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The Effect of Learning by Teaching on Pre-Service Science Teachers' Attitudes towards Chemistry

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ABSTRACT

This study examined the effect of learning by teaching on pre-service science teachers' attitudes towards chemistry. The method used in this study; *learning by teaching*, was developed by Jean-Pol Martin for foreign language classes and is frequently used in Germany. This method has been restructured over a 3-year process to be used in a science course in this study. The current study presents the implementation of the method after three years' revision. The sequential explanatory method was followed which is one of the mixed methods research designs. The study was conducted during the 2015–2016 academic year with 49 pre-service science teachers, who were selected by purposeful sampling. Data was collected twofold: with a Chemistry Attitude Scale and focus group interview. The results of this study showed that learning by teaching was effective in positively increasing the attitudes towards chemistry.

Keywords: Attitude towards chemistry, learning by teaching, pre-service science teachers.

INTRODUCTION

Students' attitudes have a significant position in educational research (Osborne, Simon & Collins, 2003). The fact of attitudes being emphasised in instructional programmes also addresses their significance in education. A positive increase in students' attitudes is stated as an important goal in these programmes (National Board of Education [NBE], 2013, p. 1, 3, 23, 25). There are two main reasons behind the intent to positively increase students' attitudes towards the content (e.g. chemistry). The first one is the positive relationship between attitude and academic achievement (Bakar, Tarmizi, Mahyuddin, Elias, Luan & Ayub, 2010; Hacieminoğlu, 2016; Hançer, Uludağ & Yılmaz, 2007; Narmadha & Chamundeswari, 2013; Wang, Tsai, Chu, Lei, Chio & Lee, 2015). In other words, students' attitudes affect their academic achievement. The second reason is that attitudes can predict behaviour (Kayaoğlu, 2011, p. 175). They have an impact on feelings, beliefs and behaviours (Jain, 2014). Attitudes can influence students' decisions on choice of career or course (e.g. socio-scientific issues like GMOs) as well as their participation in an activity in a certain discipline (Germann, 1988).

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Thus, it can be suggested that once students' attitudes are revealed, their behaviours can be predicted (Arkonaç, 2008, p. 137).

The definition of attitude is in support of these explanations provided above. Güney (2013, p. 219) defines attitude by consolidating a wide range of definitions in the research base: 'Attitude is a tendency of reaction created in a cognition, affect and behaviour coherence. This tendency is organised based on experiences and knowledge towards oneself and towards everything else; alive or not, concrete or not.' According to the studies conducted on attitudes, it can be concluded that attitude has three components: cognitive, affective and behavioural (Arkonaç, 2008, p. 138; Güney, 2013, p. 224–228; Jain, 2014; Yüksel, 2006, p. 102).

In the cognitive component, the organisation of knowledge is the sum of the individual's views, ideas and beliefs towards the attitude object (e.g. chemistry) (Arkonaç, 2008, p. 138; Güney, 2013, p. 227; Jain, 2014). The feelings and evaluation of the individual towards the attitude object forms the affective component. This includes judgements such as liking or not liking and loving or not loving attitude objects. These objects can be alive-not alive or concrete-abstract. (Güney, 2013, p. 227; Jain, 2014; Yüksel, 2006, p. 102). The affective component is considered the most important component because emotions play a major role in the attitude development process (Jain, 2014). The final component of attitude, the behavioural component, can be described as the tendency to move in line with the emotion or with the claims (Güney, 2013, p. 228). This is the verbal or practical representation of the attitude (Yüksel, 2006, p. 102) and can result in positive or negative actions towards the attitude object. It can be predicted that one would show positive behaviour towards the attitude object if she/he has a positive attitude towards it. Similarly, one would show negative behaviour towards the attitude object if she/he has a negative attitude towards it (Güney, 2013, p. 228).

