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HIGH SCHOOL STUDENTS' VIEWS ON THE 5E-BASED STEM LEARNING STRATEGIES[1]

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Abstract: The aim of this study is to examine the views of ninth grade students about 5E-based STEM learning strategies in the atomic and periodic system unit. The research was carried out with phenomenology which is one of the qualitative research designs. Purposive sampling was used and eight students participated in the study. The data was collected through a semi-structured interview at the end of the intervention and analyzed by content analysis. Based on findings, students emphasized that 5E-based STEM learning strategies promote their meaningful learning. Although the participants mentioned that 5E-based STEM learning strategies had advantages in terms of meaningful learning, they thought that this strategy could not be implemented efficiently due to the difficulties they experienced during the 5E-based STEM learning strategies as the incompatibility with the university entrance examination system. It was recommended that student-centered teaching methods should be utilized and students should be active in their learning process in order to overcome these difficulties.

Key words: STEM learning strategies, 5E leaning cycle model, phenomenology, semi-structured interview, science education

1. Introduction

1.1. Constructivism

Constructivism suggests that students build their new knowledge using their prior knowledge. Also, constructivism expects that students build their knowledge through their teachers' guidiance. According to constructivism, students complete meaningful learning instead of rote learning during their learning process (Von Glasersfeld, 2013). Constructivism also guides STEM learning strategies as teachers facilitate and scaffold students' meaningful learning (Becker & Park, 2011).

1.2. 5E Learning Cycle Model

In this study, the 5E learning cycle model was preferred in order to apply STEM activities because this model is also based on the views of constructivism and involves students actively in the learning process (Dass, 2015). In addition, there are many studies indicating that the 5E learning cycle model increases students' meaningful learning (eg. Liu, Peng, Wu & Lin, 2009). The 5E learning cycle model was proposed by Atkins and Karplus in 1962. This model has been adapted to science learning, guided by Dewey's experiential learning philosophy (Kolb & Kolb, 2009) and Kolb's (1984) experiential learning theory. According to Kolb's model, learning is the result of experience (Kolb & Kolb, 2009). The steps of the 5E learning cycle model includes engegament, exploration, explanation, elaboration, and evaluation (Bybee & Landes, 1990).

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1.3. STEM Education

STEM is defined as the integration of "Science, Technology, Engineering and Mathematics" disciplines (Bybee, 2010; Dugger, 2010). There are different views on how different disciplines can be integrated into the classroom environment and course content. However; it is seen that three approaches are widely used as multidisciplinary, interdisciplinary and transdisciplinary (Dugger, 2010; Moore, Stohlmann, Wang, Tank, Glancy & Roehrig, 2014; NRC, 2012). In the multidisciplinary approach, a theme that includes different discipline areas is determined (Drake & Burns, 2004). While working on the determined theme, students also acquire the objectives from different disciplines. The boundaries between disciplines are not clear, and students focus on the theme rather than the objectives of the disciplines (English, 2016). The transdisciplinary approach enables students to face real life problems. Students benefit from different disciplines while solving the current problem. Students establish the relationship between the objectives of different disciplines and daily life (Drake & Burns, 2004). Interdisciplinary approach enables students to learn without borders between different disciplines (Lederman & Niess, 1997). Through this approach, teachers identify areas of learning. Also, they expect students to collaborate and communicate. Different disciplines take place homogeneously in the learning process (Drake & Burns, 2004). Interdisciplinary approach was preferred in this study.

STEM education is an approach that science and mathematics subjects is learned by integrating engineering and technology into the regular curriculum. Teaching STEM disciplines through integration would be more in line with the nature of science (Merrill & Daugherty, 2010). Integrated STEM education is an interdisciplinary learning process that removes the barriers between four disciplines (Wang, Moore, Roehning & Park, 2011).

Integrated STEM education enables students to promote meaningful learning by solving real-life problems (Murphy & Mancini-Samuelson, 2012). It also may improve students' motivation, sef-efficacy, and self-confidence to take higher-level mathematics and science courses in secondary school and college (DeJarnette, 2012; Russell, Hancock, & McCullough 2007). Moreover, Lottero-Perdue, Lovelidge & Bowling, (2010) state that integrated STEM education emphasizes engineering principles and hands-on and inquiry-based strategies and positively affects the self-management of students who struggled with traditional lessons. Furthermore, students produce innovation through STEM education. In addition, STEM education enables students to develop 21st-century skills and use their skills and knowledge to solve problems (Bybee, & Fuchs, 2006).

