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Is Learning by Teaching Effective in Gaining 21st Century Skills? The Views of Pre-Service Science Teachers

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Abstract
Learning by teaching is an educational method developed by Jean-Pol Martin for foreign language lessons and is commonly used in Germany. This study discusses a reconstruction of learning by teaching as developed for use in a science context where in the adapted version of this method is introduced, the views of pre-service science teachers are explored, and the effectiveness of this method for gaining 21st century skills is examined. The qualitative case study was conducted with 33 pre-service science teachers. Data was gathered through focus group discussions and structured written interviews, and analyzed using content analysis. The views of pre-service science teachers were examined concerning the advantages of the following 11 themes: the advantages of learning by teaching, preparing research questions and working together to find answers through research, preparing and implementing activities, the role of the teacher, a letter writing activity, the strengths of learning by teaching, the weaknesses of learning by teaching, difficulties faced during its implementation, the use of learning by teaching in teacher-training programs, other lessons appropriate for the use of learning by teaching, and how to apply the experiences gained to the future. Following a two-year pilot study and implementation of the final version, learning by teaching within the context of science was found to be an effective method for gaining 21st century skills.

Keywords: Chemistry education • Learning by teaching • 21st century skills • Pre-service science teachers • Views

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Rapid developments in science and technology have caused changes in the needs and expectations of society. In analyzing these needs and expectations, the area of "quality education" is a key subject. In particular, it raises the question of which competences an individuals in 21st century societies should have. These expected individual skills, termed 21st century skills, are described in terms of knowledge, skills, and expertise (National Research Council [NRC], 2010; Partnership for 21st Century Learning, 2015). These skills are further deconstructed and placed into the categories of life and career skills, learning and innovation skills, and digital literacy skills (Partnership for 21st Century Learning, 2015; Trilling & Fadel, 2009). Life and career skills contain the criteria for evaluating the performances of employees according to their general quality of work, flexibility, adaptability, entrepreneurship, self-directedness, social and intercultural skills, efficiency, accountability, leadership, and responsibility. Learning and innovation skills include the skills of focused critical thinking, problem solving, communication, cooperation, creativity, and innovation, all of which are essential for unlocking lifelong learning and productivity. Digital literacy skills involve information, media, and technology. Information literacy includes the skills to find, assess, use and manage knowledge; media literacy includes the skills to analyze and create media products; technology literacy includes knowing how to use technology effectively (Köğce, Özpınar, Mandacı Şahin, & Aydoğan Yenmez, 2014; Partnership for 21st Century Learning, 2015; Trilling & Fadel, 2009). An important issue facing educators is how to provide individuals with effective learning opportunities so that they may gain and retain the above-mentioned skills. One such teaching method was developed for foreign language lessons by Jean-Pol Martin in the early 1980s, called Lernen durch Lehren (LdL) in German, or Learning by Teaching in English (Karakaya, 2007; Martin & Kelchner, 1998; Skinner, 1994). This method was designed to effectively and efficiently aid individuals in gaining the competences expected in an information society. Commonly used in secondary education in Germany, this method was revised and detailed in the late 1990s and began to be used in higher education (Grzega & Schöder, 2008). The basis of this method, which can be considered as a special type of peer education, is based on the idea that the responsibility of teaching should be undertaken by students for teaching their own classmates (Legenhausen, 2005). This scenario adopts the concept of controlling all processes of a lesson by the learners (Hanbay, 2009; Serindağ, 2007), and students are given the opportunity to prepare all or part of a lesson (Grzega & Schöder, 2008). The method is considered to be an individual and social learning style, which is student-centered for the learning and teaching activities of students (Karakaya, 2007). In learning by teaching, the role of the student is to teach a topic that the teacher suggests, or a topic of their own choice, with a group of students (preferably three) by methodically encouraging classmate participation and enabling communication between them. At this point, the students are not expected to present the topic directly, and learning by teaching should not be confused with student presentations or lectures. Students are not expected to transfer the content to their classmates, but rather they are expected to define their own methods and teaching approaches as well as implement them in order to teach the topic. Students who do the teaching need to learn ways to motivate and ensure that their messages and the topic being taught are understood by their classmates. Therefore, students must use various approaches and educational tools, not just a direct presentation (Ahmed, 2013; Grzega & Schöder, 2008; Lernen durch Lehren, 2015). For learning by teaching to be effective, students thus need to accept themselves as teachers and learners while undertaking the responsibility of teaching, learning for themselves, and being able to perform research (Karakaya, 2007). The teacher's role becomes one of a facilitator who suggests topics for students to teach, offers teaching methods and materials, gives advice on activities, and helps in the process of preparation. During the lesson, the teacher observes the actions and reactions of the class during the learning process, assesses potential problems, and ensures students are learning the concepts contained in the lesson. The teacher remains in the background during lessons, only interfering if there is a problem or misunderstanding with the students teaching or their classmates. The teacher evaluates not only the performance of the students who are teaching but also the learning level of all students in the classroom by observing the process; collecting worksheets, reports, and homework; and providing feedback. When the roles of teacher and students are examined, the teacher and students are thought of as partners with a flat hierarchy between them (Grzega & Schöder, 2008; Karakaya, 2007; Lernen durch Lehren, 2015; Skinner, 1994).

Learning by teaching gives students the opportunity to gain many competences such as creativity, inde-

pendence, self-confidence, self-efficacy, teamwork, communication, complex thinking, empathy, knowledge on searching and managing, research methodology, presentation and discussion skills, digital skills (using internet tools), punctuality, reliability, and patience (Grzega & Klüsener, 2011; Grzega & Schöder, 2008; Ponnusamy & Pandurangan, 2014). All of the above-mentioned skills are thought to be key 21st century skills, and learning by teaching can be an effective method for learning these competences. In regards to higher education, learning by teaching has also been used for those working towards their Bachelor's degree. The method was used by Jean-Pol Martin and his students, Grzega and Schöder, in European History, French Literature, different language courses, and courses which containing internet and project competences. Although learning by teaching was used for specific lessons, it was suggested that it could be used in a variety of different contexts (Grzega & Schöder, 2008; Skinner, 1994). Recently, learning by teaching has been used in contexts different from Martin's implementation (Goto & Schneider, 2010; Norintan, 2008; Roscoe, 2014; Suvannatsiri, Santichaianant, & Murphy, 2015). Conversely, there have also been recent studies that take a different approach to peer tutoring not reflective of Martin's method of implementation. The constructivist approach and social-interaction paradigms, which have become prominent in learning-and-teaching processes in recent years, have expanded the methods of peer-supported learning (Shunk, 2011). For example, the 5E and 7E models (Ersoy, Sarıkoç, & Berber, 2013; Kanlı & Yağbasan, 2008), jigsaw (Roland & Martin, 2015; Tarhan, Ayyıldız, Ogunc, & Sesen, 2013), peer tutoring (Crouch & Mazur, 2001; Mazur, 1997), argumentation (Aslan, 2012, 2014a; Cavagnetto, Hand, & Norton-Meier, 2010; Erduran & Jimenez-Aleixandre, 2007), six thinking hats (Bono, 1997), station technique (Alacapınar, 2009; Kılıç, 2014) and concept cartoons (Aslan, 2014b; Keogh & Naylor, 1996; Naylor & Keogh, 2013) are all styles that have developed methods and techniques based on the constructivist paradigm (Köseoğlu &Tümay, 2013). The difference with learning by teaching from other models, methods, and techniques is evident in the role of students. In the models, methods, and techniques mentioned above, while students directly undertake the responsibility of learning, they do not directly undertake the responsibility of teaching. Thus, they are not directly responsible for the learning of their classmates. In learning by teaching, students directly undertake both the responsibility of learning and teaching. Students must first learn the topics to be able to teach effectively, and therefore learning is realized during the preparation and teaching process. During the teaching process, students must use different methods and materials as well as develop strategies for motivating, getting attention, and realizing understanding. In addition, the students define the model, method, and techniques used during the process of teaching, and they design the lesson accordingly. The expression, "To make the student the teacher" (Skinner, 1994) is the most distinctive aspect of this method.