When the above information is considered from the perspective of students' attitudes towards chemistry, important conclusions can be drawn. Students' attitudes towards chemistry might have an effect on their academic achievement in chemistry and on their decisions and behaviours within chemistry content. In this respect, it is significant to increase students' positive attitudes towards chemistry. The literature on attitudes towards chemistry can be summarised in four prominent headings. These can be stated as a) developing or adapting surveys to measure students' attitudes towards chemistry (Cheung, 2009; Coll, Dalgety & Salter, 2002; Demircioğlu, Aslan & Yadigaroğlu, 2014; Kan & Akbaş, 2005; Salta & Tzougraki, 2004; Şenocak, 2011), b) comparing students' attitudes towards chemistry among grade levels or between certain classes (Can & Boz, 2012; Çalık, Ültay, Kolomuç & Aytar, 2015; Heng & Karpudewan, 2015; Kan & Akbaş, 2006; Salta & Tzougraki, 2004), c) examining the correlation between attitudes towards chemistry and other variables (Berberoğlu & Demircioğlu, 2000; Fah & Hoon, 2012; Dara & Charles, 2011; Demircioğlu & Norman, 1999; Kan & Akbaş, 2006; Kıngır & Aydemir, 2012) and d) investigating the effect of an instructional approach, method, technique, tool or activity on students' attitudes towards chemistry (Akgün, 2005; Ayyıldız & Tarhan, 2012; Buluş Kırıkkaya & Vurkaya, 2011; Chase, Pakhira & Stains, 2013; Marasigan & Espinosa, 2014; Morgıl, Gungor Seyhan, Ural Alsan & Temel, 2008). The present study can be considered among the fourth group of studies presented above. The goal of this study is to understand the effect of the instructional method, learning by teaching, on pre-service science teachers' attitudes towards chemistry. The literature on the implementation of this method in chemistry education is limited. This study also presents an example of such an implementation within chemistry curriculum.

The learning by teaching (LbT) method comprises two important processes: learning to be able to teach others and teaching others what has been learned (Fiorella & Mayer, 2013). It can be stated that these two processes provide a powerful way of learning. LbT is practised

in various ways (Fiorella, & Mayer, 2013; Frager & Stern, 1970; Okita, Turkay, Kim & Murai, 2013; Goto & Schneider, 2010; Norintan, 2008; Roscoe, 2014; Suvannatsiri, Santichaianant & Murphy, 2015). One of these applications is the way used in Jean-Pol Martin's foreign language lessons (Aslan, 2015; Grzega & Klüsener, 2011; Grzega & Schöner, 2008; Karakaya, 2007; Lernen durch Lehren, 2015; Martin & Kelchner, 1998; Skinner, 1994). The LbT method used in this study has been developed based on Jean-Pol Martin's applications. The first implementation was in the academic year 2012–2013 with the LbT method that Jean-Pol Martin suggested for foreign language classes. In line with the students' views and the constructivist paradigm, the framework was restructured to make it more effective with science content (see Aslan, 2014). The second implementation took place in the academic year 2013–2014 in a 'Special Topics in Chemistry' class. Following this, the LbT method was revised once more based on students' views and experiences during the second implementation. This new revised version was practised in the academic year 2014–2015. In summary, after each implementation, the method was restructured and new stages were added based on students' views and experiences (see Aslan, 2015).

This study represents the last stage of the method that was modified. This last stage was changed from a 'Writing to learn activity (letter writing): Writing a letter regarding the topic to a recipient chosen by all the students' to 'Reflective thinking activities: Creating an activity (letter, story, poem, concept map, picture, poster, banner, puzzle, etc.) reflecting what the students learned on each topic'. This includes a different activity for each topic (e.g. letter, story, poem, concept map, picture, poster, flyer, puzzle). The new version of the method can be visualised as shown in Figure 1.