Lederman & Niess (1997) associates integrated STEM education with the process of formation of a chemical compound from its elements. Elements with different properties come together to form a different compound (Lederman & Niess, 1997). As in the compound example, students should learn science lessons using knowledge and skills from different disciplines such as mathematics, engineering, and technology. They should conduct this learning process by using student-centered strategies. Meyrick (2011) asserts that student-centered learning strategies such as problem-based learning and inquiry offer some advantages to implementing STEM education and these strategies facilitate development of 21^{st}-century skills. However, the education programs are not sufficient to achieve this integration. Therefore, curriculum should ensure the integration of different disciplines with each other. If this integration is not achieved, students cannot solve real-life problems (Clark & Ernst, 2006), think critically (Felix & Harris, 2010), be creative (Morrison & Raymond-Bartlett, 2009), and relate issues to daily life (NRC, 2012). Therefore, this study examines the views of students who have learned the atomic and periodic system unit using 5E based STEM learning strategies. Through this review, the research will shed light on program developers whether STEM education can be integrated into programs or not. On the other hand, there are studies in the literature that examine teachers' views on STEM learning strategies (DeChambeau & Ramlo, 2017; EL-Deghaidy, Mansour, Alzaghibi & Alhammad, 2017; Nuangchalerm, 2018; Yıldırım, 2020). Even in these studies, there is no consensus on how STEM activities should be implemented. Therefore, there is a need for more studies on students' views on STEM activities because of both the inadequacy of the studies conducted with high school students and the more need for students' meaningful learning. Finally, the atomic and periodic system unit is one of the units that is difficult to understand by students (Cokelez, 2012; Niaz & Luiggi, 2014; Wang & Barrow, 2013) and is at the top of the interdisciplinary units suitable for STEM activities (Wisudawati, 2018). For these reasons, this unit was preferred in this study. The research question that frames the study is: What are the perceptions of high school students regarding the 5E-based STEM learning strategies (5E-bSTEMls)?

2. Method

Phenomenology is a qualitative research design and it examines the facts, events and experiences that we encounter in our lives but do not think much about (Creswell, 2009). Participants' opinions about their experiences and the structuring processes of these opinions are discussed in phenomenology studies (Van Manen, 2007). In this study, phenomenology was employed to address the research question of this study since it was aimed to investigate the students' views about 5E-based STEM learning strategies after the intervention process.

2. 1. Participants

In accordance with the purpose of the study, easily accessible situation sampling was preferred from purposeful sampling types. Through this sampling, we worked with participants who are appropriate in terms of time, money, place and location (Merriam, 2013). Participants were determined on a voluntary basis. Some students did not accept the interview and in this case other students were preferred. All participants were chosen from the experimental groups in the fall semester of 2016-2017 because these students had learned the topics using 5E-based STEM learning strategies. Six of the students were girls and two were boys and their ages ranged between 14 and 16 years. In order to meet the assumption of sufficient sampling and to generalize the results to the population, 5E-based STEM learning strategies was applied in two groups. Therefore, these groups were coded as EG1 (experimental group 1) and EG2 (experimental group 2). While five participants were in EG1, three of them were in EG2. Students were coded as EG11f, EG12f, EG13f, EG14f, EG15f, EG21f, EG22m, and EG23m. For example, the fourth participant in the EG1 was coded as EG14mf, while the second participant in the EG2 was coded as EG22m. The lowercase "m" indicates that the gender of the participant is male and the lowercase "f" is female.

2. 2. Data Collection Tool

Semi-structured interview was used in this study in order to probe high school students' views about the effect of 5E-based STEM learning strategies. To form interview protocol, the literature was reviewed (Bruce-Davis, Gubbins, Gilson, Villanueva, Foreman & Rubenstein, 2014; Walton, 2014). Interview questions were checked in terms of clarity, suitability, and competence by an expert in science education and qualitative research. The question of "*What kind of activities were included during the implementation? Which event / events did you like the most*?" was revised to "*What activities did you like during the intervention? Why?*" after the control. Some sample questions asked in the interview were given in Table 1.

Table 1. Sample questions asked in the interview

Order of the question	Sample question
1	Could you compare the teaching method you learned about the atomic and periodic system unit with the previous teaching methods? What kind of differences do you think there are?
2	What kinds of activities were included during the implementation? Which event/activities did you like the most?
3	How did the use of different activities in chemistry lessons contribute to you? Please explain.
4	Do you think that there are positive aspects of learning the atomic and periodic system unit with the 5E-based STEM learning strategies? Why?
5	Do you think that there are negative aspects of learning the atomic and periodic system unit with the 5E-based STEM learning strategies? Why?
6	Did you encounter any difficulties during the treatment? If yes, give examples of these difficulties.

7	What aspects of the implementation do you find interesting? Please explain.
8	Do you think your learning is permanent at the end of the implementation?
9	Would you like to use such rich activities in your next chemistry lessons? Why?

The final interview form was consisted of nine questions. The interviews were conducted by the first researcher and each participant was interviewed individually for about 25 min. All interviews were also conducted in a quiet and comfortable environment. Each interview was audio-taped and transcribed in full by the first researcher.

2. 3. Data Collection Process

Lesson plans consisting of 5E based STEM learning activities were applied to the experimental groups for 10 weeks. In order to ensure treatment verification as intended, the first author trained the chemistry teacher of the study how to implement the treatment by one week before the treatment. All instructional materials, activities and teacher manuals were provided for the teacher before the intervention.