Learning by teaching, which is similar to the style suggested by Martin, is generally used in language lessons. In Turkey, few studies based on learning by teaching have been done, and of those, they were found to be in the context of language courses (Hanbay, 2009; Karakaya, 2007; Serindağ, 2007). No studies were found regarding science courses, the Faculties of Education, or the field of science teacher-training programs. The current study is thus unique in exploring learning by teaching and its usefulness for courses in the field of science. This study in particular proves that learning by teaching can be used effectively for the Special Topics in Chemistry course in the Education Faculty's Science Teacher Programs. Moreover, it also shows that student-centered methods can be used by those working towards their Bachelor's degree. When course information packages were examined for science content in Turkey, it was seen that most lessons were conducted by instructors via lectures or computer-supported lectures with question-and-answer sessions and discussions. This study explores an alternative to the traditional styles of teaching, detailing a teaching process wherein students have the responsibility of learning and teaching at the same time. Prior to undertaking this project, it was predicted that pre-service science teachers would experience a few difficulties while applying science-teaching programs that use learning based on research and inquiry. Moreover, it was expected that the use of this method in teacher-training programs would be effective for gaining teacher proficiencies. Teacher proficiencies are described as "…the knowledge, skills, and attitudes which must be gained in order for teachers to perform their profession efficiently and effectively," (Milli Eğitim Bakanlığı [MEB], 2008, p. 8). It is strongly suggested that these knowledge, skills, and attitudes be gained by teachers early on in their career while they are still pre-service teachers. The use of learning by teaching in teacher-training programs is considered to be helpful for meeting this expectation.

The following research questions were used to guide the inquiry:

1) What are the views of the pre-service science teachers for learning by teaching in the Special Topics in Chemistry course?

2) Is learning by teaching effective in gaining 21st century skills from the view point of pre-service science teachers?

Method

This research uses the case-study design, one of the qualitative research methods. Qualitative research is a research model consisting of sample taking, collecting data with open-ended questions, analyzing documents or visuals, and interpreting findings individually towards for a specific purpose (Creswell, 2013a, p. 22). In qualitative research, the researcher attempts to understand the logic of the facts and events from the point of view of the participant or participants (Merriam, 2002, p. 6). A case study is a qualitative research approach in which information is thoroughly collected over a period of time via multiple sources of information such as observations, interviews, documents, and reports; the case description and themes are reported (Creswell, 2013b, p. 97). In case studies, researchers will deeply analyze a phenomenon, event, action, process, or social unit such as a person, group, institution or community (Creswell, 2013a, p. 14; Merriam, 2002, p. 8). Thus, case studies help to explain the subject within its own context in the research (Yin, 2003, p. 5). In this study, the effectiveness of learning by teaching regarding the Special Topics in Chemistry class; the stages, strengths, and weaknesses of this method; the difficulties encountered during application; and the possibility of future uses were examined deeply from the perspective of pre-service science teachers.

Two pilot studies were conducted with pre-service teachers to refine the learning-by-teaching method. The first pilot study lasted for 12 weeks with 41 pre-service science teachers for learning special topics from their chemistry course during the 2012–2013 academic year. The method, according to Jean-Pol Martin's style used in his language lessons, was implemented in the first application. Participants watched sample videos of Martin's implementation to gain an understanding of his technique, which can be found at *www.ldl.de*. Implementation of the first pilot for the learning-by-teaching method was conducted at the start of the special topics section in the chemistry class. The group was first given information about the method, and the roles of the teacher and students were clarified. Following this introduction, groups of four to five students were arranged and subject matter was distributed according to group preference. Students then made preparations for teaching the topic to their classmates using methods and materials of their choosing. Throughout this process, students presented their design to the teacher in a report; the teacher collected their reports and worksheets, and supported the students' role as course execute or by acting as a guide, advisor, and facilitator. After this first pilot implementation, the students were interviewed about their experiences using the learning-by-teaching method. After taking their views and experiences into consideration, the method was restructured for implementation within a specific scientific context. In this restructuring, the learning-and-teaching process was expanded to include other methods based on the constructivist paradigm (Köseoğlu & Tümay, 2013) in addition to the implementations from the first pilot study. Processes related to the preparation of research questions about the topic, information gathering and sharing, activity preparations related to the topic, and implementation stages were added. This adapted version of the method was implemented into the Special Topics in Chemistry course by 32 pre-service science teachers for 12 weeks during the fall semester of 2013.The students were interviewed about the method upon completion of the pilot study phase (Aslan, 2014c). Preliminary results collected during this second phase suggested that the adapted version of the learning-by-teaching method was more effective than the first implementation. For the third and final implementation of the method, conducted during the fall semester of 2014, a letter-writing activity was added. For this activity, students were asked to write a letter about the topic they were given during the course to a recipient of their choosing. The letter-writing activity was included for the purpose of giving students the opportunity to synthesize in their own words all of the information they had learned throughout their learning-by-teaching experience. The following case study explores the implementation of the final version of the adapted method as developed from the pilot studies. This study aims to examine the views of pre-service science teachers regarding the adapted learning-by-teaching method and discusses the effectiveness of this method in gaining 21st century skills.

Participants

The participants in the study consisted of 43 prospective teachers taking the Special Topics in Chemistry course while studying science teaching at a state university in Turkey; only the 33 prospective

teachers who continually attended the lesson, however, were included in the study. The pre-service science teachers who participated in the study consisted of 10 men and 23 women between the ages of 19 and 21. Special Topics in Chemistry is a course given in the 5th semester of the science teacher program and was purposefully chosen for this study because of its content relationship between science, technology, society, and environment. The vision of the science teaching program is to ensure all students become scientifically literate. In the program, those who are scientifically literate are expected to understand the relationship between social and technological change as well as transformations in science and the natural environment (Talim Terbiye Kurulu Başkanlığı [TTKB], 2013). To meet this expectation, teachers should first perceive these relationships. Thus it is important for them to take and maintain courses in this context while they are pre-service science teachers. One such course is Special Topics in Chemistry. This course was therefore chosen for this study, and a sample on maintaining the course effectively has been presented. The study was conducted for 9 topics over 12 weeks during the fall semester of 2014.