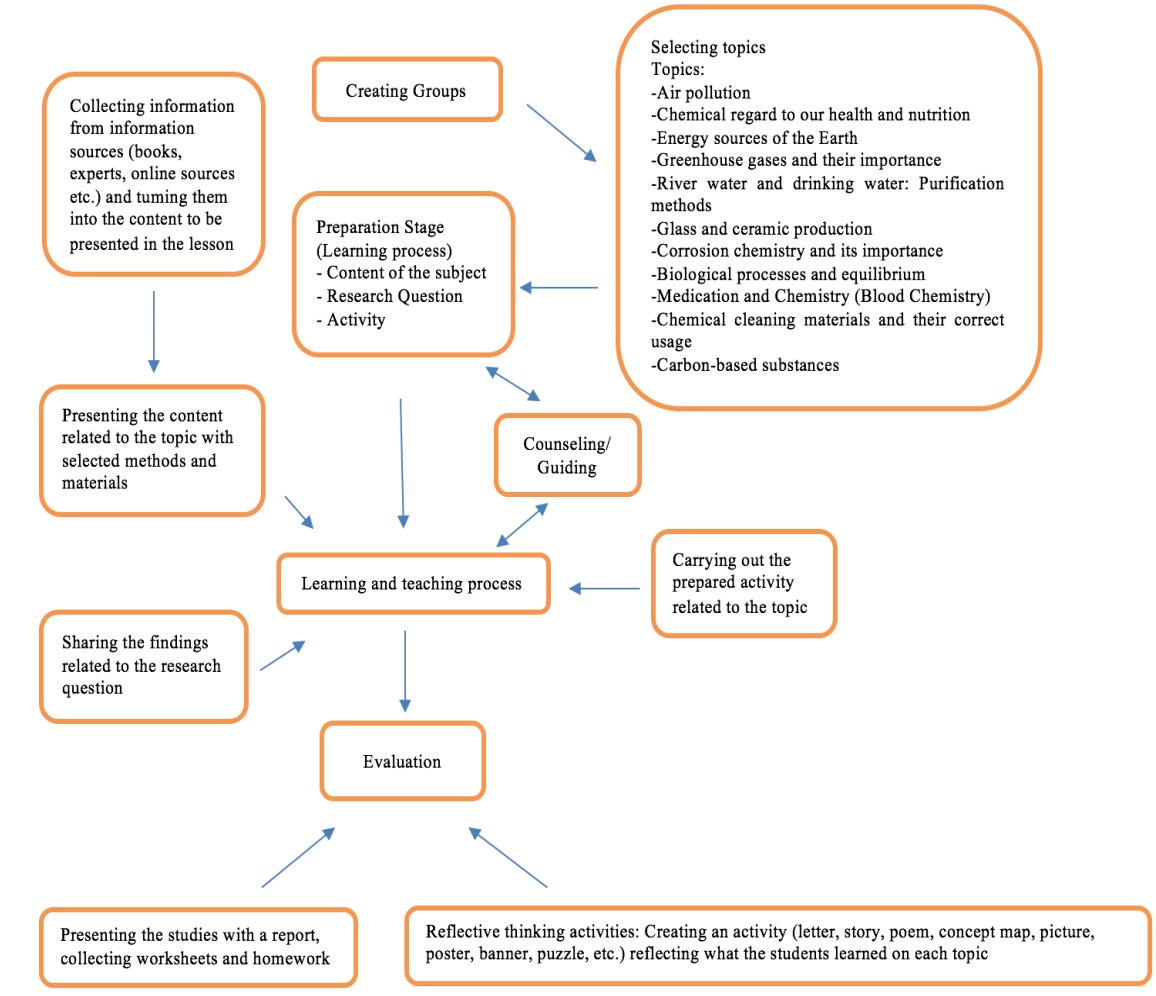

Figure 1: Learning by Teaching (LbT) for Special Topics in Chemistry Class

In this method, the teacher is responsible for teaching the ways of accessing knowledge and for internalising it. The teacher's role includes, but is not limited to, suggesting content areas to teach, suggesting instructional methods and activities, providing materials, helping students to effectively prepare, observing the actions and reactions during the preparation stage, interfering when there are potential problems and making sure that each student learns the concepts. The teacher should stand at the back of the class during lessons. The teacher should only step in when problems arise between the students, or when misunderstandings or mistakes take place. Another role of the teacher is to evaluate both individual students and the learning progress of the whole class. Some methods to undertake the evaluations are observing students' performances and providing feedback on activities, reports and assignments. The role of the teacher in the implementation of this method can be summed up as a guide or a facilitator (Grzega & Schöner, 2008; Karakaya, 2007; Skinner, 1994; Lernen durch Lehren, 2015).