The contents of the lessons were arranged in accordance with the steps of the 5E learning cycle model (Bybee, 1997). Activities have been prepared in the "Atom and Periodic System" unit by integrating science, technology, engineering, and mathematics disciplines. Therefore, while integrating STEM into lessons, chemistry was taken to the center. Context based integration was realized by including at least one of the other disciplines in chemistry. At each step of the 5E learning cycle model, at least two disciplines were used in accordance with the interdisciplinary approach. Since the dependent variables of the study were academic achievement, views on the nature of science and scientific creativity, the activities were developed to cover these variables. During the implementation process, STEM activities were used abundantly. Some examples of these activities are design activities, activities related to scientists for the nature of science, technological applications (video, 4D element application etc.) and the conservation of mass activity including worksheets and brainstorming that improves scientific creativity. Considering the content of the chemistry unit, activities including engineering design process were used. Since the atomic and periodic system concepts have abstract concepts, designs (atomic models, periodic table etc.) were presented in accordance with the content. In addition, a new technology was not produced in the technology discipline-oriented activities and existing digital technological tools were used. After the intervention, post-tests were administered. Then, semi-structured interviews were conducted after the post-tests by the first researcher.

2. 4. Validity and Reliability

In this study, various strategies or perspectives were used to establish validity and reliability (Creswell, 2009; Creswell & Miller, 2000). These perspectives were presented in Table 2.

Table 2. *Validation and reliability strategies in the study*

Validity & reliability	**Strategies used**
Internal validity	Expert control
	Member checking
	Prolonged engegament
	Direct quotation
External validity	Thick description (Detailed explanation all stages of the study)
	Explaining the characteristics of participants
	The role of the researchers
	Purposive sampling
Internal reliability	Presenting the findings without any comment
	Peer debrifing sessions / Researchers' consensus on coding
External reliability	External audits

2. 5. Data Analysis

Interviews were analyzed using content analysis. Each of the researchers read the transcripts and analyzed them with respect to participants' views about 5E-based STEM learning strategies in an effort to find codes and develop categories and themes. Researchers held meetings in order to compare the codes, discuss conflicts between codes constructed when necessary and reach consensus (Patton, 2002). One theme and two different categories have been identified during the analysis. Theme and categories were presented in Table 3. The codes for each category were created using the opinions of the students and these codes were presented in the relevant tables in the findings section. Students' views were collected under more than one code in some categories.

Table 3. *Theme and categories in the study*

Theme	Category
5E-based STEM learning strategies (5E-bSTEMls)	Contributions
	Difficulties

3. Findings

Findings were presented according to categories as seen in Table 3. The codes of each category were examined separately and presented in tables below respectively.

3. 1. Contributions of 5E-bSTEMls

When Table 4 is examined, it is seen that each of the participants compared 5E-bSTEMls with traditional methods from more than one perspective. According to them, this strategy was different from the traditional methods in twelve different ways and these ways are the contibutions of 5E-bSTEMls.

Table 4. *The codes and participants in the category of "contributions"*

Codes	Participants
Experiment	EG12f, EG15f and EG22m
Teamwork	EG11f, EG12f, EG22m, and EG23m
Scientists	All participants in EG1 and EG2
Applications (Videos, 4D elements etc.)	EG11f, EG13f, EG15f, and EG22m
Meaningful learning	All participants in EG1 and EG21f, EG23m
Designing	EG11f, EG21f
Practical learning	EG13f, EG14f, EG15f, and EG21f
Enjoyable process	EG11f, EG12f, EG13f, EG15f, and all participants in EG2
Worksheets	EG11f, EG13f, EG14f, EG22m, and EG23m
Increasing exam scores	EG11f and EG22m
Imagination	EG12f and EG15f
Effective communication	EG15f

They had a positive view on 5E-bSTEMls. For instance, EG22m stated that he had a positive view on experiments, teamwork, scientists, and videos. EG22m thought, *"In the previous chemistry lessons, experiments weren't much. We did many experiments here, we worked together as a group here. Previously, chemistry lessons were an ordinary thing. Here we did experiments as a group, watched videos, learned about scientists."* EG12f had also positive view on the experiments and teamwork. She mentioned that the experiments were instructive. She got along better with her friends and her leadership quality increased thanks to teamwork. EG12f expressed, *"We did an experiment. We put the water in the balloon and inflated the bubble. Then, we calculated the mass. The same results came out from the other experiments. These experiments proved the conservation of the mass. Moreover, we worked as a team. As a group, this enabled us to get along better in a friend environment and increased our leadership power."*

All participants had a positive view on scientists. For instance, EG21f stated, *"When we researched the scientist's life, we saw his work not only in chemistry, but in other fields. We have learned about how their private life is. So, in our eyes, scientists seem to be had very easy life; but as we learned about their life stages, we learned that they faced difficulties in their lives. We have learned that they really make an effort to reveal some things in them and that there is nothing easy."* One of the most striking statements is EG12f' statement. She stated, *"It* (5E-bSTEMls) *helps us to think like scientists. Possibly, we will find something in the future."*

Four participants had positive views on applications. For instance, EG11f expressed, *"We used the Elements 4D application. In this way, we have seen how the particles that we cannot see by eye look like."* Similarly, EG13f said, *"We watched different videos, so I remembered and learned related topic very quickly."*