Data Collection Tools

Focus Group Interviews: Focus group interviews were selected for the purpose of exploring the views of pre-service science teachers regarding the learning-by-teaching method. The focus group interview was intended to be conducted with the participation of one pre-service science teacher from each group. In total, there were expected to be 9 participants, but 2 pre-service science teachers couldn't participate because of other reasons. This left 7 participants for the focus group interview. Volunteer pre-service science teachers were accepted in order to determine who would participate in the interview (Morgan, 1997 as cited in Çokluk, Yılmaz, & Oğuz, 2011). The questions for the focus group interview were developed by two experts in the science education field. The questions were: (*1*) Was learning by teaching useful for you? Why? (*2*) Did you find the stage of preparing research questions and searching for the answers with your classmates useful? Why? (*3*) How do you evaluate the role of the teacher in learning by teaching? (*4*) Did you encounter any difficulties during the lesson? If yes, what type of difficulties did you encounter? The interview lasted for 40 minutes and was recorded on audiotape. The voice records of the interview were later transcribed verbatim. During analysis, the data was transcribed and checked for errors multiple times. The information derived from the focus group interviews was then used as the basis for the structured interviews and questionnaires (Çokluk et al., 2011).

Structured Written Interview Form: The second data collection tool for determining the views of the pre-service science teachers for learning by teaching was the written interview form. This interview consisted of 11 open-ended questions prepared by the researcher in coordination with field experts. The questions were arranged to determine if learning by teaching was a useful method for pre-service science teachers, and if so, which aspects; the effectiveness of the stages; strengths and weaknesses of learning by teaching; and the opinions about its use in teacher-training programs. The open-ended questions on the form were prepared by considering the views of the focus group and examining similar studies in the literature. Additionally, the opinions of two experts related to this subject were sought, and revisions were made accordingly.

Analysis: The data obtained from the focus group interviews and written interviews were analyzed using content analysis. The purpose of choosing content analysis was to explore concepts which could explain the data and how it relates to the participants (Yıldırım & Şimşek, 2005). Inductive content analysis, a qualitative method of content analysis, was used. In inductive content analysis, the concepts underlying the data and the relationships among the concepts are developed through a system of coding (Yıldırım & Şimşek, 2005). In this context, the coding was first done according to the concepts obtained from the study data. For this reason, the transcribed data was read line-by-line four times, taking into consideration the words and concepts of the pre-service science teachers; as much as possible, their preferred wording was used in the coding. In some situations, the words and concepts used by the pre-service science teachers were inadequate for coding the data. In these situations, other concepts that were thought to express their ideas with more clarity were used according to the research questions and related literature. Themes were then created using general codes and more specific codes were placed under themes that were considered relative (Strauss & Corbin, 1990). To provide coherence in coding, the data was coded by the researcher and an instructor experienced in qualitative research separately. Coding continued until consensus was reached. Codes were compared and the reliability of the codes was calculated for the focus

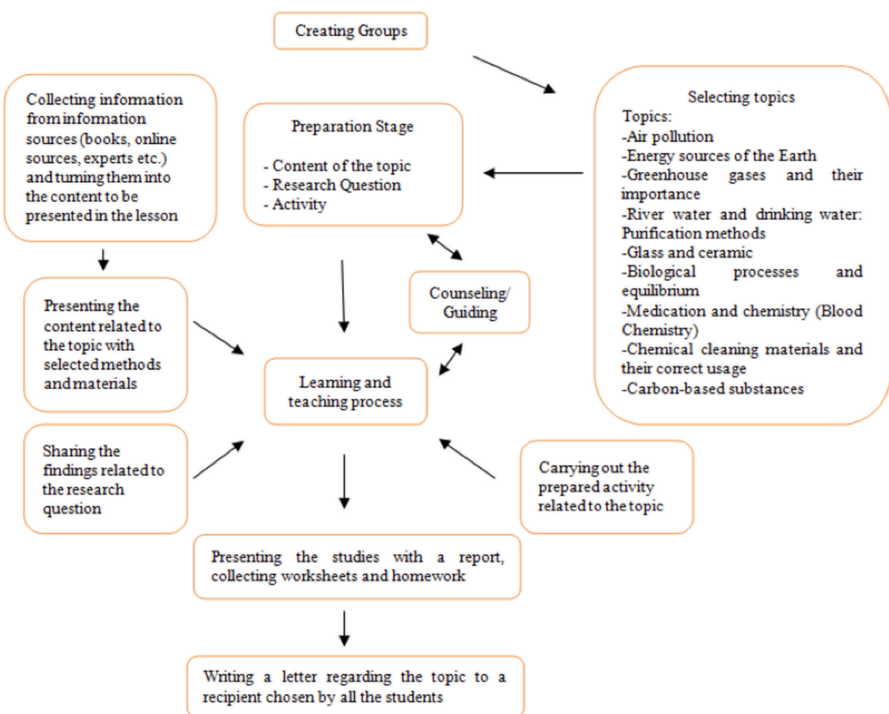
group interview and each written interview separately by using the formula of Reliability=Agreements/(Agreements + Disagreement) × 100 as suggested by Miles and Huberman (1994). As a result of the calculation, the reliability of the coding was found to be between 77% and 90%. A calculation of reliability over 70% is considered to be an acceptable result proving reliability for the data analysis (Miles & Huberman, 1994).

Implementation: In this study, the learning-by-teaching design was established in six stages. Firstly, information about the subject was collected and turned into content to be presented in the lesson. Secondly, the presentation was prepared by using materials as well as different teaching techniques, methods, and approaches related to the subject content such as the 5E method, argumentation, concept cartoons, six-hat thinking technique, brain storming, predict-observe-explain, computer-supported teaching, learning outside the classroom, and so forth. Thirdly, research questions related to the subject were created, and answers to the research questions were sought and shared. Fourthly, activities were prepared related to the subject and its implementation. Fifthly, tasks were presented in the form of a report, worksheets to be collected, and homework. Sixthly, a letter was written to a respondent regarding the topic.

In the implementation of the first five stages, all group members who undertook the responsibility of teaching had active roles. Students in groups shared the tasks from all stages to balance the responsibility of teaching. Thus all group members were included in the teaching process with equal responsibilities. To implement the method, student and teacher roles were fulfilled within the previously mentioned parameters. These steps given above were compared to the Special Topics in Chemistry course's workload chart in terms of total workload (ECTS, 90-91) to ensure students were not exceeding the lesson workload. The study stages, which were monitored, are presented below:

Examples have been given for the 3rd stage of the method, preparing and finding answers to the research questions. The research question and how pre-service science teachers answered them are presented below.

1. What are the medication behaviors in Turkey? The answer to this question was presented based on previously collected data related to this subject. According to expert views, what are the behaviors of



our city's residents regarding medication as well as unused medicine? For the answer to this question, the students interviewed pharmacists and doctors, and they prepared a video presentation from these interviews. What are the habits of students in the Faculty of Education regarding medication and unused medicine? For the answer to this question, students presented data analysis developed on this subject and made a questionnaire for a reliability study using 77 students from the Faculty of Education. The final step involved students sharing their opinions of correct medication behaviors with their classmates.