During the implementation of the method, there are certain expectations for the students. The students should teach a topic that they decide on or one recommended by the teacher. The students form groups of three ideally. The students should ensure the engagement of their classmates and communication between everyone and follow a clear teaching methodology. The students are not expected to just present on the topic. That is why the LbT method should not be confused with students' presentations or explanations. In this method, students are not responsible for conveying a message or a topic to their classmates. They are responsible for specifying and implementing their own methods and instructional strategies to teach the topic to their classmates. Also, while teaching, the students should ensure that they are motivating their classmates, drawing in their attention and checking for their understanding of the topic and the concepts they are teaching. To do this, they should use different strategies rather than solely present the topic to their friends (Ahmed, 2013; Grzega & Schöner, 2008; Lernen durch Lehren, 2015). In this method, the students are directly responsible for both learning and teaching. Learning takes place both in the preparation and teaching stages (Aslan, 2015). To apply this method, the students should consider themselves as learners and teachers simultaneously, taking the responsibility of learning and research and learn by themselves (Karakaya, 2007). This might prove that this method can be particularly useful at the undergraduate level as well as in teacher education programmes.

METHODOLOGY

The sequential explanatory method was followed in this study, one of the mixed methods research designs (Creswell, 2013, p.15). In this methodology, both qualitative and quantitative data are essential (Robson, 2015, p. 199). In the sequential explanatory method, first, the quantitative data is analysed and interpreted and then is further explained by analysis of qualitative data (Creswell, 2013, p. 15). So, these two stages follow a certain order. The results of the quantitative data are explained together with qualitative data and all results are unified in the conclusion section of the study (Creswell, 2013, p. 15; Robson, 2015, p. 204).

This study focussed on the LbT method in a Special Topics in Chemistry course. The effect of this method on pre-service science teachers' attitudes towards chemistry was investigated in two consecutive stages: 1) collecting and analysing quantitative data, 2) collecting and analysing qualitative data to better interpret the results. The study was conducted in the academic semester of Fall 2015 for 14 weeks covering 11 different topics.

a) Participants

In total, 49 pre-service science teachers participated in the study; they were students of the science education programme in a public university in Turkey. The ages of the participants ranged from 19–22, with both females (n=31) and males (n=18). All of the pre-service science teachers take the course Special Topics in Chemistry. In the science education programme, the courses related to chemistry are as follows: General Chemistry I and General Chemistry Lab I are in the first semester, General Chemistry II and General Chemistry Lab II are in the second semester, General Chemistry III (Analytic Chemistry) is in the third semester, General Chemistry IV (Organic Chemistry) is in the fourth semester and Special Topics in Chemistry is in the fifth semester. Special Topics in Chemistry was purposefully chosen for this study because of its content relationship between science, technology, society and environment (STSE). It is thought that if pre-service science teachers' understanding and recognition of the relationships among STSE in the context of chemistry is provided with a better understanding of the importance of chemistry by them then this situation will affect their attitudes towards chemistry.

The science education programme is in total an eight-semester programme. After pre-service science teachers complete the programme, they will have a certificate to teach science to 5^{th} through 8^{th} grade students. Pre-service science teachers must take science content (e.g. Physics, Chemistry and Biology), pedagogical content knowledge and general culture courses to graduate from the science education programme.

b) Data Collection Tools

Attitude towards Chemistry Scale (ATCS)

The quantitative data of the study was collected with the ATCS to understand the effect of LbT on pre-service science teachers' attitudes towards chemistry. It was developed by Geban, Ertepınar, Yılmaz, Altın and Şahbaz (1994). This scale was chosen because it has been used in numerous studies (Akgun & Deryakulu, 2007; Can, 2012; Can & Boz, 2012; Erdem, 2015; Kaya & Geban, 2011; Kurbanoglu & Akim, 2010; Kıngır, 2011; Kıngır & Aydemir, 2012; Yuksel & Geban, 2014). In total, the scale includes 15 items placed on a five-point Likert scale. The statements that the scores correspond to are 'strongly agree' 5, 'agree' 4, 'undecided' 3, 'disagree' 2 and 'strongly disagree' 1. Among the items, five are negative statements, and ten are positive. The negative statements were reversed in the coding process. Possible scores may range between 15 and 75. Higher scores in the ASTC mean more positive attitudes towards chemistry. The Cronbach alpha reliability coefficient of the scale for this study was .90. The scale was used as a pre-post measure. Some items of the ATCS are the following:

(1) Chemistry is an area that I love.
(2) I like reading books related to chemistry.
(3) Chemistry does not have a very important place in daily life.
(4) I like solving chemistry problems.
(5) I would like to learn more about chemistry topics.

