it was hard for the balls to pass to the other section when the barrier between two sections was high, we could concretely see that when the threshold energy is higher, it is more difficult for reactions to take place."

P6 expressed the effect of the activity on permanent learning as follows:

"I had watched the collision of particles and the formation of a product as a result in an animation on the computer before. Our teacher had showed it. However, I do not remember its details. It was too short. In this game, however, everything was more detailed. We did everything ourselves. We did not just watch. I think it was permanent and easier to remember."

P5 highlighted a different aspect of the activity and the analogy as follows:

"In the past, I thought that when there is a chemical reaction, something happens and ends. I would think about just its beginning and end or I would say its internal structure changes, but I would not understand what happens actually. In this game, it seemed as if we had been going through a reaction. We tried to see what happened."

In this way, P5 tried to explain the effect of the activity on capability to explain the events taking place in the process. Two pre-service teachers (P1 and P7) said that the activity was suggestive in that it made them think that different methods and techniques could be used in teaching. Their views are as follows:

"I would like to develop similar activities and analogies for some difficult topics, though not for all topics, when I become a teacher."

"It was useful in that it showed us that chemistry can be made interesting not only through experiments but also by use of different methods."

Half of the pre-service teachers mentioned the effects of the group work on increasing communication among friends and its contribution to learning by doing and experiencing. P3 delivered his opinion on this subject as follows:

"*Chemistry is always associated with experiments, but I cannot say that we have frequently conducted experiments in our lessons. Our teacher either carried out demonstration experiments and did not allow us to touch the materials or had us carry out very simple experiments. Though we did not carry out an experiment in this activity, there were materials which we could use and touch. That is, we did it ourselves.*"

Most of the pre-service teachers found the activity different and authentic. Two of the pre-service teachers (P3 and P5) expressed their views on this subject as follows:

"*While our textbooks or teachers were demonstrating this topic, we would see figures in which arrows indicated round particles colliding with one another. There used to be only two particles. In this activity, we saw that there could be more than two colliding particles, too.*"

"*Filling in the analogy table was like a puzzle. It was something different and distinctive. We had not used similar things to the worksheet and the analogy in our lessons before. Our teachers would distribute worksheets, but they would mostly have questions on them.*"

The negative views of the pre-service teachers about the activity were about three-dimensional materials, activity duration and arrangement, and group work. P1 stated her view on this subject as follows:

"*As we are 1st grade students, we do not know each other enough. I could have worked better if I had been in the same group as the people I knew better.*"

In this way, P1 evaluated the effect of in-group communication on the activity. The views and the evaluations of the other students about the activity and direct quotations from their statements are presented in **Table 2** in detail.

Findings Obtained from the Observation Data

At the beginning of the activity, the students touched and examined the materials and asked questions to the researcher. Thus, it can be said that they were generally willing and excited to do the analogy activity. In addition, it was observed that the arrangement of the analogy as a competition increased the students' willingness and excitement to do the activity, and that the male students were more enthusiastic for the competition. It was seen that the students mostly did the activities together, listened to the ideas of each other while answering the questions, mentioned the points they disagreed with in the answers, and tried to persuade one another. Though few in number, some students had difficulty in understanding the way the analogy table would be filled in. Their group friends or the researcher helped these students by making explanations about the table.

Findings Obtained from the Analogy Table

Table 2 presents findings concerning the analogy table filled in by the pre-service teachers. In filling in the table, the pre-service teachers were expected to establish 11 connections about the activity properties similar or dissimilar to those of chemical reaction and collision theory. The first column of **Table 2** shortly presents comparisons concerning similar and dissimilar aspects in the analogy table.