2. Most of the people in our city use bottled water in their houses. What is the main reason for this? Describe the tap water in your city? Students interviewed a variety of citizens from different age groups and genders in the city for the use of tap water or bottled water and the reason for their choice. They collected and presented video records of the interviews. They also interviewed instructors in the Department of Environmental Engineering as well as the city's mayor. After combining the data from the interviews with data from written sources, the information was shared through the use of visual elements such as videos and PowerPoint presentations.

3. What are the energy sources of the city we live in and in Turkey in general? What are your opinions about the nuclear power plant planned to be built in Turkey? Firstly, students answered the question by making an energy map of Turkey and presenting their answers on the map. Secondly, they explored their classmates' opinions by organizing a class discussion, followed by a video compiled from expert opinions related to the subject.

For the 4th stage of the method, which consists of activity preparations and implementations, creative activities were performed such as experiments shown to the class (making a simple water purification device, purifying water, and then showing the features of the cleaning agents), role playing, doing a quiz show in the classroom, and examining the topic using visual aids designed and made by the pre-service science teachers.

Results

The views of the pre-service science teachers on learning by teaching in the context of the Special Topics in Chemistry course were examined under the following 11 themes: the advantages of this method, preparing research questions and working together to find answers though research, preparing and implementing activities, the role of the teacher, a letter writing activity, the strengths of this method, the weaknesses of this method, difficulties faced during the application, its use in teacher-training programs, other lessons which are appropriate for the use of this method, and how to apply the experiences gained to the future. To protect the identities of participants, direct citations from the focus group discussions were coded as K1, K2, and so forth. The themes, frequency of codes, and sample expressions are presented in the tables below.

The Advantages of Learning by Teaching

All pre-service science teachers answered yes to the first question on the written interview form, "Is learning by teaching useful to you?" For responses to the second part of this question, "Explain your answer," 10 codes can be seen. Pre-service science teachers generally emphasized self-confidence (23.64%) and vocational experience (23.64%) as the most common benefit. Others also expressed communication (10.91%), directing research (10.91%), and permanent learning (9.08%) as important. Other benefits included class management (5.45%), pleasures of teaching (5.45%), learning different methods and techniques

Table 1
Percentage and Frequency Values for the Advantages of Learning by Teaching

Codes	Sample Expressions	*f*	%
1. Self-confidence	• *While maintaining the lesson, I managed to be less nervous and more comfortable. I could make eye contact. It was very important for me.*(*1*)	13	23.64
2. Vocational experience	• *Our communication got stronger, especially in the process of preparing the lesson.* (*3*)	13	23.64
3. Communication	• *Yes this method was very useful to me. It helped me research and study.* (*4*)	6	10.91
4. Directing research	• *With lessons that are just verbally presented, students start to take notes and become robotic. But with this method we start to research the subject and gain full knowledge; this knowledge becomes more permanent.* (*5,10*)	6	10.91
5. Permanent learning	• *This method gave me the chance to teach something and be happy about teaching…*(*7*)	5	9.08
6. Class management	• *I understood that the teacher should definitely come to the lesson prepared. This helps to maintain the lesson plan.* (*9*)	3	5.45
7. Pleasures of teaching		3	5.45
8. Learning different methods and techniques		2	3.64
9. Coming to class prepared		2	3.64
10. Having full knowledge		2	3.64

(3.64%), coming to class prepared (3.64%), and having full knowledge (3.64%). All the pre-service science teachers who participated in focus group interviews expressed that the learning-by-teaching method was useful to them. They discussed benefits such as raising awareness, communication, becoming aware of different opinions, discussions, full learning, and group work. Examples from the focus group results are given below:

"I think I have raised my awareness… I've learned to know the value." (K1, Male)

"Learning different ideas and creating something with different ideas was very enjoyable. One idea is not enough. For example, we were a group of five people. Five ideas emerged and we evaluated these five ideas, taking in its essence. In my opinion it is very beautiful and valuable." (K3, Female)

"We discussed a lot between us during the preparation stage. We discussed what to enter about the subject, what to put in the beginning, how to do things. We started to persuade each other. I think this developed us." (K5, Female)

"In this method I found group work very effective. We were in contact with all the students, I mean, our classmates in the lesson too. Everybody can put forward their ideas. We selected from these ideas. I think one of the most important contributions of this process was learning how to choose." (K2, Female)

"I understood that basic learning happens when you teach what you have learned to others. I now realize that full learning happens when you teach the things you know to others." (K7, Female)

Creating Research Questions and Working Together to Find Answers through Research

For the question "Did you find the stage of creating research questions and working together to find answers through research in the learning-by-teaching method useful?" all but one pre-service science teacher stated that it was useful. Analysis of the answers is found in Table 2. Codes developed under this theme include offering more opportunities for learning (21.67%), the opportunity to relate the topic to daily life (11.66%), directing research (10.00%), realizing different ideas (8.33%), and finding answers to the questions (8.33%). Apart from these, learning how to research (6.67%), communication (6.67%), group work (6.67%), determining problems and learning to describe problems (5.00%), learning how to ask questions (5.00%), permanent learning (5.00%), and reaching knowledge and learning how to disperse knowledge (5.00%) were defined as advantages of the mentioned stage. For the same question, pre-service science teachers who participated in the focus group interviews expressed that they found this stage beneficial and emphasized that it taught research skills as well as how to ask questions, reach knowledge, and relate to daily life. Examples about these explanations are given below:

"This stage taught me how to perform research. It taught me to struggle. If you struggle, you reap the results of your efforts. This was a better thing." (K7, Female)

"The stage of research taught me what to do or not to do. For example, in a section of our research we interviewed from the Mayor, instructors in the university, and students about their views on the subject. In this process I learned how to communicate with people; I learned which questions can or cannot be asked to whom. It was really an important experience for me." (K5, Female)

"In the process of research I learned how to use different sources." (K2, Female)

"We learned to find knowledge. We learned how to find more reliable knowledge. For example, we examined the articles of an expert who studied our subject and some theses. We learned the importance of reliable knowledge, the source of knowledge, and not to accept everything we found." (K3, Female)

"We found the opportunity to associate the topic with daily life through the research questions. You examine teaching not in terms of knowledge for answering questions on exams, you see the returns of knowledge in daily life, and how it is important for people, what it means to them." (K1, Male)

Preparation and Application of the Activity

All the pre-service science teachers found the activity preparation and application stage useful. When examining the findings, the following general codes were seen to belong to this theme: attention getting (28.26%), provides permanent learning (21.74%), supports understanding (17.39%), communication (8.70%), group work (6.52%), supports discussion (6.52%), supports inquiry and critical thinking (6.52%), and motivation (4.35%).