Focus group interview

The focus group interview was conducted to understand how the LbT method affects pre-service science teachers' attitudes towards chemistry. The interview was undertaken with 11 pre-service science teachers; one pre-service science teacher was selected from each group. They were identified randomly and then asked if they would volunteer for the interview. All

participants agreed to volunteer for the interviews. The interview questions were finalised by the opinions of two experts. The interview questions are listed below:

- Did the LbT method you used in Special Topics in Chemistry class cause any change in your attitudes towards chemistry?
- If your answer is yes to the first question, can you please define/describe the change(s)?

The focus group interview lasted 65 minutes. The interview was voice recorded and then analysed. During this analysis, the recording was transcribed verbatim and then its accuracy was controlled. Data was analysed using content analysis. First, coding was completed based on the concepts obtained from the interview. Following this, themes were created to organise codes under certain categories and to interpret the collected data (Strauss & Corbin, 1990). To ensure consistency among the codes, three experts coded the data. Two of them were experienced faculty members in qualitative analysis and one was a researcher. The reliability of the focus group interview data was calculated. The formula recommended by Miles and Huberman (2015, p. 64) was used which can be noted as follows: Reliability=Agreement/(Agreement+Disagreement). According to the results, the reliability was found to be .75. Since the results were above .70, it was concluded that reliability is ensured (Miles & Huberman, 2015, p. 64).

c) Implementation

In the implementation of the LbT method, the stages presented in Figure 1 were followed. These stages are explained here in order:

1) Forming the groups and selecting the topics: This is the first stage. Before this, the teacher (researcher) gave information to all students (pre-service science teachers) on the content and significance of the Special Topics in Chemistry class. This was followed by the teacher asking the students to form groups of 4 or 5; the teacher did not interfere with this process. After the groups were formed, the teacher introduced the topics to the class. Then the groups were asked to select the topic they wanted to teach. Every group selected a different subject (e.g. air pollution, energy sources of the Earth, greenhouse gases and their importance). When all groups made their choices, a timeline was created for the whole semester.

2) Collecting information on the selected topic and organising the information to present in class: At this stage, the students conducted detailed research. The sources that they used were the library, the internet and experts on the selected topic (e.g. environment, chemistry, biology, physics). Informal learning environments (e.g. detergent factory, glass factory, solid waste treatment plant, drinking water treatment plant) and experts in these settings also acted as knowledge sources. The students discussed the knowledge gained in the research process and the part that should be included in their teaching. They also decided on the techniques, methods and approaches (e.g. 5E model, argumentation, concept cartoons, computer-supported teaching, informal learning environment, six-hat thinking technique) to be used for teaching. During these discussions, the teacher was directly involved occasionally. At other times, the students first agreed on a decision and then evaluated it together with the teacher. Following this, they finalised their lesson design. The teacher guided the students on teaching methods and activities and on how to reach knowledge sources. The teacher was helpful in accessing the necessary materials, responding to the questions coming from the students and supporting them in solving problems.

3) Presenting the topic selected with different instructional methods and materials: At this third stage, the students implemented the lesson design they created in the previous stages. During the implementation, the teacher waited at the back of the class; their only role was observation. The teacher observed from the perspectives of both the teaching student groups and the students in the classroom. The teacher interfered when there were problems, or when

misunderstandings and/or mistakes arose between the teaching student group and the rest of the class.

4) Constructing the research questions on the topic selected, investigating and presenting the answers: This stage exists in both the second and third stages. The teaching student group formed significant research questions and performed an investigation to answer their questions. The students discussed and agreed on the research question and on the appropriate methods to investigate the question. Following this, the students had a face-to-face or an online discussion with the teacher on the significance of the research question and on the feasibility of their plan for investigation. Through this, the students completed this stage. The students then shared their research question and their findings during their teaching. Some of the research questions that the students created were presented as follows:

- How is the drinking water supplied to our city?
- What are some characteristics of the drinking water?

To answer these research questions, the students contacted the local government to access information on drinking water. After this, they visited the dam where the drinking water came from. They observed and video recorded the processing of the water in the dam so that it became drinkable. They also obtained documents depicting the features of drinking water and its parameters. The students used the data they collected as well as the video footage in their teaching.