It is noteworthy that all participants except that EG22m stated that 5E-bSTEMls promoted more meaningful learning compared to traditional methods. For example, EG12f said, *"As we do it as a practice, it becomes more permanent in our minds and prevents us from forgetting."* EG13f and EG23m aslo achieved meaningful learning through scientists. EG13f stated, *"I have learned to think very differently even if I had a little difficulty in interpreting scientists' lives differently."* EG23m declared, *"We talked about the scientists we have been working on, like Lavosier and Einstein. Their characteristics, their family lives, etc. This contributed to our better learning."* Moreover, EG13f, EG14f, and EG21f stated that they achieved meaningful learning because they actively participated in the lessons. For instance, EG14f claimed, *"Because we do something ourselves, it remains more in our minds. We learn more, better and more effectively. Our education system now is based on memorization. Everyone is already aware of this. However, the chemistry lessons we learned now were more based on learning than memorization"* Similarly, EG13f and EG21f indicated that they promoted meaningful learning by doing research. For instance, EG21f said, "*We did some research to do periodic system and atomic model. Thanks to this research, we also learned."*

As seen in Table 4, two participants stated that they were able to make designs owing to 5E-bSTEMls, unlike traditional methods. For instance, EG21f pointed out, *"We did different activities. For example, we designed our own periodic system and made the atomic model."*

As another difference, four participants stated that 5E-bSTEMls contributed to practice-based learning. For instance, EG15f mentioned, *"It is more practical method…. We were writing, reading, and solving questions in the previous lessons. However, with this method we had a chance to apply what we learned. We had never encountered such a method before. The activities we did, especially the activity what is in the box, had been very interesting and practical".*

Seven participants declared that 5E-bSTEMls was also different from traditional methods in terms of affective domain and the lessons were more enjoyable. For instance, EG11f pointed out, *"In general, our lessons were very fun. I liked the Element 4D application very much. Because as we all have different fingerprints, I have learned that their elements differ in terms of feature and appearance."* Similarly, EG13f mentioned, *"We cannot enforce a person to do something that (s)he does not want or enjoy. It was a very fun process. We did not come to chemistry class by complaining. We were actively participating in the lessons."* Moreover, EG15f said, *"…our lessons are more fun…. The Pandora's Box drew my attention and I had a lot of fun with it…."* Also, EG21f stated that *"We made the atom model that I liked the most. I liked it very much."* In fact, she claimed, "*It* (5E-bSTEMls) *attracted our attention more, the interest in the lesson increased. With the increase of our interest, chemistry has become very popular. That's why it really made me love chemistry more."*

Five participants evaluated the use of worksheets as a difference from traditional methods in this process. EG13f stated that the worksheets helped her to learn meaningfully and participate actively in the lessons, while EG22m stated that he wrote her own ideas on the worksheets. EG13f expressed, *"After learning the subject in the lesson, worksheets were given. Thanks to the worksheets, we were both getting ready and coming to the lesson, and it was important to reinforce the topic. It was more permanent, and we were attending the lessons more actively."* EG22m also said, *"Worksheets were distributed, we did studies on them, we wrote our ideas there."*

As seen in Table 4, some participants stated that 5E-bSTEMls contributed to them in terms of the test scores and imagination. Regarding test scores, EG22m claimed, *"First of all, this was reflected in our writing. Our grades were also increased. These projects, performances, videos, and the works we have made are also reflected in the grades."*. About imagination, EG15f stated, *"We were looking from different perspectives and we were using our imagination. Certain topics were not limited; they were left to our dream. It allowed us to be more effective in these lessons. I think we could show more our thoughts, not just what the teacher told us".*

One of the most meaningful findings about the research is the finding related to effective communication. EG15f emphasized the importance of communication with her teacher in this process. She stated, *"The teacher gave importance to our ideas. In other words, it was interesting to pay attention to our ideas. We were talking and interacting more with the teacher."*

3. 2. Difficulties of 5E-bSTEMls

Participants were asked about the difficulties they experienced during the 5E-bSTEMls process. They asserted that they suffered from eight different aspects during this period.

Table 5. *The codes and participants in the category of difficulties*

Codes	Participants
Inability to use imagination	EG11f, EG13f, EG15f, and EG22m
Supply of materials	EG14f
Additional work	EG14f
Teamwork	EG12f and EG23m
Project works	EG22m
Tiring process	EG12f
Note-taking	EG23m
Incompatibility with the central examination system	EG12f and EG15f

