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SCIENCE TEACHING LABORATORY APPLICATIONS: COMMON KNOWLEDGE CONSTRUCTION, LEARNING CYCLE MODELS AND STEM APPROACH

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Abstract
To achieve the purpose of inquiry learning approaches and models, it is necessary to identify the difficulties encountered because the science teacher candidates have key prescriptions. Therefore, the aim is to reflect fruitful and high level critical views at the end of the process providing them different learning difficulties using different learning models and approaches at every stages. For this purpose, qualitative research method was used in the study conducted with 40 candidates selected from easily accessible case sample among the third-grade students attending the undergraduate program of science teacher education. Open-ended form was prepared as a data collection tool and the data were generated using content analysis. Finally, the answers given by the teacher candidates are thematized as advantages, disadvantages, cognitive domain, skills, affective domain, SETSE dimension, TQF. The codes generated under the themes vary according to the applied model and approach. The nature of science, team work, and discussion culture code were most evident in CMCK. While the STS code was on the forefront in 5E model, the engineering and design skills code was found to be at a high level in STEM implementation.

Keywords: Inquiry-based approach, 5E, CMCK, STEM, science teaching.

INTRODUCTION

Traditional teaching methods with long-lasting application possibilities are changing today by leaving its place to the contemporary learning concept and keeping the individual in the foreground. In this context, the aim of science teaching is to provide learners with opportunity to develop their mental representations of the natural world with the help of more reliable and useful structuring process (Loxley, Dawes, Nicholls & Dore, 2016). Ausubel's theory of meaningful learning sees this process as valuable, but its main emphasis is on preliminary knowledge and current knowledge (Özmen, 2014). When the literature is examined (Ausubel, 1968; Novak, 2002; Kara & Özgün-Koca, 2004) meaningful learning means a type of learning that is not mechanical (conditional), that is not based on memorization, and does not involve a single point of view and the acceptance of the knowledge of a particular authority. Meaningful learning can be described as a learning activity based on learning and individuality, product of high level thinking skills (transfer, problem solving, interpreting, critical thinking, etc.), result of research and examination of the individual, interactive, shaping with original thinking, learning by doing and living (Uçar & Yesilyaprak, 2006). Therefore, meaningful learning, which is one of the most basic features of learning, can be realized with the most effective constructivist approach in today's teaching concept (Gijbels & Loyens, 2009; Rikers, Van Gog & Paas, 2008). Constructivism, which enables the individual to inquire into the newly encountered and existing knowledge in the learning process and to make meaningful learning by associating information on this subject, has an important influence on modern science teaching (Matthews, 2002). It is an inquiry-based learning approach in an important approach that fosters active participation of learners in the learning environment in the learning environment and is consistent with the basic principles of constructivist learning approaches (Budak-Bayır, 2008). Even inquiry-based learning represents a constructivist approach (Zion, Michalsky & Mevarech, 2005).

National education standards encourage learners to participate in the learning process by conducting group activities and practical activities (Hayden et al., 2004). Students are encouraged to participate in and adapt the existing knowledge of the students (Hess & Trexler 2005), to support the results with evidence and observations, and to share ideas and discussions with students' peers (Wolf & Fraser, 2008). In this process, the teacher acts as a guide that allows students to think through asking different questions (Windschitl, 2002). These practices are known collectively as inquiry-based teaching and learning (Wolf & Fraser, 2008).

In science, inquiry involves exploring natural phenomena using processes, experiments, and high-level thinking (Lee et al, 2004). Inquiry-based learning is a student-centered approach that is often used in science education (Savery, 2006). In inquiry-based learning, students are confronted with an open-ended question or surprising situation that allows for various answers or solutions. Students can ask questions about the problem and formulate their own hypotheses (Loyens, Kirschner & Paas, 2011). In the interrogation process, the teacher assigns tasks, supports or facilitates the process, but students follow their own inquiries, use existing knowledge, and determine the resulting learning needs. They seek evidence to support their ideas and undertake the responsibility of analyzing and presenting it as part of a group or as an individual supported by others (Kahn & O'Rourke, 2005). When the literature is examined, there are studies about the increase of motivation and inquiry ability and the development of scientific process skills in students with inquiry-based teaching (Colley, 2006; Davies, Collier & Howe, 2012; Ketpichainarong, Panijpan & Ruenwongsa, 2010).

Inquiry-Based Learning Approach and Models

Inquiry Based Learning is used as a broad umbrella term to describe learning models and methods guided by a research process (Kahn & O'Rourke, 2005). The first learning model and approach used in the study is the 5E learning model, a research-inquiry model based on the Science Curriculum Improvement Study (Harurluoğlu & Kaya, 2011). This learning model is used in science education researches for daily cognitive process skills, attitudes, achievements and motivations in students. The 5E-learning model consists of five steps (Bybee & Landes, 1988; Eisenkraft, 2003). These steps; enter, explore, explain, elaborate and evaluation. The second one is a Common Knowledge Construction Model (Demircioğlu & Vural, 2016), which is accepted as a model considering the deficiencies in the previous constructivist and questioning learning environments, attitudes towards nature of science, conceptual change in the phenomenon frame and development. CKCM consists of four phases (Ebenezer, et al., 2010). These steps; exploring and categorizing, constructing and negotiating, extending and translating, reflecting and assessing. The third one is the, blend of scientific research and inquiry (Wendell, et al., 2010) called STEM education approach. This approach was placed in the science program in 2017 in Turkey due to the lack of application of the skills and experienced disruptions throughout the teaching process (Çepni & Ormancı, 2017). The application of this approach in questioning learning environments can be achieved through the enrichment of learning ring models, REACT, probing and project-based learning. In this study, problem-based learning (PBL), which shares the same philosophical trends (Price, 2001) and educational intentions as the inquiry-based learning for the STEM approach was used.PBL is basically composed of four basic stages: analysis of the problem, students' orientation about their own learning, brain storming and solution testing (Massa, 2008). PBL represents an important development in the practice of education that continues to influence both lectures and disciplines around the world (Schmidt, van der Molen, te Winkel, & Wijnen, 2009).

Inquiry Based Science Teaching Laboratory Applications

Inquiry can be planned with primary data collection processes such as research activities, laboratory experiments, trips and observations, while secondary data provided through printed and digital resources can be developed (Köseoğlu & Tümay, 2015). In this process, science laboratories are a unique resource that enhances the knowledge of important tools and skills that enable students to gain interest, scientific concepts and processes and develop new understanding (Lunetta, Hofstein & Clough, 2007). The behaviors and attitudes of the learners observed in a questioning laboratory environment within a changing learning context can vary astonishingly. This is because there are a number of struggling students who are trying to solve the problems they are trying to solve during a research they have designed, rather than students who follow the instructions defined during the lab (Lord & Orkwiszewski, 2006). Similarly, according to Johnstone and Wham (1982), inquiry-oriented laboratory surveys were conducted from students; (eg: the use of a microscope) and intellectual inquiry skills (eg: formulating hypotheses) at the same time.