- What is the chemical cleanser usage behaviour of the residents in our city?

To answer this research question, the student performed many steps. They interviewed residents of different ages and gender on how they used chemical cleansers and what they paid attention to while using them. All interviews were recorded. They also collected survey data with 40 pre-service teachers on which cleansers are used and what is important in using them. This was followed by visits to the city health and environment boards to gain information on previous and current research on chemical cleanser usage of city residents. The information collected from these steps was shared in the class in the following way: First, the students presented some of the selected interviews, and through a whole-class discussion, identified the chemical cleanser usage behaviours. Then, the data collected from the rest of the interviews and the survey was shared with the class. Based upon these sets of data, the students indicated various standards for ideal healthy chemical cleanser use compared to actual behaviours. Lastly, they shared information on the research conducted by official authorities.

5) Preparing and implementing activities on the topic selected: This stage exists in the second and third stages as well. The students prepared activities to deliver their topic more clearly and also to attract their classmates' attention better. As in the fourth stage, the teacher facilitated and guided the group work of the students. Communication with the teacher was both face-to-face and online. The students implemented the activity in the most appropriate part of their lesson. Some of the activities performed by the students included demonstrations with simple materials (e.g. experiments on air pollution and global warming), role plays, competitions, debates, use of QR codes, designing and presenting materials. These activities helped in the topic better understanding of the topic by the class.

6) Reporting the implementation, collecting the worksheets and the assignments: At this stage, the teaching students prepared and presented a report on all the stages to the teacher. They were informed of the preparation of such a report at the beginning of the study. With this knowledge, they started working on their report during the early stages of the study. This enabled the students to monitor themselves as they progressed through the stages. The teacher collected the worksheets, assignments and materials for the implementation in this sixth stage as well.

7) Reflective thinking activities: Creating an activity reflecting on what the whole class learned on each topic (e.g. letter, story, poem, concept map, picture, poster, cartoon, flyer, puzzle): At this final stage, the whole class was asked to prepare an activity on what they learned at the end of each implementation. This activity was an assignment for the students. They prepared a different activity each week on the topic of that week. The teacher collected these assignments the next week. The teacher evaluated the assignments and provided feedback to the students.

In the implementation of these six stages, all members of the teaching student group were active. They all practised teaching and shared responsibilities among themselves. Thus, all students engaged in teaching with a shared responsibility. While the student group was teaching, their classmates completed their respective parts. They prepared their assignments as planned each week.

FINDINGS

In this section, quantitative and qualitative data, which were obtained from the research, are given. Quantitative data was obtained with the ATCS. The scale was used as a pre-post measure. The scores of the pre-service science teachers before and after the implementation were compared with the Paired Samples t-test. The Paired Samples t-test is used to determine whether there is statistical evidence that the mean difference between paired observations on a particular outcome is significantly different from zero (Büyüköztürk, 2009, p. 67–68).

Table 1. *T-test results of the pre- and post-scores of the ATCS*

	N	X	SD	df	t	p
Pre-test	49	55.22	9.77	48	-5.488	.000*
Post-test	49	63.69	7.31			

*p<.01

The examination of Table 1 indicates that with the implementation of LbT method, there was a positive increase in the pre-service science teachers' attitudes towards chemistry ($t(48)=-5.488$, $p<.01$). The average score of the pre-service science teachers from the survey increased from 55.22 to 63.69 following the implementation. Another noteworthy point is that there was a decrease in the standard deviation. This finding shows that the LbT method positively increased pre-service science teachers' attitudes towards chemistry.

To determine the effect size of the significant difference between the pre- and post-scores, the eta square value η^2 was calculated. Effect size, or η^2, presents how much the independent variable or the factor accounts for the total variance of the dependent variable. The values .01, .06 and .14 are interpreted as small, medium and large effect sizes respectively (Büyüköztürk, 2009, p. 44). In this study, the dependent variable is the attitude towards chemistry and the independent variable is the LbT method. To calculate the eta square, the formula suggested by Büyüköztürk (2009, p. 69) for t-tests for dependent groups was used. According to the results, the eta square value was found to be .38. When this result is examined together with the above information, it can be concluded that the LbT method has a large effect on the significance difference between the average scores obtained before and after the implementation. The quantitative data analyses revealed that the LbT method has a positive effect on pre-service science teachers' attitudes towards chemistry.