Table 2. The categories and the percentages of the answers given by the students to the comparisons in the analogy table

Comparisons	CCC	PCC	IC	Blank
1. Balls-particles	71%	29%		
2. Being clamped-generating a product	100%			
3. The side on which the balls collide-the side on which the particles collide	83%	17%		
4. The direction in which the balls collide-the direction in which the particles collide	50%	14%	22%	14%
5. Barrier between the sections-activation energy barrier	50%	19%	31%	
6. The link between the balls-chemical bond	83%			17%
7. Poorly clamped balls-non-steady-state	17%	50%	33%	
8. The motion of the balls-the motion of particles	50%	26%	14%	10%
9. The balls being different-particles being different	86%	14%		
10. The number of the balls-the number of particles	19%	67%	14%	
11. The shapes and the sizes of the balls-the shapes and the sizes of particles	57%	17%	6%	

CCC: Completely correct comparison **PCC:** Partially correct comparison **IC:** Incorrect comparison

Table 2 shows that more than half of the students could make completely correct comparisons between the balls in the game and the particles participating in a chemical reaction; between that the balls were clamped together through collision and that particles generate a product through collision; between that the balls could be clamped together only when they collided on the correct sides and that particles can generate a product only when they collide on the correct sides; between the links between the balls and the chemical bonds between particles; between that colliding balls were different in color and that particles generating a product through collision in reactions are different; and between the shapes and the sizes of the balls and the shapes and the sizes of particles participating in a real chemical reaction. On the other hand, half of the students were able to make completely correct comparisons between the direction in which the balls collided and the direction in which particles collide; between the barrier between the sections in the material and the energy barrier to be overcome in a chemical reaction; and between the motion of the balls in the horizontal plane and the motion of particles in a real chemical reaction. 31% of the students incorrectly compared the barrier between the sections in the material with the energy barrier to be overcome in a chemical reaction. These students stated that the energy barrier that has to be overcome in a chemical reaction can be compared with the kinetic energy or the potential energy to be possessed by the balls or with the speed at which the box was shaken.

Less than half of the students made completely correct comparisons between that the poorly clamped balls fell apart and that the activated complexes fall apart and transform into reactants again and between the number of the balls before clamping/the number of the balls after clamping and the number of the particles participating in a chemical reaction/the number of the particles formed in the end. Not less than half of these students wrote answers that could be considered partially correct comparisons in the analogy table. Some of the students who made incorrect comparisons between that the poorly clamped balls fell apart and that the activated complexes fall apart and transform into reactants again (33%) likened that the poorly clamped balls fell apart to non-elastic collision or to an unproductive chemical reaction.

DISCUSSION AND CONCLUSION

The pre-service teachers usually found the activity interesting, amusing, and exciting. The fact that the activity was carried out in the form of a competition contributed to the formation of these impressions among the pre-service teachers. Harrison (2002) also reports that the use of analogy provides motivation, which is an important element of learning, and increases students' levels of interest.

Most of the pre-service teachers described the activity as "different" and "authentic" relative to the teaching methods they had used until then. P5 stated her view on this subject as follows: "Filling in the analogy table was like a puzzle. It was something different and distinctive. We had not used similar things to the worksheet and the analogy in our lessons before. Our teachers would distribute worksheets, but they would mostly have questions on them." The pre-service teachers participating in the study were 1st grade university students, and it is known that traditional methods are frequently used in schools in Turkey because of lack of materials, inexperience, time problems encountered in the implementation of curricula, laboratory problems, or concentration on courses that are important for the university entrance exam (Kurt, 2010). Thus, the participants may be more familiar with traditional methods and techniques.

Many pre-service teachers focused on the positive aspects of the activity that contribute to conceptual learning. They thought that the activity helps concretize concepts, contributes to permanent learning, allows students to learn by their own experiences, and helps understand concepts more easily. The fact that the students were able to fill in the connections under the categories of CCC and PCC in the analogy table at a high level may be taken as a finding supporting the above-mentioned views of the students.