There are many variables that need to be considered in laboratory activities and these variables have been seen to have an important place in teaching programs related to science classes since the beginning of the 19th century. These include (1) learning objectives, (2) the quality of the instructions (printed and / or electronic and / or oral) provided by the teacher and the laboratory guide, (3) available materials and equipment for use in laboratory research, (4) the nature of the activities during the laboratory work and student-student and teacher-student interactions (5) students and teachers' perceptions about how students' performances will be assessed, (6) laboratory reports of students, (7) preparations, attitudes, knowledge and attitudes of teachers (Lunetta, Hofstein & Clough, 2007).

As seen, the responsibilities that the student or the level of guidance provided by the teacher vary the learning gains of the learners and the classification of experiment types. Hegarty-Hazel (1986) points to four different experimental activities by adding the degree of openness to the interrogator to classify laboratory activities (Table 1). If the science curriculum (MEB, 2013) is compared with the classification set out by Hegarty-Hazel (1986), the researcher inquiry approach for elementary schools can be matched in the first level. For junior high school students, the guided researcher-questioner approach in grades 5 and 6 and the open-ended researcher questioner approach for grades 7 and 8 can be associated with 2b level.

Table 1: Classification of experiment types according to contents of laboratory activities

Level	Problem	Experiment Tools	Operation Sequence	Results	Common Name
0	Given	Given	Given	Given	Verification
1	Given	Given	Given	Open	Guided Inquiry
2a	Given	Given	Open	Open	Open Ended- Guided Inquiry
2b	Given	Open	Open	Open	Open Ended - Guided Inquiry
3	Open	Open	Open	Open	Open Ended Inquiry

According to Table 1, it is possible to engage students with inquiry laboratory studies and to provide opportunities for activities ranging from highly structured laboratory experiences to open-ended surveys that students search for a question in which they can express themselves. The nature of the teacher's learning approaches and models and the guidance provided by the students in the teaching activities are very important for real learning. In this case, the selection of the relevant experimental activities in science teaching, the achievements provided by the learners, and the selection of the instructional models and methods gain importance. As a matter of fact, according to Lawson (1988), it is known that learning environments based on the constructivist approach that uses the same philosophy as interrogation, are based on collaborative learning, probabilistic learning, and approaches such as learning ring, which is widely used in science teaching.

There are a lot of laboratory studies in science teaching in which the subject is related to the permanence of learning, science literacy, academic achievement and thinking skills. Especially, 5E learning model in the laboratory environment based on the inquiry approach (Bozdoğan & Altunçekiç, 2007; Gençer & Karamustafaoğlu, 2014; Hanuscin & Lee, 2008; Kanlı & Yağbasan, 2008; Özbek, Çelik, Ulukök & Sarı, 2012; Tural, Akdeniz & Alev, 2010; Wilder & Shuttleworth, 2005; Yalçın & Bayrakçeken, 2010), problem-based within the open-ended researcher inquiry approach (Akpınar & Yıldız, 2006; Aydoğdu & Ergin, 2010; Chin & Chia, 2006; Çelik, Katrancı & Çakır, 2017; Kocakülah & Savaş, 2013; Temel & Morgil, 2007; Yaman & Yalçın, 2005), project-based learning methods (Juhl, Yearsley & Silva, 1997; Korkmaz & Kaptan, 2002; Morgil, Seyhan & Seçken, 2009; Sezgin, Çalışkan, Çallıca & Erol, 2001; Özer & Özkan, 2011) and CKCM construct on deficiencies in existing models (Bakırcı, Çepni & Yıldız, 2015; Demircioğlu & Vural 2016) and STEM approach (Bozkurt-Altan, Yamak & Buluş-Kırıkkaya, 2016; Cotabish, Dailey, Robinson & Hughes, 2013; Gökbayrak & Karışan, 2017; Yıldırım & Altun, 2015) have frequently been examined recently.

The relevance of current science programs and science teacher candidates training depend on teacher candidates' thoughts on questioning. Teacher candidates' attitudes and beliefs affect the methods and techniques they use in their classroom when they become teachers. In this respect, 5E, CKCM, PBL and STEM approaches are frequently used in science applications and ideally suited to collaborative student team work (Kahn & O'Rourke, 2005), although there are many studies, as mentioned earlier, which reveal the opinions of candidates about inquiry learning approaches and models that provide candidate teachers to put their opinions forward.

In this respect, it is necessary to identify the difficulties encountered because teacher candidates have a key prescription to reach the aim of inquiry learning approaches and models. It is thought that the data obtained from this research will help the teacher candidates to overcome the shortcomings in this area. The data obtained from these reasons are thought to be meaningful and valuable for the literature. Considering that the inquiry learning approach is different from the more traditional approaches, the challenges of inquiry-based learning can be a crucial factor for success (Kahn & O'Rourke, 2005). The first purpose of the research is to determine the different learning difficulties of science teacher candidates by using different inquiry learning models and approaches at each stage of the inquiry process, and to put forward efficient and high-level critical views that they will reflect at the end of this process. The second aim of the research is to inform candidate teachers about inquiry learning models and approaches that they can use in their classrooms when they become teachers.

Within the framework of these objectives; The following questions have been searched for laboratory applications.
1- What are the critical views of science teacher candidates towards the model of learning circle 5E?
2. What are the critical views of science teacher candidates towards CKCM?
3- What are the critical views of prospective science teachers towards the STEM approach?

METHODOLOGY

Qualitative research method was used in the research. Because qualitative research focuses on the text and imaginary data and makes it possible to assess a situation, a case, a subject, and an event in detail through original analyzes (Creswell, 2013). The opinions of the teacher candidates were provided by content analysis through written texts in the study. In content analysis, the data may be in verbal, written or electronic form, as well as in written media such as open-ended questionnaires, interviews, focus groups, observations or articles, books and guides (Kondracki, Wellman & Amundson, 2002).

Participants
Participants of this study consisted of third-year students studying in the undergraduate program of the science teacher of a state university in the 2016-2017 academic year, and participants were selected using the easily accessible sampling. The easily accessible sampling method gives speed and practicality to the researcher. Because, in this method, the researcher chooses a situation that is close and easy to access, so that it can provide a more practical and easy perception of study, data and analysis on a familiar sample (Yıldırım & Şimşek, 2011). In this study, since the application of learning models and approaches in the laboratory environment have analyzed the projective reflections, the use of the easily accessible case sample was preferred. The study group was limited to 40 teacher candidates who participated in science teaching laboratory practices-I, II courses and volunteered to work.