Table 2
Percentage and Frequency Values of Codes related to Creating Research Questions and Sharing Answers

Codes	Sample Expressions	*f*	%
1. Offering more opportunities for learning	• *…I believe I've learned more.* (*1*) • *For me, this stage helped us relate the subject to daily life as well as deepen our understanding of it.* (*2*)	13	21.67
2. Opportunity to relate to daily life	• *As for the question which we researched using our friends' ideas, we learned how wrong our answers were. We've seen so many different ideas emerge. (4)*	7	11.66
3. Directing research	• *I believe that defining the proper research for solving the problem makes us a researcher as well as a teacher.* (*6*)	6	10.00
4. Realizing different ideas		5	8.33
5. Finding answers to the questions	• *I've found it to be very useful, because even putting forth the problem before the solution is a stage in itself.* (*9*)	5	8.33
6. Learning how to research	• *… It teaches what kind of questions we have to ask about the subject. (10)*	4	6.67
7. Communication	• *I have learned how to reach true knowledge and disperse the knowledge usefully.* (*12*)	4	6.67
8. Group work		4	6.67
9. Determining problems/learning to describe problems		3	5.00
10. Learning how to ask questions		3	5.00
11. Permanent learning		3	5.00
12. Finding knowledge and learning how to disperse knowledge		3	5.00

The Role of Teacher

Only one pre-service science teacher answered negatively when asked, "Did you find constant communication with the teacher and the role of the teacher useful?" This pre-service science teacher expressed himself by saying "When I am in contact with the teacher, I feel more nervous." Those who answered positively expressed that it was useful to see their mistakes and realize the limitations of the lesson (23.08%). The pre-service science teachers further indicated that teacher guidance in the lesson helped eliminate misconceptions (17.31%), directed them to make something better and motivated them to be better teachers (15.38%), and guided them towards effective teaching strategies (15.38%). Other codes included realizing different ideas (7.69%), supporting logical thinking (5.77%), learning how to prepare an activity (5.77%), self-confidence (5.77%), and increased motivation (3.85%). Pre-service science teachers who participated in the focus group interviews said for this same question that being in contact with the class teacher and the teacher's role were useful for eliminating misconceptions, defining limitations, saving time, and being better teachers.

Table 3
The Percentage and Frequency Values of the Codes related to Preparation and Application of Activity

Codes	Sample Expressions	*f*	%
1. Attracting attention	• *Activities are so important. It helps to teach with enjoyment and by attracting attention…* (*1*)	13	28.26
2. Permanency of learning	• *It helps knowledge be learned more permanently because it is fun.* (*2*)	10	21.74
3.Supports understanding	• *I think it helped understand the subject better.* (*3*)	8	17.39
4. Communication	• *It specifically empowers class communication…* (*4*)	4	8.70
5. Group work	• *It was useful because we did it with our friends working together in groups.* (*5*)	3	6.52
6. Supports inquiry and critical thinking	• *One of the most important aspects of teaching is to know how to ask questions. This stage taught us how to inquire.* (*6*)	3	6.52
7. Supports discussion	• *I believe it is useful because it helps group thinking and discussion.* (*7*)	3	6.52
8. Motivation	• *In my opinion it makes the lesson more motivating. We became more active and involved.* (*8*)	2	4.35

Table 4
Percentage and Frequency Values of the Codes related to the Role of Teacher

Codes	Sample Expressions	*F*	%
1. Realizing one's inadequacies, mistakes, and limits	• *I found it beneficial because it helped me understand where I am inadequate or mistaken.* (*1*)	12	23.08
2. Eliminating misconceptions	• *We spoke wrongly on some points. If our teacher hadn't interfered we could have caused misconceptions. In this way, we get rid of misconceptions.* (*2*)	9	17.31
3. Making something better	• *We could do everything better.* (*3*)	8	15.38
4. Teaching effectively	• *I found it so useful to consult people with more experience (our instructors) in order to teach more effectively, make the lesson more effective.* (*4*)	8	15.38
5. Realizing different ideas	• *It was useful for us to see our teachers put forth new ideas apart from our ideas.* (*5*)	4	7.69
6. Supporting logical thinking	• *When I had contact with the lesson teacher, my self-confidence increased.* (*8*)	3	5.77
7. Learning activity preparation	• *I found it useful because it increased lesson motivation.* (*9*)	3	5.77
8. Self-confidence		3	5.77
9. Motivation		2	3.85

"To me it is so important that the teacher is involved in the lesson. Teacher influence is very important both in guiding lesson preparation and during class especially for contradictory or confusing topics. This helps prevent misconceptions." (K3, Female)

"In my opinion, it was so important to be in contact with the teacher for knowing our limitations. Otherwise the topic could be presented so disorderly." (K2, Female)

"I think that teacher guidance helped us save time. Otherwise, it could have taken us a lot longer. Maybe we would have finished late or have become confused." (K6, Female)

"I think with teacher guidance we could do it better. Their suggestions to think of alternatives were important." (K7, Female)

Letter Writing Activity

All of the pre-service science teachers were asked to write a letter to a respondent of their choosing about the subject at the end of the lesson. When the pre-service science teachers' opinions were gathered, 23 said that the activity was useful for them. Three of the pre-service science teachers were indecisive about the subject, and seven did not find the activity useful at all. Of the pre-service science teachers who found the activity useful, 54.84% thought that writing letters helped to repeat what they learned and to consolidate their knowledge. They thought that writing a letter also gave the opportunity to assess and evaluate (16.13%), and it helped teach others (9.68%). Furthermore, pre-service science teachers thought that letter writing helped to express what they had learned in their own words (6.45%), assisted permanent learning (6.45%), and helped them associate what they had learned with life (6.45%). Three of the pre-service science teachers who did not find the activity useful did not explain why. The other pre-service science teachers explained that the activity was not appropriate for the level of the class (20.00%), the activity took too much time (40.00%), it was difficult to write the letter in a way that the respondent could understand (20.00%), or they preferred different kinds of assessment and evaluation tools (20.00%).

Strengths of Learning by Teaching

The strengths of learning by teaching are described in Table 6. As shown, pre-service science teachers defined the most powerful aspect of this method as gaining teaching experience (21.06%). They defined other strengths of this method as supporting communication (12.28%) and gaining self-confidence (10.53%). Other strengths of the method that were expressed are it facilitates learning (8.77%), supports deep learning (7.02%), gives the opportunity to learn by doing and living (7.02%), is student-centered (7.02%), leads to permanent learning (5.26%), supports group study (5.26%), directs students toward research (5.26%), gives the opportunity to associate the topic with life (5.26%), and helps students be motivated for the lesson (5.26%).