As seen in Table 5, four participants said that they had difficulties in using their imaginations during this process. For instance, EG22m stated, *"There was a bit of a problem with the projects we did with imagination, not with theoretical knowledge. Thinking was a nuisance. My friends used very good imagination. I had trouble because I am accustomed to theoretical knowledge. We always do projects with theoretical knowledge. We have not included our imagination in many projects until now."* Since simple materials were used in this study, only one participant had problems in terms of supply of mateials. EG14f stated, *"I thought very much especially about finding materials. What can I add on this? From what angles can I fix it? I thought a lot like."* She also said that she had difficulty in terms of additional work. She did not participate in the additional studies voluntarily. EG14f mentioned, *"We are trying a little more. Actually, not as much as it should be."* On the other hand, EG12f and EG23m stated that they had trouble during the teamwork. For instance, EG12f expressed, *"For example, we worked as a team. There were some disagreements between us. There was also a leadership problem."* Likewise, EG22m had trouble with respect to project works. He claimed, *"I'm a little bored with the project work."* Moreover, EG12f said that intervention was a tiring process. She stated, *"It was a little bit tiring to express our thoughts. For example, we were constantly doing something. There are other lessons. This made us a little tired, but it still worked well."* In addition, EG23m stated that he had difficulties in this process because they always had to take notes themselves. He believed, *"We took notes sometimes. We couldn't keep up with some important points. We wrote ourselves. There was no other negativity."* Finally, two participants stated that they had difficulties because 5E-bSTEMls was not compatible with the central examination system. For instance, EG15f claimed, *"We have an exam-based education system and we memorize what is written in the notebook and take the exam. We teach the lessons according to the curriculum. Our thoughts are not evaluated as important. However, in this method, lessons were designed according to our thoughts."*

4. Conclusion, Discussion and Implications

The purpose of this study was to explore the participants' views on 5E-bSTEMls. Based on the findings, participants revealed that 5E-bSTEMls had some contributions and difficulties during the learning process. In fact, when the students' thoughts were examined in terms of the contributions of the applied 5E-bSTEMls, it was concluded that 5E-bSTEMls was a suitable strategy for the constructivist philosophy. Constructivism emphasizes that learning involves an active process in which learners construct their new knowledge by linking new ideas with their prior knowledge (Naylor & Keogh, 1999). In this regard, the participants stated that 5E-bSTEMls supports the active participation of students during the learning process. Also, in Kolb's (1984) theory, he argued that learning would be through experience. Hence, in this study, using the 5E learning cycle model, students learned through experience.

Constructivism claims that students are responsible for their own learning (Osborne, 1996). In this study, thanks to 5E-bSTEMls, students were responsible for their own learning by doing experiments, teamwork, applications, practical work and design. They also took on this responsibility, using worksheet and imagination. In fact, the students liked the lessons and this love led them to take this responsibility. Based on all this, they promoted their meaningful learning throughout this process. Similarly, there are studies in the literature indicating that STEM learning strategies contribute to students' meaningful learning. These studies asserts that STEM learning strategies generate meaningful learning through teamwork (Acar, Tertemiz, & Taşdemir, 2018; Tseng, Chang, Lou, & Chen, 2013), enjoyable process (Acar, et al., 2018; Lamb, Akmal, & Petrie, 2015), experiments (Acar, et al., 2018; Lestari, Sarwi, & Sumarti, 2018; Sagala, Umam, Thahir, Saregar, & Wardani, 2019), designing (Acar, et al., 2018; Lestari, et al., 2018), worksheets (Sagala, et al., 2019; Sulistiyowati, Abdurrahman, & Jalmo, 2018), technological applications (Anjarsari, Prasetyo, & Susanti, 2020), effective communication (Anjarsari, et al., 2020; Yıldırım, 2020), and practical learning (Murphy & Mancini-Samuelson, 2012). Although there are many studies stating STEM learning strategies improve creativity (Henriksen, 2014; Yıldırım, 2020), there are no studies stating STEM learning strategies develop imagination. Unlike the literature, this study concluded that 5E-bSTEMls increase students' imagination. Therefore, it is thought that students who can use their imagination can also improve their design skills. Moreover, they might choose engineering as a future career (Worker, & Mahacek, 2013).

STEM education advocates that student will learn meaningfully by integrating science, technology, engineering and mathematics disciplines. With this STEM education, closely linked concepts and skills are learned from two or more disciplines to build the new knowledge and skills (Vasquez, Sneider, & Comer, 2013). Therefore, in this study, the participants stated that technology, engineering, and mathematics disciplines were integrated with the concepts and skills in chemistry course, thus they generated meaningful learning in the atomic and periodic system unit.

If we consider the situation in terms of the integration of technology and science disciplines, Schaefer, Sullivan & Yowell (2003) states that the inclusion of technology-related applications in science course enriches the course content and makes it more meaningful for students. In this study, the participants stated that technological applications such as element 4D and QR code contributed to the learning of the structure of the atom and the properties of the periodic table. Thus, they accepted that the integration of technology discipline and chemistry was ensured. Similarly, there are many studies stating the integration of technology and science disciplines increases students' meaningful learning (Anjarsari, et al., 2020; Devlin, Feldhaus, & Bentrem, 2013).