Learning is a complex and active process influenced by many factors. A teacher who enters a classroom should not regard learners as passive individuals who are isolated from the external world and focus on only learning. There are a lot of factors influential on learning such as students' prior experience and knowledge about concepts, interests, and needs as well as factors related to the learning environment (Coll & Treagust, 2003; Dursun & Dede, 2004; Shiland, 1999). Recent research on the cognitive aspect of learning emphasizes that student-centered technologies and approaches should be used in lessons (Chiu & Lin, 2005; Pekdağ, 2010). This is because; these approaches take into account students' prior experience about concepts, misconceptions (if any), expectations related to learning, interests, and needs as much as possible, and learning environments are arranged accordingly. Research indicates that students learning in these learning environments have higher interest in and motivation for lessons, have higher academic achievement, and learn concepts more meaningfully and permanently (Özerbaş, 2007; Tezcan & Yılmaz, 2003; Ürek & Tarhan, 2005).

P5 said, "In the past, I thought that when there is a chemical reaction, something happens and ends. I would think about just its beginning and end or I would say its internal structure changes, but I would not understand what happens actually. In this game, it seemed as if we had been going through a reaction. We tried to see what happened." That shows that the activity contributed to the visualization of the chemical reaction process.

In traditional learning environments, chemical reactions are generally taught by writing a simple equation on the board: two particles like A and B come together and generate a new substance like C (İcik, 2003; Eilks et al., 2007). However, simple representations of this sort may lead to wrong ideas such as "chemical reaction is the process in which two substances come together and generate a new substance" or decomposition reactions are not reactions (İcik, 2003; Kurt, 2010). A similar result was obtained by Eilks et al. (2007). In their study, despite teaching, students continued to define chemical reaction as the formation of a product out of two starting substances. It is reported in many studies that difficulties in understanding the chemical change process result from deficiencies in understanding such non-concrete concepts as particle structure of matter, element, compound, atom, and ion and problems in associating the macroscopic properties of substances with their particle properties (Ahtee & Varjola, 1998; Ayas, 1995; Lee, 1999; Özmen, 2004; Papageorgiou, Grammaticopoulou, & Johnson, 2009; Solsona et al., 2003; Tsaparlis, 2003). In this sense, visualizing and concretizing micro-processes taking place during chemical events (e.g. atom, ion, intermolecular collisions, bond formation) with animations or analogies similar to those in the present study may help achieve a more effective and permanent chemistry teaching (Bilgin & Geban, 2001; Brown, 1992; Chiu & Lin, 2005; Heywood, 2002; Kelly & Jones, 2007; Williamson & Abraham, 1995; Yang, Andre, Greenbowe, & Tibell, 2003).

It is clear from the observation findings and the views of the pre-service teachers expressed in the interviews that the arrangement of the activity in the form of group work helped group members put forward and discuss different ideas and correct wrong ideas and increased communication among the students. It is reported in various studies that a collaborative learning of this sort is more effective in making sense of concepts and has positive effects on understanding relative to traditional teaching (Bilgin & Geban, 2006; Carpenter & McMillian, 2003; Gokhale, 1995; Nakiboğlu, 2001; Şenol, Bal, & Yıldırım, 2007, Tanel & Erol, 2008).

The pre-service teachers also stated that the activity provided them with insight into the teaching of science concepts. The participants were the 1st grade students. In this regard, the activity also contributed to the professional development of the pre-service teachers by enabling them to become familiar with methods for the teaching of science concepts, take interest in these methods, and search them.

IMPLICATIONS

This study involved the evaluation of an analogy activity developed for the concepts of chemical reaction and collision theory, which tries to explain the chemical reaction process, from the perspectives of pre-service science and technology teachers. Experimental research that investigates the influence of this activity on conceptual understanding or attitudes may be carried out.

The concepts which the analogy used in the study tried to concretize are not only used for explaining the chemical reaction process but also associated with concepts related to reaction rate. Collision theory is taught within the scope of the topic of reaction rate within the secondary education chemistry curriculum implemented in Turkey (MEB, 2013). It is reported that failure in learning this topic well affects learning concepts related to reaction rate and even chemical equilibrium (Alkan & Benlikaya, 2004; Hackling and Garnett, 1985). Thus, the degree to what the analogy used in the study influences the learning of concepts related to reaction rate and chemical equilibrium may be investigated.

It may also be investigated whether or not the analogy used in the study may be improved and used in teaching different concepts involving particle model of matter.