Weaknesses of Learning by Teaching

The question "According to you, what are the weaknesses of learning by teaching?" was not answered by three of the pre-service science

Table 5
Percentage and Frequency Values of the Codes Related to Letter Writing Activity

Codes	Sample Expressions	*f*	%
Yes		23	
1. Consolidation/ Repetition	• *Yes, I found it useful. When I wrote the letter after the lesson I could consolidate the lesson more.* (*1*)	17	54.84
2. Assessment–evaluation	• *In fact, we assess what we have learned by writing a letter.* (*2*)	5	16.13
3. Opportunity to teach others	• *Because the things we learned did not stay in the class, we could learn by writing a letter telling others what we had learned.* (*3*)	3	9.68
4. Expressing the things learned in one's own words	• *We were able to express what we learned in our own words* (*4*)	2	6.45
5. Permanent learning	• *… I think it helps for remembering what we learned. It makes it more permanent.* (*5*)	2	6.45
6. Associating with life	• *… I think writing a letter is an effective study for associating the topic with life at that time.* (*6*)	2	6.45
No		7	
1. Time	• *Writing a letter took most of our time.* (*1*)	2	40.00
2. Class level	• *I think letter writing should be used in lower classes (primary school and secondary school). It is not appropriate for our level.* (*2*)	1	20.00
3. Respondent	• *It is difficult to write the letter in a way that the respondent can understand.* (*3*)	1	20.00
4. Assessment - evaluation	• *We can use other assessment tools instead of writing a letter.* (*4*)	1	20.00

Table 6
Percentage and Frequency Values of the Codes related to Strengths of Learning by Teaching

Codes	Sample expressions	*f*	%
1. Gaining teaching experience	• *Students gain self-confidence, communication skills, experience, and how to teach and perform group work.* (*1, 2, 3, 9*)	12	21.06
2. Communication		7	12.28
3. Self-confidence	• *It helps in development of self-confidence. It helps by gaining experiences associated with the teaching profession and in overcoming the fear of being a teacher.* (*1, 3*)	6	10.53
4. Facilitates learning	• *In my opinion effective communication is the most important point of this method.* (*2*)	5	8.77
5. Deep learning	• *Being student-centered. Students find the opportunity to combine what they know with their creativity.* (*6*)	4	7.02
6. Student centered		4	7.02
7. Learning by doing and living	• *… It helps to facilitate learning. It also helps us be more qualified teachers for the future.* (*1, 4*)	4	7.02
8. Permanent learning	• *While we were teaching what we learned, we in fact learned that subject by living it.* (*7*)	3	5.26
9. Group work		3	5.26
10. Directing toward research	• *The strengths are in preparing the subject and finding the opportunity to research it.* (*10*)	3	5.26
11. Gives the opportunity to associate topics with daily life	• *It helps us to associate the topic with daily life.* (*11*)	3	5.26
12. Motivates	• *… It helps us be motivated for the lesson.* (*12*)	3	5.26

teachers. Seven answered, "I don't think it has weaknesses," however. Other students expressed a total of six different weaknesses. These results are given in Table 7. According to this, the pre-service science teachers assessed group work (29.16%) as the major weakness of the method as this is where they experienced the most difficulties. If students are insufficiently prepared, misconceptions (16.67%) can be made, and uninterested students may slow down the lesson (16.67%), adding to the negative views of the method. Other weaknesses expressed were that peers did not take the lesson seriously (12.50%), that full knowledge is limited to the topic (12.50%), and that preparations need time, so the time constraint may have rushed some students (12.50%).

Difficulties Using Learning by Teaching

For the question "Did you have difficulties while teaching the lesson via learning by teaching?" 16 of the pre-service science teachers answered in the negative and 15 of them answered in the positive. The difficulties that were encountered are given in Table 8. The pre-service science teachers expressed that they mostly had difficulties getting the attention and involvement of other pre-service science teachers in the lesson (27.78%). Other pre-service science teachers had difficulty in preparing the lesson (16.67%), gaining full knowledge of the topic (16.67%), being nervous (11.11%), having a lack of self-confidence (11.11%), knowing how to teach the subject (11.11%), and having problems with group study (5.55%). The question 'Did you have difficulties undertaking the responsibility of the lesson in terms of science and maintaining the lesson?' was assessed using focus-group interviews. The pre-service science teachers who participated in focus-group interviews explained their views on the difficulties preparing the lesson as teaching comprehension, excitement, and group studies. Moreover, the pre-service science teachers explained that learning science topics, the idea of associating these topics with daily life, and experimental implementations for helping teach science more efficiently were other difficulties they encountered. In this context, the explanations of the pre-service science teachers are presented below:

> "I think if I am prepared, I will be able to maintain the lesson easily. Here I think preparation is so important. If you are prepared enough it is easy then. I think it is enjoyable." (K2, Female)

> "To me it was difficult to simplify the subject according to the level of the students. I asked myself, 'Can I simplify this? Is it comprehensible?'" (K3, Female).

Table 7
Percentage and Frequency Values of the Codes related to the Weaknesses of Learning by Teaching

Codes	Sample Expressions	*f*	%
1. Group work	• *Agreement becomes difficult due to group work. It is difficult to reach consensus.* (*1*)	7	29.16
2. Misconception	• *Poor preparation leads to misconceptions.* (*2*)	4	16.67
3. Not taking 'teacher student' seriously	• *Sometimes other students don't respect the student-teacher conducting the lesson because they are also a student.* (*3*)	4	16.67
4. Not taking the lesson seriously	• *Everyone gains full knowledge with their topic but not with other topics.* (*5*) • *Time limitations sometimes can force people to rush.* (*6*)	3	12.50
5. Full knowledge		3	12.50
6. Time		3	12.50

Table 8
Percentage and Frequency Values of the Codes related to Difficulties Using Learning by Teaching

Codes	Sample Expressions	*f*	%
1. Getting the attention of students / involving them in the lesson	• *I had difficulties getting the class involved in the lesson and overcoming my nervousness.* (*1, 4*)	5	27.78
2. Preparing the lesson	• *We had some difficulties preparing for the lesson.* (*2*)	3	16.67
3. Full knowledge	• *I had difficulties getting full knowledge of the subject.* (*3*)	3	16.67
4. Excitement	• *Self-confidence became a big problem for me.* (*5*)	2	11.11
5. Self-confidence	• *We were having difficulties with how to teach a lesson and what to do for the lesson.* (*6*)	2	11.11
6. Teaching	• *It is sometimes difficult to make decisions as a group.* (*7*)	2	11.11
7. Group work		1	5.55

"I think the topics in science are easy compared to other classes because they are about nature; they are experimental and we can make activities. Besides, I think our research questions and activities help the subjects to be understood better." (K1, Male)

"I got too nervous, thus, I found it difficult to express myself. It was difficult for me but it helped me to think that I could suppress my nervousness. Of course, the process was important at the same time. Having the instructor there helped me to suppress my nervousness in time." (K7, Female)

"Group study is difficult, but it was enjoyable for us. It was difficult because of time. Determining a mutual time for coming together was difficult. But when we arranged the meeting and came together it was so enjoyable to produce something." (K6, Female)

Use of Learning by Teaching in Teacher-Training Programs

For the question "In your opinion, should learning by teaching be used in teacher-training programs?" 30 pre-service science teachers answered in the positive. Most of the pre-service science teachers indicated that it provides vocational competence (54.35%) as justification for using this method in teacher training programs. In addition, pre-service science teachers expressed that this method should be used because it improves communication skills (8.69%), improves self-confidence (8.69%), is an effective teaching method (6.52%), helps establish permanent learning (4.35%), teaches research skills (4.35%), encourages students to be versatile (4.35%), is student-centered (4.35%), and increases motivation for being a teacher (4.35%).