In terms of engineering and science disciplines, the participants tried to design the atomic model and the periodic table. They enjoyed the designing process. The designs did not allow students to create a new model due to the content and limitations of the topic. However, it offered students the opportunity to reveal different perspectives using their imaginations, just like a scientist. For example, they tried to reveal periodic tables with different shapes and properties without making any changes regarding the elements and their locations in periodic table. Worker & Mahacek, (2013) states that the more learners can use their imagination and creativity, the more their design skills will improve. In this study, imagination and creativity, which is a dimension of the nature of science, were used by the students throughout the intervention and thus their design skills were developed. On the other hand, Rockland et al, (2010) claims that the engineering design process enables students to develop scientific reasoning. Therefore, STEM activities must necessarily include the engineering design process to improve the scientific reasoning of students as in this study.

Participants stated that they used the methematics discipline during the conservation of mass experiment. The addition, which is one of the four arithmetical operations, was used to understand whether the mass of a substance was conserved in a closed environment. Shaughnessy, (2013) mentiones that some important things are needed for the integration of mathematics and science disciplines. Firstly, there must be problem to solve and mathematics involved in the problem. Secondly, teamwork was done to solve problem. In this study, researchers applied the Shaughnessy's (2013) suggestions to integrate mathematics with chemistry concepts. In this study, participants did not experience any difficulties due to the lack of math skills. Despite this, the fact that students have good math skills should not be forgotten in order to apply STEM education effectively.

Finally, participants stated that 5E-bSTEMls made them think like scientists. Similarly, the literature emphasizes that STEM learning strategies enable students to act like a scientist to solve real life problems (Rockland, et al., 2010). In addition, the positive expressions of the participants about the lives and work of scientists showed that their views about the nature of science has also improved. Likewise, Krell, Koska, Penning, & Krüger, (2015) found that STEM learning strategies improved participants'views on the nature of science.

Until this paragraph, the discussion on contribution has been carried out through the STEM dimension of 5E-bSTEMls. In this paragraph, this contribution will be discussed through the 5E learning cycle model. In the study, integration between STEM disciplines was completed at each step of 5E. Researchers think that this contribution has been reinforced by the integration of technology and science in the elaboration phase and the integration of engineering, mathematics and science in the evaluation phase. As mentioned above, constructivism advocates that knowledge is actively built up by the students (Von Glasersfeld, 2013). Therefore, the elaboration and evaluation are the phases in which the students actively build their knowledge at the highest level.

It was concluded that the participants had difficulties in nine different aspects during the intervention process. These difficulties show that participants were used to traditional teacher-centered teaching methods in the past. For example, EG23m had a very troubled time while taking notes during the activities, as he was used to dictating by his teachers in lessons. Therefore, student-centered teaching methods should be used and students should be active in their learning process in order to overcome these difficulties. However, in the Turkish education system, students have some disanvantages to be active in their learning process because of the widespread adoption of teacher-centered methods (Can, 2015), the examination system consisting of multiple choice questions (Can, 2015; Özkan, & Özaslan, 2018), the teacher having authoritarian structure in the classroom (Can, 2015), the lack of an instruction that allows students to use their imaginations (Can, 2015), the lack of teamwork due to the crowded classes (Yıldırım, 2020) and the scarcity of technological and design-based materials (Yilmaz, 2011). On the other hand, the lack of pedagogical content knowledge of the teacher can be shown among the reasons for students' difficulty in STEM activities (Shernoff, Sinha, Bressler, & Ginsburg, 2017). In this study, a chemistry teacher conducted the intervention and this teacher may have had difficulties in terms of pedagogical content knowledge while applying the 5E-bSTEMls.

As a result, the activities used in this study improved the meaningful learning of ninth grade students, their thoughts on the nature of science, and their scientific creativity. Therefore, this study will raise an important awareness for teachers who want to improve these three aspects of their students.

Regarding the implications, researchers determined that participants had difficulties in learning processes in 5E-bSTEMls. Therefore, student-centered teaching methods should be used and students should be active in their learning process in order to overcome these difficulties. Moreover, it was recommended that the question structures related to the current examination system should be harmonized with STEM learning strategies. Also, in order to carry out STEM learning strategies effectively, necessary materials should be provided, learning environments should be designed, teachers' pedagogical content knowledge should be developed, the number of students in the classroom should be made suitable for the implementation of STEM, students' imaginations and creativity should be used effectively, and the communication between teachers and students should be increased.

In this study, STEM learning strategies were implemented on the "Atomic and Periodic System" unit. It should be applied in other units of chemistry, as well as in units of other disciplines such as physics, biology and mathematics. In addition, in this study, the opinions of ninth grade students about the 5E-bSTEMls were examined. Opinions of different grade level students should also be investigated. Finally, STEM activities should be implemented based on a different teaching method instead of the 5E learning cycle model.

References

Acar, D., Tertemiz, N., & Taşdemir, A. (2018). The effects of STEM training on the academic achievement of 4th graders in science and mathematics and their views on stem training. *International Electronic Journal of Elementary Education*, *10*(4), 505-513.

Anjarsari, P., Prasetyo, Z. K., & Susanti, K. (2020). Developing technology and engineering literacy for Junior High School students through STEM-based science learning. In *Journal of Physics: Conference Series* (Vol. 1440, No. 1, p. 012107). IOP Publishing.