Application Process
In the study, firstly the learning ring model 5E, then CKCM, and finally the STEM approach in which PBL is used as a method have been introduced and implemented. In choosing this approach and models, researchers are based on changing curricula. First, the 5E model was chosen among the learning ring models by considering the 2005 science and technology course curriculum. Secondly, the STEM approach, which takes the CKCM and finally the science and engineering skills integrated into daily life, has been chosen in consideration of the researcher-questioning approach and the nature of science in the direction of the 2013 science curriculum.

At the same time, the planning of the process was also supported by the literature review. In the first phase; the candidate teachers face with some problems such as insufficiency of the training program, the problem in time management, the need for preliminary preparation, the complexity of the model and the long process steps (Özbek et al., 2012), in the second application, the length of the first phase, the lack of explanation step, difficulty in finding socio-scientific issue, lack of knowledge of the nature of science (Bakırcı, Çepni & Ayvacı, 2015), in the last application, inexperience of the teacher candidates about the time management and method, and efforts (Tatar, Oktay & Tüysüz, 2009; Eroğlu & Bektaş, 2016) . During the 6 weeks application period, these problems were solved.

For the first two models, teacher candidates were asked to perform and report experiments on the worksheets in a laboratory environment. In the third application, teacher candidates were asked to provide scenarios in accordance with the curriculum developed by the researchers and to continue and report the probing solutions with the STEM approach. The weekly schedule for all three applications is given in the Table 2 below.

Table 2: Inquiry-based science teaching laboratory applications activity plan

Teaching Model used in the laboratory	**Time schedule**	**Weeks and experiment titles**
5E Model	10 October- 18 November 2016	**Week 1:** Explaining the Historical Development of the Model, Explaining the Steps, Lastly, Presenting and Discussing a Sample Material Suitable for the Model to the Students
		Week 2: Balance and Gravity, Which Fluid Fly Away?
		Week 3: Diver in the Bottle, Gain on Rolls
		Week 4: Observation of Physical and Chemical Changes in the Material, Separation Using the Boiling Point Difference
		Week 5: Determination of Basic Organic Food Nutrients, Investigation of Diffusion Occurrence from Membrane
		Week 6: Investigation of Enzyme Effect Mechanism, Separation of Water Elements by the Effect of Electric Current

Common Knowledge Construction Model	13 February- 24 March 2017	**Week 1:** Explaining the Historical Development of the Model, Explaining the Steps, Lastly, Presenting and Discussing a Sample Material Suitable for the Model to the Students
		Week 2: Electrical Loads, Electrification, Conductivity and Insulation, Serial and Parallel Connection of Bulbs and Batteries
		Week 3: Examination of Acids, Bases and Salts
		Week 4: Investigation of Herbal Tissues, Respiration in Plants, Chloroplast and Leaf Structure in Plants
		Week 5: Sound, Is Sound Propagated in Space? Sound Propagation in different Environment, Resonance, Sound Intensity and Frequency
		Week 6: The Production of Electric Current and Ohm's Law
STEM Training Approach Supported by PBL	10 April- 18 May 2017	**Week 1:** Explaining the Historical Development of the Approach, Explaining the Steps, Lastly, Presenting and Discussing a Sample Material Suitable for the Model to the Students
		Week 2: Heat Sensitive Fan Making
		Week 3: Brightness Adjustable Lamp Design According to Usage Environment
		Week 4: Alternative a Fuel Indicator Design
		Week 5: A Free Battery Design
		Week 6: Development of an Alternative Density Measurement Method

Data Collection and Analysis

The literature on the study topic was searched and an open-ended question form consisting of 3 questions was prepared by the researchers. The purpose of the open-ended questionnaire was to collect qualitative data on teachers' responses in written form (Creswell, 2005). The prepared open-ended questionnaire was evaluated by the field experts and the necessary arrangements were made and the final form of the open-ended questionnaire was given. The data obtained from the open-ended questionnaire were analyzed by content analyzing. Content analysis consists of identifying the research questions in which answers should be found, selecting the sample to be analyzed, defining the categories to be applied, determining the coding process and coding training, applying the coding process, determining the credibility and analyzing the results of the coding process (Kaid, 1989). In this study, it is aimed to gather the similar data in the frame of specific concepts and themes and to organize them in a way that readers can understand according to the opinions of teacher candidates reflected through content analysis and new learning approaches and applications of the models (Yıldırım & Şimşek, 2011). The researchers who created the codes and the themes at the time of this process considered the contents of the relevant models / approaches. At the same time, the vision of science, technology, and science curricula of 2005, 2013 and 2017-2018 were also taken together. In this context, cognitive domain, skills, affective domain, Science-Engineering-Technology-Society-Environment (SETSE) dimensions were established. In addition to these dimensions, the advantages and disadvantages of the model/approaches are also added to the views reflected. The code is the result of parsing the data.

To increase the quality of scientific data emerging in the direction of these codes and themes, solutions for validity and reliability should be provided before data analysis. In this context, a two-step process has been followed for validity. In the first step, researchers have developed a coding scheme that specifies variables, definitions, values, and rules for recognizing these variables in coded content. In the second step, the researchers have compared the coding decisions according to the literature in terms of discipline and subject-centered. Most content analysis can adequately capture an expert standard and objective coding to ensure the validity of the data (Potter & Levine-Donnerstein, 2009). Reliability of measuring instrument; were tested with the percentage of agreement between the two investigators (Şencan, 2005). As the reflection of models and approaches on science teaching was analyzed through the opinions of teacher candidates, the opinions of teacher candidates were evaluated separately by the two field education specialist researchers. Then, the matching ratios were calculated. In the content analysis of data collected in the research, Miles and Huberman (1994) proposed coding reliability calculation; Reliability = Agreement / (Agreement + Disagreement) reliability formula is used. As a result of the calculation, the reliability of the coding was calculated as 87.5% and considered reliable. It is accepted that the analysis of the research is reliable more than %70 (Miles & Huberman, 1994).

RESEARCH FINDINGS

Findings that include the views of 5E, CKCM and STEM model/approaches of teacher candidates applied in science teaching laboratory applications I-II course are classified in Table 3. Therefore, the critical views of the teacher candidates responding to all sub-problems of the research through this table are reflected.