Courses Appropriate for the Use of Learning by Teaching

Table 10
The Codes and Frequency Values for the Courses in which Learning by Teaching can be Used

Codes	*f*	%
1. Pedagogical courses	20	35.71
2. Science courses	36	64.29

For the question "In which courses do you suggest learning by teaching should be used?" it was suggested that it could be used in vocational courses for teaching (35.71%) in the Faculty of Education, such as education courses and material designs, as well as in courses with science content (64.29%), such as biology, physics, chemistry, special topics in chemistry, special topics in physics, science labs, and anatomy.

Using the Experiences Gained in the Future

The last question on the written interview form was "Do you think that you will use the experiences you gained from this lesson the next time you teach? Explain." Sample expressions are contained in Table 11.

Table 9
Percentage and frequency values of codes related to use of learning by teaching in teacher training programs.

Codes	Sample Expressions	*f*	%
1. Professional competence	• *People who don't have the ability to teach become teachers only because they answered a few more questions correctly on the exams. It must be used to train good teachers.* (*1*)	25	54.35
2. Communication		4	8.69
3. Self-confidence		4	8.69
4. Effective teaching	• *This method can remove feelings of inadequacy or lack of self-confidence on the part of the students.* (*3*)	3	6.52
5. Permanent learning		2	4.35
6. Teaching research skills	• *It teaches how to perform research. This is so important to me.* (*6*)	2	4.35
7. Teaching to be versatile	• *An uncommon method. In my opinion it must be used because it is stands apart from classical methods and teaches versatility.* (*7*)	2	4.35
8. Student centered	• *Student centered. It provides for active participation and grabs students' attention better.* (*8*)	2	4.35
9. Motivation	• *It helps raise motivation.* (*9*)	2	4.35

Table 11
Answers on Using the Experiences Gained in the Future

Sample Expressions
• *… For example I was criticized for talking fast. From now on I will be careful about how fast I talk.*
• *I think I will communicate more effectively.*
• *I have seen my inadequacies and I will be more careful.*
• *I will know which techniques are more effective.*
• *With the help of this experience I can control my nervousness.*
• *I gained class management from this lesson. When I am a teacher, I will make it a point to lecture to the whole class, reaching everyone in the class.*
• *From now on I think I will be more aware.*
• *I will use my experiences from this class not just in teaching but also in daily life.*
• *The letter writing activity was especially effective for the 7E model evaluation stage. For this reason I will use it.*
• *I will use my research experience in other implementations, too.*
• *I think that I will especially use well the parts on research question and activity preparations.*

The views mentioned above show that the pre-service science teachers will use the teaching experiences they gained through this case study in their future as teachers. These views describe gaining experiences related to the teaching profession such as communication and class management, pedagogical content knowledge or how to teach (Shulman, 1986), and how they will use their experiences in the future. One pre-service science teacher went so far as to say that she will use these new skills not only in teaching but also in her daily life.

Discussion

This case study explores the experiences of pre-service science teachers related to the educational method of learning by teaching used during the Special Topics in Chemistry class. Findings from the study indicate that the pre-service science teachers found the method useful and valuable for enhancing their learning experience. During focus group discussions and individually written interviews, the learning-by-teaching method was critiqued. The strengths of the method include an increase in self-confidence, improved communication skills, and the ability to gain successful teaching experiences. For the focus group interviews, students expressed that learning by teaching supported an increase in awareness and communication, a realization of different ideas, discussions, permanent learning, and group work. These findings indicate that this method enhances the learning of 21st century skills as it supports the empowerment of self-confidence, self-efficacy, and communication skills through one's participation in the process of learning by teaching, as discussed by Ponnusamy and Pandurangen (2014). Such benefits can also be seen in the fields of career and life skills as well as in learning and innovation skills (Partnership for 21st Century Learning, 2015; Trilling & Fadel, 2009). The significant stages of the method are preparing the research questions and working together to find answers using effective materials. The pre-service science teachers who participated in the study indicated that learning by teaching offered many opportunities for learning in this stage as well as directing research and teaching research skills. They also felt that this method gave them opportunities to associate the topic with daily life as well as additional ways of reaching and selecting information. Based on these views and on the observations and experiences during the implementation of the method, it can be stated that the students' preparation and presentation of the topic helped them develop their ability to produce, use their imagination, think creatively, and solve problems, all of which are regarded as 21st century learning and innovation skills (Köğce et al., 2014; Partnership for 21st Century Learning, 2015; Trilling & Fadel, 2009).

Another stage in implementing the learning-by-teaching method is the preparation and implementation of the activity. All pre-service science teachers found this stage useful, and they emphasized the goals of attracting attention, permanent learning, and understanding as reasons for this. Based on these views and the experiences and observations during the implementation of the method, students were supported in developing their creativity, using their imagination, inventive thinking, and problem solving. These competencies are considered 21st century skills of learning and innovation (Partnership for 21st Century Learning, 2015; Trilling & Fadel, 2009). In this study, letter writing, which is commonly cited in the literature, was also included because in theory it should improve the learning and retention of information (Günel, Uzoğlu, & Büyükkasap, 2009; Yıldız, 2009; Yıldız & Büyükkasap, 2011). Recently, writing for the purpose of learning has been viewed as an essential strategy in learning topics within the context of science (Hand et al., 2003). During the pilot studies in this project, pre-service science teachers suggested making an out-of-class activity for that week's topic to enhance what the class had learned. Letter writing was the activity chosen for implementation during this study, but other out-of-class activities may be just as effective.

The role of the teacher as advisor and facilitator is another key characteristic of the learning-by-teaching method. In fact, the role of the teacher in this method is the main factor in successful implementation of the method. The experience

of this study shows that this can only be possible if there is effective communication among the students. Participants were therefore asked, "Did you find it useful to be in contact with the teacher of the class; was the role of the teacher conducive to learning?" When reviewing the findings of this study, it becomes clear that both roles increased the self-efficacy of the students. Here, the teacher as an adult model and the other students in the classroom as peer model increased the self-efficacy more than traditional styles of teaching. Explanations, feedback, and guidance for thinking styles from the teacher are factors which contribute positively to the self-efficacy of students within the adult model. On the other hand, other students contribute positively to the self-efficacy of the students under the peer model (Shunk, 2011, p.109). In addition to practicing the behaviors for teaching, being informed on the subject increases not only the skills on that subject but also self-efficacy (Shunk, 2011, p.114), which is considered a key component of life and career skills in the 21st century (Partnership for 21st Century Learning, 2015; Trilling & Fadel, 2009). The roles of teacher and student, in addition to all of the processes for the implementation of the method, indicate that learning by teaching supports life and career skills such as team work, flexibility, being enterprising, adaptability, self-management, responsibility, efficiency, productivity and effective studying. Given the long list of skills that can be acquired, it is clear that learning by teaching is effective in gaining the skills of 21st century societies as experienced by pre-service science teachers. This result shows similarities with the findings from Grzega and Schöner's study (2008) on learning by teaching (LdL). Grzega and Schöner, in their study evaluated the method via a 54-question questionnaire given to 97 students who were being trained in LdL classes in Germany. Their results also showed that most of the participants found LdL effective in gaining the skills which are necessary in information societies. In their findings, LdL was emphasized as crucial in improving communication skills, which is an essential cornerstone for information societies. Similarly, Skinner (1994) used LdL in English lessons and discovered that students not only learned and experienced English better, but also developed their communication skills and began to learn critical thinking. Moreover, when the views of pre-service science teachers are examined in the context of the proficiency of the teacher, the learning-by-teaching method increases personal teacher proficiency (Gibson & Dembo, 1984). Personal teaching proficiency is directly related to a teacher's beliefs about their own skills. Personal competence helps the teacher attribute their vocational teaching proficiency to their own personal understanding, as well as having positive self-perception (Celep, 1998). This situation helps the teacher increase their own success in the process of learning how to teach.