Atkin, J.M., & Karplus, R. (1962). Discovery or invention? *The Science Teacher*, 29, 45-51.

Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations & Research*, *12(5/6)*, 23-37.

Bruce-Davis, M. N., Gubbins, E. J., Gilson, C. M., Villanueva, M., Foreman, J. L., & Rubenstein, L. D. (2014). STEM high school administrators', teachers', and students' perceptions of curricular and instructional strategies and practices. *Journal of Advanced Academics, 25*, 272–306.

Bybee, R. (1997). *Achieving scientific literacy*: *From purposes to practices.* Portsmouth, NH: Heinemann Publications.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30-35.

Bybee, R. W., & Fuchs, B. (2006). Preparing the 21st century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching*, *2*(3), 349-352. doi:10.1002/tea.20147.

Bybee, R. W., & Landes, N. M. (1990). Science for life & living: An elementary school science program from biological sciences curriculum study. *The American Biology Teacher, 52*(2), 92-98.

Can, E. (2015). Qualitative obstacles in Turkish education system and suggestions. *Online Submission*, *20*, 289-296.

Clark, A. C., & Ernst, J. V. (2006). A model for the integration of science, technology, engineering, and mathematics. *The Technology Teacher, 66*(4), 24–26.

Cokelez, A. (2012). Junior high school students' ideas about the shape and size of the atom. *Research in Science Education*, *42*(4), 673-686.

Creswell, J.W. (2007). *Qualitative inquiry and research design. Choosing among five approaches.* (Second edition). California: Sage Publications

Creswell, J. W. (2009). *Research design, qualitative, quantitative, and mixed methods approaches* (Third Edition). California: Sage Publications.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into practice*, *39*(3), 124-130.

Dass, P. (2015). Teaching STEM effectively with the learning cycle approach. *K-12 STEM Education*, *1*(1), 5-12.

DeChambeau, A. L., & Ramlo, S. E. (2017). STEM high school teachers' views of implementing PBL: An investigation using anecdote circles. *Interdisciplinary Journal of Problem-Based Learning*, *11*(1), 7. https://doi.org/10.7771/1541-5015.1566.

DeJarnette, N. K. (2012). America's children: Providing early exposure to STEM (Science, Technology, Engineering, and Math) initiatives. *Education*, *133*(1), 77-84.

Devlin, T. J., Feldhaus, C. R., & Bentrem, K. M. (2013). The evolving classroom: A study of traditional and technology-based instruction in a STEM classroom. *Journal of Technology Education*, *25*(1), 34-54.

Drake, S. M., & Burns, R. C. (2004). *Meeting standards through integrated curriculum*. ASCD.

Dugger, W. E. (2010). Evolution of STEM in the United States (Paper) Presented at the 6th *Biennial International Conference on Technology Education Research* on Dec 8-11, 2010 in Australia.

EL-Deghaidy, H., Mansour, N., Alzaghibi, M., & Alhammad, K. (2017). Context of STEM integration in schools: Views from in-service science teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(6), 2459-2484.

English, L. D (2016). STEM education K-12: Perspectives on integration. *English International Journal of STEM* Education 3 (3). DOI 10.1186/s40594-016-0036-1

Felix, A., & Harris, J. (2010). Aproject-based, STEM-integrated alternative energy team challenge for teachers. *The Technology Teacher, 69*(5), 29–34.

Henriksen, D. (2014). Full STEAM ahead: Creativity in excellent STEM teaching practices. *The STEAM journal*, *1*(2), 15. DOI: 10.5642/steam.20140102.15

Kolb, D. A. (1984). *Experiential learning: experiencies as the source of learning and development.* Englewood Cliffs, N.J.:Prentice-Hall.

Kolb, A. Y., & Kolb, D. A. (2009). Experiential learning theory: A dynamic, holistic approach to management learning, education and development. *The SAGE handbook of management learning, education and development*, *42*, 68.

Krell, M., Koska, J., Penning, F., & Krüger, D. (2015). Fostering pre-service teachers' views about nature of science: Evaluation of a new STEM curriculum. *Research in Science & Technological Education*, *33*(3), 344-365.

Lamb, R., Akmal, T., & Petrie, K. (2015). Development of a cognition-priming model describing learning in a STEM classroom. *Journal of Research in Science Teaching*, *52*(3), 410-437.

Lestari, T. P., Sarwi, S., & Sumarti, S. S. (2018). STEM-based Project Based Learning model to increase science process and creative thinking skills of 5th grade. *Journal of Primary Education*, *7*(1), 18-24.

Lederman, N. G., & Niess, M. L. (1997). Integrated, interdisciplinary, or thematic instruction? Is this a question or is it questionable semantics? *School Science and Mathematics*, *97*(2), 57-58.

Liu, T. C., Peng, H., Wu, W. H., & Lin, M. S. (2009). The effects of mobile natural-science learning based on the 5E learning cycle: A case study. *Journal of Educational Technology & Society*, *12*(4), 344-358.

Lottero-Perdue, P. S., Lovelidge, S., & Bowling, E. (2010). Engineering for all. *Science and Children*, *47*(7), 24-27.