In this study, qualitative data was obtained through the focus group interview. All pre-service science teachers participating in the focus group interview answered yes to the first question, 'Did the LbT method you used in Special Topics in Chemistry class cause any change in your attitudes towards chemistry?' For responses to the second question, 'Can you please define/describe the change(s)?', two themes can be seen in Table 2.

Table 2. *Pre-service science teachers' views on the effect of learning by teaching on their attitudes towards chemistry*

Themes and codes	Frequency of codes (f)
a. Cognitive	20
1. Importance/Awareness	8
2. Interest	4
3. Curiosity	3
4. Comprehensible	3
5. Meaningful	2
b. Affective	8
1. Enjoyable	4
2. Love	2
3. Valuable	2

Table 2 makes it clear that the 11 pre-service science teachers who attended the focus group interview explained how the LbT method affected their attitudes with two major themes: cognitive and affective. They focussed on five codes under the theme cognitive. In this respect, they explained the change in their attitudes with the importance of chemistry/awareness, interest towards chemistry topics, curiosity about chemistry topics, thinking that chemistry is understandable and that it is meaningful. An important point to note is that the code importance/awareness has a higher frequency than any other code. Some of the statements made by the pre-service science teachers are presented below:

> *"I didn't like chemistry and I always was unsuccessful. But with this implementation, I realised that I started to understand better. And most importantly, I gained an awareness of chemistry." (S1, male, code a1)*

> *"In order to teach the topics to our classmates, we learn by experiencing and with making connections with real life. I believe that these helped me realise how important chemistry is as a discipline." (S4, female, code a1)*

> *"I learned how to look at things. I believe there is a difference between looking at things and then seeing and understanding them. I think I learned how to see and understand. And this created an interest towards chemistry and eagerness to learn chemistry." (S5, male, code a2)*

> *"In our classes, we only listened and no connections were made after the class is over. But in this class this semester, we started discussing the chemistry topics after the class. This was because we started to develop an interest towards chemistry topics more." (S10, male, code a2)*

> *"Before these implementations, chemistry topics never caught my attention. I was not curious and so I did not read on chemistry. But now, whenever I see a headline on a chemistry topic in a journal or a newspaper, I am curious to read it." (S3, female, code a3)*

> *"It was difficult for me to understand chemistry topics. With this Special Topics in Chemistry course, I realised that chemistry topics are comprehensible. I noticed I should not be afraid and that they can be understood easily. I believe that these implementations in our class contributed a lot to my thinking." (S8, female, code a4)*

"I think the most important part of a class is its meaning for the students. When the students do not find the content meaningful, they cannot understand it. With the implementations we had, chemistry content became more meaningful to me." (S11, male, code a5)

The second theme, affective, consists of three codes. For this theme, the pre-service science teachers stated that the change in their attitudes is linked with finding chemistry enjoyable, loving chemistry and thinking chemistry is valuable. The code enjoyable has a higher frequency than any other code. Some of the statements made by the pre-service science teachers are presented below:

"At first, I was afraid to teach chemistry. I was questioning why we do this and I thought no need. But then these implementations showed me that there is no need to be afraid. Chemistry is very enjoyable indeed." (S6, female, code b1)

"If we carried on our lessons in the traditional way where we didn't have this kind of responsibility, I would never realise how enjoyable chemistry is. I noticed that chemistry is not boring at all, it is very enjoyable." (S9, female, code b1)

"I started loving chemistry after having these implementations in class. Previously, I had no love for chemistry." (T7, male, code b2)

"I developed a new perspective. While I was teaching the chemistry content to my classmates, I felt that chemistry is very valuable. I think that making an effort to teach to my friends made it more valuable for us." (S2, male, code b3)