In this study, the views of pre-service science teachers on the weaknesses of learning by teaching and the difficulties in implementing this method were also examined. It was observed that two-thirds of the pre-service science teachers indicated weaknesses with the method, emphasizing group work and misconceptions as two main causes. All of the pre-service science teachers expressed that group study was a weakness of the method because of the difficulty group members had coming together at a mutual time and that group study was weakened by personal disputes. Even though group work was perceived as a weakness in the method, it is an important skill to acquire as pre-service science teachers will need to develop effective interpersonal skills in both their lives and careers. The second weakness of the method was conceptualized as misconceptions about the subject. Pre-service science teachers raised a very important issue during this study, and one that should be considered in future studies. If pre-service science teachers do not prepare for a lesson sufficiently, they can cause students to misconceive the subject, impacting the learning of the group as a whole. This situation was sometimes observed, occurring both during lesson preparation and during the lesson. It was overcome through effective teacher role. Thus, if a teacher does not perform their role of counseling, guiding, or facilitating effectively, misconceptions are likely to occur. It is very important that these situations are prevented and responsibility for doing so lies equally with the students and the teacher. Students can do their part by coming sufficiently prepared to class, and teachers must ensure and effectively perform their role throughout the implementation of the method.

In the context of this study, pre-service science teachers were asked about the difficulties they encountered during method implementation. The difficulties they identified as most problematic were attracting the attention of classmates and involving them in the lesson, as well as being prepared for the lesson. Again, having these experiences early in their careers and developing positive attitudes for overcoming these difficulties will help them to teach effectively in the future. Difficulties met by students while implementing this method can be mitigated by an effective teacher. The relationship

between teacher and student is symbiotic and therefore it is essential that learning by teaching be used in teacher-training programs as well as in classroom settings. Another remarkable detail which pre-service science teachers expressed is that this method can be used both in pedagogical classes and lessons which have science content. This study showed a positive impact on the motivation and attitudes of the students. This is compatible with Martin's finding that when students become the teacher in class, their motivation increases dramatically (Skinner, 1994). Conversely, when the views mentioned above are evaluated in the context of teacher proficiencies, learning by teaching also increases general teacher proficiency (Gibson & Dembo, 1984). General teacher proficiency involves the attribution of teacher's vocational proficiency with self-knowledge and skills (Celep, 1998). It is the view of pre-service teachers in this study that learning by teaching contributes to knowledge and skill acquisition for the teaching profession. In this respect, using learning by teaching in classes for those pursuing a Bachelor's degree can help to positively develop the general teaching proficiency of pre-service teachers.

Based on the above discussion related to the views of pre-service science teachers on learning by teaching and the three-year implementation experience of this study, one can conclude that the method is usable for teacher-training programs and it contributes to the attainment of 21st century skills. Pre-service science teachers who have the opportunity to gain these skills can use them in future lessons and in turn provide the same opportunity to their students. The necessity for improved educational methods in the field of science was highlighted in PISA (2012), which is a program for assessment and evaluation. According to PISA results from 2012, Turkey is ranked 44th in mathematics, 42nd in reading skills, and 43rd in science out of 65 countries. While 8% of students in Turkey are in upper performance groups in at least one of the lessons, this rate in other OECD countries is 16% according to the PISA results from 2012. Similarly, 1% of students in Turkey are in upper performance groups for all three fields, but this rate in OECD countries is 4.4% (Yıldırım, Yıldırım, Yetişir, & Ceylan, 2013). These results are more meaningful if they are viewed in conjunction with reports on the topics of teaching and assessment, an evaluation of 21st century skills in OECD countries. OECD published the report in 2009 on the basis of findings from a questionnaire created on curricula by OECD for countries which participated in the research. In Turkey specifically, critical thinking, creative thinking, communication, research, problem solving, decision making, and basic information and communication skills are included in the curricula for primary and secondary schools. However, there are no assessment or evaluation policies, nor are there teacher-training programs in place for targeting these skills and competences. In the report, it was emphasized that regulations within the teaching programs of Turkey have an effect on teacher-training programs, but do not have any significant effect on 21st century skills or competences (OECD, 2009). When this is evaluated alongside the results of PISA (2012), it becomes evident that new regulations and implementations are needed to gain 21st century skills in teacher-training programs. Teachers play an important role in delivering the essential competences regarding the fields of proficiency, information, and skills; they have a responsibility to help students overcome the problems they face as defined in the evaluations of PISA (OECD, 2014). Teachers who have gained 21st century skills and competences will be able to effectively teach their students by using these skills and competences. The results of this study show pre-service science teachers that use learning by teaching can gain 21st century skills and competences. These results resemble other studies which showed that 21st century skills such as cooperative learning, group study and research focused on peer education, effective group study, responsibility, confidence, communication, struggling with problems (Erdem & Morgil, 2002) critical thinking, self-efficacy, self-regulation (Güvenç, 2010), discovering different knowledge fields (Fougner, 2012), and motivation related to the field (Dogru, 2013) can be attained through the learning-by-teaching method. However, learning by teaching differs from other models, methods, and techniques that contain cooperative and peer-supported learning. The students' role in the learning-by-teaching method is the most distinct feature when compared to these models, methods, and techniques. Giving the responsibility of teaching directly to the students and having them be responsible for learning the subject is a unique aspect of learning by teaching. The role of the teacher differs as well and is found to be more effective than the above-mentioned methods, techniques, and models. The key difference is that the guiding role of the teacher does not only occur during and after the lesson but also during preparation for the lesson. In the process of preparing for the lesson, the teacher's guidance helps the students not just learn the subject, but also learn to teach. In the other models, methods,

and techniques, the subject and parameters for teaching the subject are all defined by the teacher. In learning by teaching, the design of the lesson is planned by the students with the guidance of the teacher and the lesson is taught by the students, resulting in students having responsibility for all steps in the method (Hanbay, 2009; Serindağ, 2007).The student is given autonomy, which means that the student will depend less on the teacher and teaching materials (Martin & Kelchner, 1998). This style of learning supports the students in using all of their potential and encourages full participation in the process of learning and teaching.

In conclusion, this study is important as it shows that learning by teaching can be used in lessons specifically with science content. Use in lessons of special topics in chemistry, special topics in physics, and special topics in biology is highly recommended due to its focus on the relationships with science, technology, society, and the environment. Further exploration of learning by teaching in lessons which have science content is encouraged, and criteria such as the effectiveness of the method on learning, attitudes, and academic success are suggested in evaluating its overall success.

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