Merriam, S. B. (2013) *Qualitative research: A guide to design and implementation*. John Wiley & Sons Inc., New York.

Merrill, C., & Daugherty, J. (2010). STEM education and leadership: A mathematics and science partnership approach. *Journal of Technology Education*, *21*(2), 21-34.

Meyrick, K. M. (2011). How STEM education improves student learning. *Meridian*, *14*(1), 1-5.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In *Engineering in pre-college settings: Synthesizing research, policy, and practices*. Purdue University Press.

Morrison, J.,& Raymond-Bartlett,V. (2009). STEM as curriculum. *Education Week,23(March 4)*, 28–31.

Murphy, T. P., & Mancini -Samuelson, G. J. (2012). Graduating STEM competent and confident teachers: The creation of a STEM certificate for elementary education majors. *Journal of College Science Teaching*, *42*(2), 18-23.

National Research Council [NRC]. (2012). *A Framework for k-12 science education: practices, crosscutting concepts, and core ideas.* Washington DC: The National Academic Press.

Naylor, S., & Keogh, B. (1999). Constructivism in classroom: Theory into practice. *Journal of Science Teacher Education*, *10*(2), 93-106.

Niaz, M., & Luiggi, M. (2014). Facilitating conceptual change in students' understanding of the periodic table. In *Facilitating Conceptual Change in Students' Understanding of the Periodic Table* (pp. 1-49). Springer, Heidelberg.

Nuangchalerm, P. (2018). Investigating views of STEM primary teachers on STEM education. *Bulgarian Journal of Science Education*, *27*(2), 208-215.

Osborne, J. F. (1996). Beyond constructivism. *Science Education*, *80*(1), 53-82.

Özkan, Y. Ö., & Özaslan, N. (2018). Student achievement in Turkey, according to question yypes used in PISA 2003-2012 mathematic literacy tests. *International Journal of Evaluation and Research in Education*, *7*(1), 57-64.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oakes, CA: Sage.

Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the "E" in K-12 STEM Education. *Journal of Technology Studies*, *36*(1), 53-64.

Russell, S., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*(5824), 548-549. doi:10.1126/science.1140384

Sagala, R., Umam, R., Thahir, A., Saregar, A., & Wardani, I. (2019). The effectiveness of STEM-based on gender differences: The impact of physics concept understanding. *European Journal of Educational Research*, *8*(3), 753-761.

Schaefer, M. R., Sullivan, J. F., & Yowell, J. L. (2003). Standard-based engineering curricula as a vehicle for K–12 science and math integration. *Frontiers in Education*, *2*, 1–5.

Shaughnessy, J. M. (2013). Mathematics in a STEM context. *Mathematics Teaching in the Middle school*, *18*(6), 324-324.

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education*, *4*(1), 13. DOI 10.1186/s40594-017-0068-1.

Sulistiyowati, S., Abdurrahman, A., & Jalmo, T. (2018). The effect of STEM-based worksheet on students' science literacy. *Tadris: Jurnal Keguruan dan Ilmu Tarbiyah*, *3*(1), 89-96.

Tseng, K. H., Chang, C. C., Lou, S. J., & Chen, W. P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*(1), 87-102.

Van Manen, M. (2007). Phenomenology of practice. *Phenomenology & Practice*, *1*(1), 11-30.

Vasquez, J., Sneider, C., & Comer, M. (2013). *STEM lesson essentials, grades 3–8: integrating science, technology, engineering, and mathematics.* Portsmouth, NH: Heinemann.

Von Glasersfeld, E. (2013). *Radical constructivism* (Vol. 6). Routledge.

Walton, J. (2014). Teachers as expert learners and fellow travelers: A review of professional development practices for problem-based learning. *Issues in Teacher Education, 22,* 67–92

Wang, C. Y., & Barrow, L. H. (2013). Exploring conceptual frameworks of models of atomic structures and periodic variations, chemical bonding, and molecular shape and polarity: a comparison of undergraduate general chemistry students with high and low levels of content knowledge. *Chemistry Education Research and Practice*, *14*(1), 130-146.

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 1-13.

Wisudawati, A. W. (2018). Science technology engineering and mathematics (STEM) education approach against a microscopic representation skill in atom and molecule concept. *International Journal of Chemistry Education Research*, *2*(1), 1-5.

Worker, S. & Mahacek, R. (2013). 4-H out-of- school STEM education. C*hildren's Technology and Engineering*, *18*, 16-20.

Yıldırım, B. (2020). Preschool STEM activities: Preschool teachers' preparation and views. *Early Childhood Education Journal*, 1-14.

Yilmaz, N. P. (2011). Evaluation of the technology integration process in the Turkish education system. *Contemporary Educational Technology*, *2*(1), 37-54.

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Compliance with Ethical Standards

All procedures performed in studies involving human participants comply with ethical standards.

Declaration of interest

As authors of the research, we declare that there is no conflict of interest for this research.

Informed Consent

Informed consent was obtained from the parents of all individual participants included in the study.