Table 3: Participatory views on model/approaches based on themes

Themes	**Codes**	**Participatory views for model/approaches (*%, f*)**					
		5E		**CKCM**		**STEM**	
		f	***%***	***f***	***%***	***f***	***%***
Advantages	Provide discussion environment (critical thinking)	8	20	28	70	25	63
	Readiness is more interrogated	3	7,5	18	45	13	33
	Problem solving skills	2	5	5	13	22	55
	Creativity	3	7,5	8	20	24	60
Disadvantages	Less experimental activities are given	3	7,5	12	30	0	0
	Does not adequately support life skills	7	18	0	0	0	0
	Activities take a long time	12	30	24	60	18	45
	No effective communication	8	20	7	18	8	20
	Inadequacy of teacher as guide	9	23	8	20	4	10
	Lack of material	12	30	14	35	26	65
	Classroom management problem	9	23	13	33	22	55
	Lack of Content knowledge	8	20	12	30	24	60
Cognitive Domain	Provides permanent learning	22	55	26	65	18	45
	Provides conceptual change	21	53	26	65	19	48
	Provides learning by doing-living	28	70	26	65	32	80
	Student-centered	24	60	27	68	30	75
	Associated with daily life	25	63	28	70	26	65
	Phenomenographic	0	0	2	5	0	0
Skills	Scientific process skills (basic skills)	28	70	18	45	16	40

	Scientific process skills (experimental skills)	28	70	24	60	35	88
	Life skills	8	20	17	43	34	85
	Engineering and design skills	0	0	0	0	35	88
Affective Domain	Attitude	9	23	16	40	15	38
	Self-efficacy	13	33	16	40	27	68
	Motivation	8	20	15	38	18	45
	self-reliance	11	28	7	18	18	45
	Courage	10	25	16	40	25	63
	Responsibility	14	35	18	45	28	70
SETSE Dimensions	Socio-scientific issues are also included	5	13	21	53	12	30
	It gives understanding of the nature of science	9	23	24	60	18	45
	There is an emphasis on science and technology	14	35	18	45	32	80
	Integrates science, engineering and technology	0	0	6	15	36	90
	It provides the connection of science and technology to society	4	10	16	40	26	65
	Sustainable development brings awareness	0	0	8	20	16	40
	Develop science and career consciousness	3	7,5	5	13	34	85

When Table 3 examined, considering the percentages and frequencies, it can be said that teacher candidates gain sufficient awareness about the level of application of 5E, CKCM and STEM models / approaches. For example, the 5E teaching model is emphasized more (70%) in the scientific process skill codes. The codes in the cognitive domain are more important than the others. In the case of life skills (20%) and SETSE sub-codes (mean: 12.6%), the emphasis on the 5E teaching model seems to be insufficient. Therefore, the determinants of the 5E teaching model are emphasized by teacher candidates. Some example statements are given below.

TC24: Creativity in the 5E model is virtually absent. We make a solution, but there is no decision-making ability.
TC18: Communication problems among students in group work may occur.
TC7: 5E model is the forefront of concept teaching as it is aimed to learn and comprehend information directly. Therefore, teacher knowledge is important.

When the frequencies and percentage distributions of CKCM codes examined, it was found that critical thinking-based culture (70%), readiness (45%), higher level representation, life skills (43%), science nature (53%) and science and technology (45%) codes are higher than others. It proves that teacher candidates are qualified within CKCM.

TC15: The disadvantage of the CKCM is that it does not have an explanation step. Students will increase their self-confidence because they will express their knowledge freely in this model, but they will not be able to verify their information because it does not have an explanation step.
TC33: Time is not enough in this model due to the fact that the subject and achievement are excessive. In addition, there is a waste of time since it has lots of activities.

It is also seen that the first two activities were compared by teacher candidates. This can be seen in Table 3 that the problem of classroom management for 5E and CKCM will increase and take more time to defeat CKCM. Thus, the participant's views in this regard are as follows: TC21: "*CKCM is more difficult than 5E model*" and TC9: "*5E learning model is like STEM and CKCM preparation stage*".

The PBL activities in the direction of the STEM approach, included in the last stage of the working period, provided sufficient awareness of the prospective teachers. Because the subcategories of the theme are compatible with the elements of the STEM approach's contribution to science teaching. For example; Discussion (63%), problem solving skills (55%), creativity (60%), conceptual change (45), science process skills (88%), life skills (85%), engineering and design skills (88%) and the codes in the content of the SETSE theme (mean: 62.14%) were adequately emphasized by teacher candidates. On the other side, there are also negative opinions of teacher candidates for STEM applications. This is mostly originated from the content knowledge, teacher competences and conceptual change elements. For example, one of the teacher candidate's view of the STEM approach is that, TC3: "*I think that STEM practice may have a negative trend in concept teaching if it is not applied properly*". In a similar case, TC17:"*In STEM, product creation is more prominent, learning dimension is less important.*"andTC11:"*I think there may be a negative trend in concept teaching if STEM practice is not applied properly.*" similar emphasis was made on the perspective. In terms of content knowledge and classroom management, TC36: "*STEM actually makes us think like an engineer, but we are not used to doing it, so we have difficulty in adaptation*", TC15: "*When there are not enough materials, more active students lose their interest and others stay silent at the back.*" These are some evaluations made by the teachers.

DISCUSSION AND RESULTS

1. Teacher candidates have awareness of the basic concepts of model/approaches. It is seen in the percentage distribution in Table 3 that teacher candidates can extract the basic elements of all three activities. Therefore, it can be said that there is awareness about approaches and models. An important reason for the improved awareness of approaches and models can be considered as planning in a sequential process. This situation seems to add value to the model from a critical point of view.
2. Limitations of models and approaches, especially CMCK, take a long time to work. Özbek, Çelik, Ulukök and Sarı (2012) compared the 5E and 7E learning models over science literacy. The repeated activities took the longest time in the classroom and it was the negative side of the model. When the literature is examined in a similar way, the science teachers have limited time for the model to take, the first stage of CMCK, Discovering and Classifying, for a long time (Bakırcı, Çepni & Ayvacı, 2015). Thus, the criticism of the CMCK model is seen more frequently than other activities in Table 3 may be related to the first step of the model.
3. Possible classroom management problems are anticipated for activities that can be implemented in both constructivist and inquiry-based approaches. Classroom management is also an important responsibility for teachers in the learning process. If classroom management does not address possible undesired behaviors, good teaching does not occur. If the students are irregular and disrespectful and the rules and instructions cannot guide them to perform good behaviors, chaos in the classroom is inevitable. As a product of the same educational philosophy, both constructivist approach and inquiry-based approach require a successful teacher to choose the effective teaching strategy, to facilitate learning and to use classroom management techniques effectively (Marzano, Marzano & Pickering, 2008).
4. While CMCK thinking skills are supported, the most emphasis is on STEM. The CMCK is often needed for creativity, imagination, and critical thinking in the process of seeking and linking to learning, active debate and socio-scientific issues in the discovery-negotiation and expansion-transfer stages (Çepni, Özmen & Bakırcı, 2012). However, among the activities in life skills in which entrepreneurship skills are included as one of the dominant factors, the most emphasis is on STEM approach.