Though they were few in number, some students had difficulty in filling in the analogy table. Conducting a similar activity with students prior to an activity of this sort which they are not very familiar with may make the process more effective.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Sevil Kurt holds a PhD in science education and now is an associate professor at Recep Tayyip Erdogan University, Rize, Turkey.

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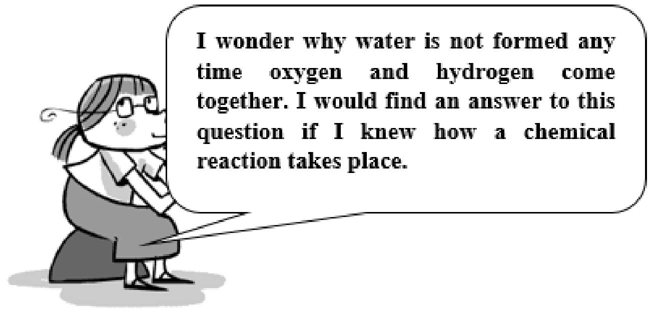
APPENDIX 1



Materials

A double-section transparent box
Hook balls of different colors made of play dough
Connecting pieces
Timekeeper

You can answer these questions through the activities you are to carry out. To achieve that, you need to follow the instructions given and answer the questions together with your group friends.

The game whose process steps are given below has certain rules. Let's read these rules!

- The winner of the game is the group that puts the biggest number of clamped ball pairs in the other section of the box within 5 minutes. 
- Clamped ball pairs containing balls with the same color are not counted.
- Ball pairs containing poorly clamped balls are not counted.

Process Steps:

- Put all balls of different colors (green and orange) given to your group in one section of the transparent box.
- Begin to shake the box when you start the timekeeper, and ensure that balls are clamped together.
- Allow every group member to shake the box in regular turn.
- Get each ball pair composed of different colors clamped during shaking out of the box.
- Manually strengthen the links between the clamped balls and put ball pairs in the other section of the box.
- Do that for five minutes and stop the timekeeper at the end of this period.
- Write the number of total ball pairs put in the other section of the box at the end of this period in the table.
- The winner of the game is the group that puts the biggest number of clamped ball pairs in the other section of the box within 5 minutes.

Table. Activity Data

Group no	
The number of clamped ball pairs	

? Was every colliding ball clamped with the ball with which it collided when you shook the balls? Explain the conditions under which the balls were clamped together and the conditions under which they were not clamped together in items.

………

? Discuss whether or not the balls of different colors in your activity are analogous to two particles like A and B in a chemical reaction and whether or not the game you play is analogous to the formation of a chemical reaction. Discuss analogous and non-analogous aspects and fill in the table provided below, some parts of which are already filled.

The property in the game that is likened to a property in a chemical reaction	**Comparison**	**The chemical reaction property to which a property in the game is likened**
Green and orange balls	Comparable	
The collision of the balls	Comparable	The collision of particles in chemical reactions
	Comparable	The particles collide with one another and generate a product
The balls are clamped together only when they collide with each other on a proper side	Comparable	
The balls are clamped together only when they collide with each other in hooks	Comparable	
The balls that do not collide with each other fast enough are not clamped together	Comparable	Elastic collisions do not result in a product
	Comparable	Energy barrier to be overcome for a product to come out of reactants
Links between the balls in ball pairs	Comparable	
Strengthening the links between the balls in ball pairs	Comparable	A stable product comes out of an unstable activated complex (non-steady-state)
Poorly clamped balls fall apart	Comparable	
The motions of the balls in the horizontal plane	Incomparable	
2 balls simultaneously collide in the beginning	Incomparable	The number of particle types participating in a chemical reaction. This is because; more than two particles can collide and generate a product (as in $5Fe^{+2}+MnO4^{-}+8H^{+}\rightarrow 5Fe^{+3}+Mn^{+2}+4H_2O$) just like two particles can participate in a reaction.
The colliding balls have different colors	Incomparable	
The number of the balls before clamping and the number of the balls after clamping	Incomparable	
The shapes and the sizes of the balls	Incomparable	