DISCUSSION and CONCLUSION

The quantitative data analysis of this study showed that the LbT method used in a Special Topics in Chemistry class has an effect on pre-service science teachers' attitudes towards chemistry and that there is a positive progress in their attitudes. Supporting this, qualitative data analysis explained this progress with cognitive and affective themes and the codes that fell under them. One reason for this could be that the LbT method enabled each pre-service science teacher to have a different experience. The steps for the implementation of the method show that each step provides the pre-service science teachers with a wide range of experiences on chemistry (e.g. inquiry, hands-on activities related to real world objects and events, social interaction, communication, group work, group performance, teaching experience). These experiences might have increased the complexity of pre-service science teachers' attitudes towards chemistry. Since the complexity of attitudes or their components depend on the number and variety of the factors they include (Güney, 2013, p. 230), it can be inferred that the LbT method increases the number and variety of factors included in attitudes towards chemistry. In line with this, it can also be specified that the complexity of the pre-service science teachers' attitudes increased as well. An increase in the complexity of attitudes implies an increase in its strength (Güney, 2013, p. 230; Yüksel, 2006, p. 104).

The strength of the attitudes expresses the sum of the strengths of all attitude components. The strength of these components can vary. However, the total strength of the attitude mostly relies on the strength of the affective component (Güney, 2013, p. 229). The qualitative data on the attitudes of pre-service science teachers from the effect of LbT mostly accumulated under the cognitive theme. However, there were still some views that existed under the affective theme. Based on these findings, it can be stated that the affective component of pre-service science teachers' attitudes towards chemistry is gaining strength through the LbT method. This results in an increase in the overall strength of pre-service

science teachers' attitudes as explained above. The pre-service science teachers' statements on finding chemistry important and their awareness of the importance of chemistry can also be linked with the overall significance they attach to it. The importance of the attitude object for the individual has an impact on the individual's attitude towards the object (Güney, 2013, p. 229). The fact that pre-service science teachers find chemistry important might be concluded to have a positive effect on the strength of their attitudes towards chemistry.

The effect of the LbT method on pre-service science teachers' attitudes towards chemistry can be evaluated in the context of experiences the pre-service science teachers had with the attitude object. It is known that experiences with the attitude object may result in the formation of attitudes (Güney, 2013, p. 236). So, from the perspective of experiences, it is inferred that the LbT method enables pre-service science teachers to have a direct connection with chemistry. The pre-service science teachers are going through an experience where they can connect with chemistry directly via the LbT method. This experience might change the pre-service science teachers' connection with chemistry into a repeated and accumulated one impacting their attitudes towards chemistry. Based on the quantitative data in this study, it can be stated that this impact is, in fact, an increase in the intensity of the attitudes (Yüksel, 2006, p. 103).

Another perspective to evaluate is the effect of the LbT method on pre-service science teachers' attitudes, which can be the knowledge gained on the attitude object. Individuals tend to construct a belief system by combining their previous knowledge with the new knowledge they attain (Güney, 2013, p. 235; Yüksel, 2006, p. 102), which results in judgements about the attitude object such as positive-negative, good-bad, or sufficient-insufficient (Güney, 2013, p. 235). The changes in individuals' knowledge levels have a critical role in the construction of their belief systems (Güney, 2013, p. 235). Based on the views of the pre-service science teachers, it can be inferred that the LbT method created changes in their knowledge levels. Some of the pre-service science teachers stated that they started thinking chemistry as being meaningful and comprehensible after the LbT process. Since individuals have attitudes towards objects that have psychological meaning to them (Güney, 2013), their ideas on meaningfulness and comprehensibility of chemistry might contribute to their attitude development towards it.

The effect of the LbT method on pre-service science teachers' attitudes towards chemistry is evaluated from the different perspectives above. When these perspectives are examined, it can be stated that the LbT method positively increases pre-service science teachers' attitudes towards chemistry. This conclusion supports the study which stated that active learning and student-centered pedagogy improved student attitudes (Armbruster, Patel, Johnson, & Weiss, 2009) and it shows that the LbT method can contribute to one of the most important goals of chemistry education, which is developing students who have positive attitudes towards chemistry. The pre-service science teachers need to have positive attitudes towards chemistry to create such attitudes for their future students in their teaching. Teachers have a critical role in developing attitudes towards any discipline (e.g. chemistry) (Kumar, Krishna & Rao, 2004, p. 36). In line with this, it is significant that pre-service science teachers have a positive attitude towards the discipline they will teach in their in-service teaching. One way to make this possible is in the pre-service science teachers' learning processes before they start teaching, such as going through the teaching experiences shown in this study. The findings of this study demonstrate that the LbT method can provide this in teacher education programmes.

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