5. As an alternative to experimental activities for structuring the concepts under C, discussion and negotiation within the group can be proposed. Participants criticize this situation in the laboratory environment despite active learning activities. This can be explained by the importance and attitude of the students to the experiment. Students will be directed to make efforts to make the experiment meaningful and to investigate the situation if they cannot explain it with their prior knowledge. In this case, it encourages them to obtain data through experimentation and observation with an investigator-questioning approach (Köseoğlu & Tümay, 2015). Therefore, the students who start with the 5E model for this study process and who are in great agreement with the inquiry learning culture might criticize the effectiveness of the active learners who do not participate in the experiment.
6. Effective domain learning products are more influential on models/approaches than the other learning products. The fact that the activities are held at a certain time is not introduced at the previous level of education and that the student does not take responsibility enough can be cited as the cause of this result. Because Gibson and Chase (2002) stated that inquiry-based science teaching is more interesting and motivate the students, rather than by oral presentations, taking notes, or enjoying demonstration experiments in the laboratory. The fact that the products of effective learning remain below the expectation can be explained by the fact that the above situation is incomplete or inadequate in the learning environment. Gibson and Chase (2002) in their studies pointed out that lessons in the learning environments based on the inquiry approach for the higher education level are not at sufficient level, and effective learning products such as attitude and motivation for the lower levels are under the expectation.
7. Collaborative group work has an effective communication problem. The solution can be related to the culture of discussion. The lack of learning discipline or culture of discussion within the group negatively affects the expectation of peer education. Speaking is very important in group work for exploration. Discussions within a group can only be provided by a specifically designed or improved classroom management culture (Loxley, Dawes, Nicholls & Dore, 2016). Köseoğlu and Tümay (2015) view learning as learning and cultural contexts as an internalization of cultural means and independent use over time, and social interactions are the key points. For a supportive social interaction, teachers and students in a learning environment should share their thoughts with a constructive and critical approach, be reasonably supported, or engage in an interrogation and collaborative effort. The problem may be that the students have earned their critical thinking skills and reflective inquiry skills earlier to increase their productivity in dialogue within the group work in the process of constructing knowledge through doing-living.
8. 5E and CMCK have more emphasis on teacher guidance. Possible professional deficiency of the teacher will affect the efficiency. In a student-centered learning environment, the teacher is a facilitating guide. For the process of structuring knowledge, the teacher is like a learning and teaching engineer in a sense. However, to be able to do these things, he/she should be able to master the basic concepts of discipline which he teaches compared to the traditional teacher understanding (Köseoğlu & Tümay, 2015). In this context, teacher candidates pointed out that the adequacy of teachers in the direction of anticipation is also important by matching the activities in the implementation process with the last three curricula respectively.
9. The STEM approach emphasizes the lack of material in freeing the student in selecting materials. Similarly, in the study conducted by Yıldırım and Türk (2018), it was concluded that STEM applications should have sufficient materials for practice in class but there may be practical problems due to lack of materials or the lack of ability to use existing materials for different purposes.
10. It was seen that the students who participated in the laboratory study emphasized that the lack of content knowledge could significantly affect the learning process in these three active teaching models/approaches. Indeed, both the constructivist and the inquiry approach are also present in the literature review, where lack of content knowledge in the reach of anticipated fertility has shown significant resistance (Demirbaş & Pektaş, 2015; Yıldırım & Türk, 2018).
11. Turkey Qualifications Framework (TQF) 's competence in learning to learn all three model / approach has been concluded that complimented on. The "Mathematical competence and basic competencies in science/technology" dimension in connection with thinking-life and engineering-

design skills within the eight competencies of TQF included in the science curriculum updated by 2018; the "learning to learn" dimension with the views to make the learning process effective at the cognitive level; "Digital competence" with emphasis on the fact that teacher candidates make effective use of information technology in the study; It can be said that the SESTE themes emphasize the "social and citizenship competencies" with the sub codes. On the other hand, the result can be reached by using all these three approaches and models that overlap with current curriculum and teacher candidates have awareness about it.

12. Scientific Process Skills (SPS) are classified as experimental and basic skills. It has been seen that the BSB is more important or aware of the 5E model. In the literature, the 5E model seems to be the most reflective learning spiral to SPS (Anagün & Yaşar, 2009).
13. Life skills were criticized negatively in 5E, while constructive in STEM. Life skills such as creativity and entrepreneurship are not among the dominant factors in science teacher candidates' views on model 5E (Özbek, Çelik, Ulukök & Sarı, 2012).
14. There is awareness of mathematics, engineering and technology related to the integration of science in nature of STEM. The fact that the STEM approach is valued within the context of current science teaching, the involvement of the activities in the vision of the internet-based environment, and its popularly on the agenda has increased the emphasis on the integrated interdisciplinary dimension and components of the STEM approach built on probabilistic learning in practice (Table 3).
15. The sub-dimensions of the SSTE dimension found in the vision of the 2013 science lesson curriculum came to the forefront in CMCK. Similarly, according to Bakırcı, Çepni & Ayvacı (2015), it can be said that the teaching processes on which the CMCK is based concentrate on the achievements of SSTE in addition to many achievements. In the process of expanding and transferring CMCK, students use a critical thinking structure to uncover the interaction between knowledge, technology, society and the environment while solving problems in daily life, thus it increases their sensitivity to socio-scientific issues (Ebenezer et al., 2010). The size of SESTE integrated with engineering and technology is dominant in STEM approach. This result is also supported in the literature (Yıldırım & Türk, 2018).

SUGGESTIONS

1. Activities to develop social communication culture in collaborative learning environments should be designed and effective classroom management skills should be developed for teacher candidates towards inquiry-based learning environments.
2. It is a fact that learning in a constructivist and inquiry-based class can take place slowly and it takes time. This situation which is taken into consideration in the developing educational programs should be felt by the teacher candidates.
3. Teacher candidates are expected to become a guide to facilitate learning. Therefore, the number of practical courses at the undergraduate level should be increased so that the pedagogical content knowledge integrating the content knowledge and pedagogy can have a cultural product.
4. Teacher candidates should be able to use the laboratory equipment for other purposes within the scope of their suitability and convenience, and to develop their competence to ensure the safety and security of the laboratory environment.
5. Attention should be paid to the fact that previous laboratory cultures are gained in previous teaching life to achieve higher levels of affective competence.
6. If it is considered that the practices in this study have provided competence and awareness to the prospective teachers, activities should be planned to provide practical professional development for the active teachers.
7. When the STEM approach is desired to support engineering and design skills, it is possible to make recommendations to the practitioner at the point of planning and managing the activities by taking negative criticism in concept teaching and considering the long duration of CMCK activities reflected in the opinions of teacher candidates.

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REFERENCES

Akpınar, E., & Yıldız, E. (2006). Açık uçlu deney tekniğinin öğrencilerin laboratuvara yönelik tutumlarına etkisinin araştırılması. *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi*, *20*, 69-76.

Anagün, Ş., & Yaşar, Ş. (2009). İlköğretim beşinci sınıf fen ve teknoloji dersinde bilimsel süreç becerilerinin geliştirilmesi [Developing scientific process skills at science and technology course in fifth grade students]. *Elementary Education Online, 8(3),* 843-865.

Ausubel, D. P. 1968. *Educational Psychology: A Cognitive View*, New York: Holt, Rinehart and Winston Inc.

Aydoğdu, B., & Ergin, Ö. (2010, November). Fen ve teknoloji dersinde kullanılan farklı deney tekniklerinin öğrencilerin öğrenme yaklaşımlarına etkileri. In *International Conference on New Trends in Education and Their Implications* (pp. 11-13).

Budak-Bayır, E. (2008). Fen Müfredatlarındaki Yeni Yönelimler Işığında Öğretmen Eğitimi: Sorgulayıcı-Araştırma Odaklı Kimya Öğretimi. *Yayınlanmamış Doktora Tezi. Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü:* Ankara.

Bakırcı, H., Çepni, S., & Yıldız, M. (2015). Ortak bilgi yapılandırma modelinin altıncı sınıf öğrencilerinin akademik başarılarına etkisi: Işık ve ses ünitesi [The effect of common knowledge construction model on sixth grade students' academic achievement: Light and sound unit]. *Dicle University Journal of Ziya Gökalp Faculty of Education, 26*, 182–204. https://doi.org/10.14582/DUZGEF.660.

Bakırcı, H., Çepni, S., & Ayvacı, H. Ş. (2015). Ortak bilgi yapılandırma modeli hakkında fen bilimleri öğretmenlerinin görüşleri [Science teachers' opinions about common knowledge construction model]. *YYU Journal Of Education Faculty, 12 (1),*97-127.

Bozdoğan, A. E., & Altunçekiç, A. (2007). Fen Bilgisi Öğretmen Adaylarının 5E Öğretim Modelinin Kullanılabilirliği Hakkındaki Görüşleri [The opinion of pre-service science teachers about the utility of 5e teaching model]. *Kastamonu Eğitim Dergisi*, *15(2),* 579-590.

Bozkurt-Altan, E., Yamak, H., & Buluş-Kırıkkaya, E. (2016). FeTeMM eğitim yaklaşımının öğretmen eğitiminde uygulanmasına yönelik bir öneri: Tasarım temelli fen eğitimi [A proposal of the STEM education for teacher training: Design based science education]. *Trakya University Journal of Education Faculty*, *6*(2), 212-232.

Bybee, J. W., & Landes, N. M. (1988). The biological sciences curriculum study (BSCS). *Science and Children, 25 (8),* 36-37.

Chin, C., & Chia, L. (2006). Problem-based learning: Using III-structured problems in biology project work. *Science Education, 90(1)*, 44-67. https://doi.org/10.1002/sce.20097

Colley, E. K. (2006) Understanding ecology content knowledge and acquiring science process skills through project-based science instruction. *Science Activities: Classroom Projects and Curriculum Ideas, 43 (1)*, 26-33. https://doi.org/10.3200/SATS.43.1.26-33.

Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics, 113(5),* 215-226.

Creswell, J. W. (2013). *Araştırma deseni* (S. B. Demir, Çev., Ed.). Ankara: Eğiten Kitap.

Çelik, H., Katrancı, M., & Çakır, E. (2017). Fen Öğretiminde Açık Uçlu Araştırmacı Sorgulayıcı Laboratuvar Yaklaşımının Yaratıcı Düşünme Becerisine Etkisi. *Turkish Journal of Primary Education*, *2*(1), 1-10.

Çepni, S., Ormancı, Ü. (2017). Geleceğin Dünyası. Salih Çepni (Ed.), *Kuramdan Uygulamaya STEM Eğitimi (s. 1-32)*. 1. Baskı. Ankara: Pegem A Akademi.

Çepni, S., Özmen, H. ve Bakırcı, H. (2012, Haziran). Ortak Bilgi Yapılandırma Modeline Uygun Öğretim Materyali Geliştirilmesi: Işığın Madde ile Etkileşimi ve Yansıma Örneği. Sözel bildiri, *X. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, Niğde Üniversitesi,* Niğde.

Davies, D. J., Collier, C., & Howe, A. (2012). A matter of interpretation: developing primary pupils' enquiry skills using position-linked datalogging. *Research in Science & Technological Education, 30(3),* 311-325.

Demircioğlu, H. & Vural, S. (2016). Ortak bilgi yapılandırma modelinin (obym), sekizinci sınıf düzeyindeki üstün yetenekli öğrencilerin kimya dersine yönelik tutumları üzerine etkisi [The effect of common knowledge construction model (ckcm) on the 8th grade gifted students' attitudes toward chemistry course]. *Journal of Hasan Ali Yücel Faculty of Education, 13 (1),* Sayı: Özel Sayı-1, 49-60.

Demirbaş, M. & Pektaş, H. M. (2015). Evaluation of experiments conducted about 5e learning cycle model and determination of the problems encountered, *International Online Journal of Educational Sciences, 7(1),* 51-64.

Ebenezer, J., Chacko, S., Kaya, O.N., Koya, S. K. & Ebenezer, D.L. (2010). The effects of common knowledge construction model sequence of lessons on science achievement and relational conceptual change. *Journal of Research in Science Teaching, 47(1),* 25–46. https://doi.org/10.1002/tea.20295

Eisenkraft, A. (2003). Expanding the 5E model: A proposed 7E model emphasizes "transfer of learning" and the importance of eliciting prior understanding. The Science Teacher, 70, 56–59.

Eroğlu, S., & Bektaş, O. (2016). STEM eğitimi almış fen bilimleri öğretmenlerinin stem temelli ders etkinlikleri hakkındaki görüşleri [Ideas of science teachers took STEM education about STEM based activities]. *Journal of Qualitative Research in Education, 4(3),* 43-67. [Online]. https://doi.org/10.14689/issn.2148-2624.1.4c3s3m.

Gençer, S., & Karamustafaoğlu, O. (2017). "Durgun elektrik" konusunun eğitsel oyunlarla öğretiminde öğrenci görüşleri [The views of students regarding teaching of "static electricity" with educational games]. *Journal of Inquiry Based Activities, 4(2),* 72-87.

Gibson, H. L., Chase, C., (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education, 86,* 693– 705. https://doi.org/10.1002/sce.10039

Gijbels, D., & Loyens, S. M. (2009). Constructivist learning (environments) and how to avoid another tower of Babel: reply to Renkl. *Instructional Science*, *37*(5), 499-502. https://doi.org/10.1007/s11251-009-9100-2

Gökbayrak, S., & Karışan, D. (2017). STEM temelli laboratuvar etkinliklerinin fen bilgisi öğretmen adaylarının STEM farkındalıklarına etkisinin incelenmesi [Investigating the effect of STEM based laboratory activities on preservice science teacher's STEM awareness]. *Journal of Human Sciences*, *14(4),* 4275-4288.

Hanuscin, D. L., & Lee, M. H. (2008). Using the learning cycle as a model for teaching the learning cycle to preservice elementary teachers. *Journal of Elementary Science Education*, *20(2),* 51-66. https://doi.org/10.1007/BF03173670

Harurluoğlu, Y. & Kaya, E. (2011). Öğrenme halkası modelinin fen bilgisi öğretmen adaylarının tohum-meyve-çiçek konularındaki başarılarına ve hatırlama düzeylerine etkisi [The effect of learning cycle model on the achievements and retention levels of pre-service science teachers in seed-fruitflower topics]. *Iğdır Univ. J. Inst. Sci. & Tech. 1(4),* 43-50.

Hayden, C. T., O'Neill, D., Meyer, J. E., Carballada, R. C., Sanford, A. L., Cohen, S. B., et al. (2004). *Intermediate level science: Core curriculum grades 5–8.* Retrieved March 31, 2018, from http://www. emsc.nysed.gov/ciai/mst/pub/intersci.pdf.

Hegarty-Hazel, E. (1986). *Lab work. SET: Research information for teachers, number one.* Canberra: Australian Council for Education Research.

Hess, A. J., & Trexler, C. J. (2005). Constructivist teaching: Developing constructivist approaches to the agricultural education class. *Agricultural Education Magazine, 77*, 12–13.

İyibil, Ü. (2011). A new approach for teaching 'energy' concept: The common knowledge construction model. *Western Anatolia Journal of Educational Sciences (WAJES),* Dokuz Eylül University Institute, Izmir, Turkey.

Johnstone. **A.** H. and Wham, **A.** J. B. (1982). The demands of practical work, *Education in Chemistry,*19(3). 71-73.

Juhl, L., Yearsley, K. & Silva, A. J., (1997), Interdisciplinary project- based Learning through an environmental water quality study. *Journal of Chemical Education, 74 (12),* 1431-1433. https://doi.org/10.1021/ed074p1431

Kahn, P., & O'Rourke, K. (2005). Understanding enquiry-based learning. In T. Barrett, I. Mac Labhrainn, & H. Fallon (Eds.), *Handbook of enquiry and problem-based learning (pp. 1–12).* Galway, Ireland: CELT. Retrieved March 28, 2018, from http://citeseerx.ist.psu.edu/viewdoc/download? https://doi.org/10.1.1.461.5829&rep=rep1&type=pdf

Kaid, L. L. (1989). Content analysis. In P. Emmert & L. L. Barker (Eds.), *Measurement of communication behavior* (pp. 197-217). New York: Longman.

Kanlı, U., & Yağbasan, R. (2008). 7E modeli merkezli laboratuvar yaklaşımının öğrencilerin bilimsel süreç becerilerini geliştirmedeki yeterliliği [The efficacy of the 7E learning cycle model based on laboratory approach on development of students' science srocess skills]. *Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi*, *28(1),* 91-125.

Kara, Y., & Özgün-Koca, S. A. (2004). Buluş Yoluyla Öğrenme ve Anlamlı Öğrenme Yaklaşımlarının Matematik Derslerinde Uygulanması:" İki Terimin Toplamının Karesi" Konusu Üzerine İki Ders Planı. *İlköğretim online, 3(1).* http://ilkogretim-online.org.tr

Ketpichainarong, W., Panijpan, B., & Ruenwongsa, P. (2010). Enhanced learning of biotechnology students by an inquiry-based cellulase laboratory. *International Journal of Environmental and Science Education, 5(2),* 169-187. http://www.ijese.com

Kiryak, Z. (2013). *Ortak bilgi yapılandırma modelinin 7. sınıf öğrencilerinin su kirliliği konusundaki kavramsal anlamalarına etkisi* (Yayımlanmamış yüksek lisans tezi), Karadeniz Teknik Üniversitesi, Trabzon.

Kocakülah, A., & Savaş, E. (2013). Akran öğretimi destekli bilimsel süreç becerileri laboratuvar yaklaşımının öğretmen adaylarının bazı bilimsel süreç becerilerine etkisi [Effect of the science *process skills laboratory approach supported with peer-ınstruction on some of science process skills of pre-service teachers]. Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 7(2)*, 46-77.

Kondracki, N. L., Wellman, N. S., & Amundson, D. R. (2002). Content analysis: review of methods and their applications in nutrition education. *Journal of nutrition education and behavior, 34(4),* 224-230.

Korkmaz, H., & Kaptan, F. (2002). Fen eğitiminde proje tabanlı öğrenem yaklaşımının ilköğretim öğrencilerinin akademik başarı, akademik benlik kavramı ve çalışma sürelerine etkisi [The effects of project-based learning on elementary school students' academic achievement, academic self concepts and study time in science education]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *22*, 91-97.

Köseoğlu, F. & Tümay, H. (2015). *Bilim eğitiminde yapılandırıcı paradigma*, Pegem Akademi Yayıncılık, Ankara.

Lawson, A. E. (1988). A Better Way to Teach Biology. The American Biology Teacher, 50, 266-89. doi: 10.2307/4448733.

Lee, O., Hart, J. E., Cuevas, P., & Enders, C. (2004). Professional Development in Inquiry-Based Science for Elementary Teachers of Diverse Student Groups. *Journal of Research in Science Teaching. 41(10)*, 1021-1043.

Lord, T., & Orkwiszewski, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. *The American Biology Teacher, 68(6)*, 342-345. https://doi.org/10.1662/0002-7685(2006)68[342:DTIIIA]2.0.CO;2.

Loyens, S. M. M., Kirschner, P. A., & Paas, F. (2011). Problem-based learning. In K. R. Harris, S. Graham, T. Urdan, A. G. Bus, S. Major, & H. Swanson (Eds.). *APA educational psychology handbook: Application to learning and teaching, 3, 403–425. Washington D.C.: American Psychological Association*. Retrieved March 20, 2018, from http://dspace.ou.nl/bitstream/1820/2934/1/Problem-Based%20Learning.pdf

Loxley, P., Dawes, L., Nicholls, L. & Dore, B. (2016). *İlköğretimde eğlendiren ve anlamayı geliştiren fen öğretimi.* H. Türkmen, M. Sağlam & E. Şahin-Pekmez (çev.). Ankara: Nobel Yayınevi.

Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. Sandra K. Abell,Ken Appleton,Deborah L. Hanuscin (Eds.). *Handbook of research on science education*, 393-441.

Mantzoukas, S. (2007) Reflection and problem/enquiry□based learning: confluences and contradictions. *Reflective Practice: International and Multidisciplinary Perspectives, 8(2),* 241-253. https://doi.org/10.1080/14623940701289311.

Marzano, J. R., Marzano, S. J., & Pickering, J. D. (2008). Etkili sınıf yönetimi stratejileri (Ç. Aksoy, Çev., Ed.). İstanbul: Sev Yayıncılık.

Massa, N. M. (2008). Problem-based learning. A real-world antidote to the standards and testing regime. *The New England Journal of Higher Education, 22(4),* 19-20. Retrieved March 15, 2018, from https://files.eric.ed.gov/fulltext/EJ794238.pdf

Matthews, M. R. (2002). Constructivism and Science Education: A Futher Appraisal. *Journal of Science and Technology, 11(2)*, 121-134. https://doi.org/10.1023/A:1014661312550

Miles, M, B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded Sourcebook. (2nd ed). Thousand Oaks, CA: Sage.

Milli Eğitim Bakanlığı (MEB) (2013). İlköğretim kurumları fen bilimler dersi öğretim programı *(İlkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar*), Talim ve Terbiye Kurulu Başkanlığı, Ankara.

Morgil, İ., Seyhan, H. G., & Seçken, N. (2009). Proje destekli kimya laboratuvarı uygulamalarının bazı bilişsel ve duyuşsal alan bileşenlerine etkisi. *Türk Fen Eğitimi Dergisi, 6(1),* 89-107. http://www.tused.org

Novak, J. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science education*, *86(4),* 548-571. https://doi.org/10.1002/sce.10032

Özbek, G., Çelik, H., Ulukök, Ş. & Sarı, U. (2012). 5E ve 7E öğretim modellerinin fen okur-yazarlığı üzerine etkisi. *Journal of Research in Educationand Teaching, 1(3),* 183-194.

Özer, D. Z., & Özkan, M. (2011). Proje tabanlı öğrenme yaklaşımının fen bilgisi öğretmenliği bölümü öğretmen adaylarının biyoloji konularındaki akademik başarılarına etkisi [The effect of project based learning approach to the academic achievement of prospective teachers of science education department towards biology lesson]. *Uludağ Üniversitesi Eğitim Fakültesi Dergisi*, *24(1),* 181-207.

Özmen, H. (2014). Öğrenme Kuramları ve Fen Bilimleri Öğretimindeki Uygulamaları. Salih Çepni (Ed.), *Kuramdan Uygulamaya Fen ve Teknoloji Öğretimi* (s. 51-119) 11. Baskı. Ankara: Pegem A Akademi.

Özsevgeç, T. (2006). Kuvvet ve hareket ünitesine yönelik 5E modeline göre geliştirilen öğrenci rehber materyalinin etkililiğinin değerlendirilmesi. *Türk Fen Eğitimi Dergisi*, *3*(2), 36-48. http://www.tused.org

Potter, W. J., & Levine□Donnerstein, D. (2009). Rethinking validity and reliability in content analysis. *Journal of Applied Communication Research, 27 (3),* 258-284.

Price, B. (2001) Enquiry-based learning: an introductory guide, *Nursing Standard, 15(2)*, 45–55.

Rikers, R. M., van Gog, T., & Paas, F. (2008). The effects of constructivist learning environments: A commentary. *Instructional Science*, *36*(5-6), 463-467. https://doi.org/10.1007/s11251-008-9067-4

Savery, J. R. (2006). Overview of problem-based learning: definitions and distinctions. *The Interdisciplinary Journal of Problem-Based Learning, 1*, 9-20. https://doi.org/10.7771/1541-5015.1002

Schmidt, H. G., Van der Molen, H. T., Te Winkel, W. W. R., & Wijnen, W. H. F. W. (2009). Constructivist, problem-based learning does work: a meta-analysis of curricular comparisons involving a single medical school. Educational Psychologist, 44, 1-23.

Sezgin, G., Çalışkan, S., Çallıca, H., & Erol., M. (2001). Fizik Eğitiminde Projeye Dayalı Laboratuvar Çalışmalarına Yönelik Öğrenci Tutumları. *Maltepe Üniversitesi Fen Bilimleri Sempozyumu,7-8 Eylül*, İstanbul.

Şencan, H. (2005). *Sosyal ve Davranışsal Ölçümlerde Güvenirlik ve Geçerlilik*, 1. Baskı, Seçkin Yayınları, Ankara.

Tatar, E., Oktay, M., & Tüysüz, C. (2009). Kimya eğitiminde probleme dayalı öğrenmenin avantaj ve dezavantajları: bir durum çalışması [Advantages and disadvantages of problem based learning in chemistry education: a case study]. E*rzincan Eğitim Fakültesi Dergisi, 11 (1),* 95-110.

Temel, S. & Morgil, İ.(2007). Kimya eğitiminde laboratuvarda problem çözme uygulamasının öğrencilerin bilimsel süreç becerilerine ve mantıksal düşünme yeteneklerine etkisi [The effect of problem solving application in laboratory within chemistry education on students' scientific process skills and reasoning abilities]. *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi, 22*, 89- 97.

Tural G., Akdeniz, A.R., & Alev, N. (2010). Effect of 5e teaching model on student teachers' understanding of weightlessness. *Journal of Science Education and Technology, 19 (5),* 470–488.

Uçar, E. & Yeşilyaprak, B. (2006). *Öğrenmeden Öğretime.* Yeşilyaprak, B. (Ed.) Eğitim Psikolojisi. Pegema Yayıncılık, Ankara.

Wendell, K. B., Connolly, K. G., Wright, C. G., Jarvin, L., Rogers, C., Barnett, M., & Marulcu, I. (2010). Incorporating engineering design into elementary school science curricula. *American Society for Engineering Education Annual Conference & Exposition, Louisville, KY. Retrieved March 30, 2018*, from http://ceeo.tufts.edu/documents/conferences/2010kwkccwljcrmbim.pdf.

Wilder, M., & Shuttleworth, P. (2005). Cell inquiry: A 5E learning cycle lesson. *Science Activities: Classroom Projects and Curriculum Ideas, 41(4),* 37-43. https://doi.org/10.3200/SATS.41.4.37-43.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research, 72 (2)*, 131–175.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in science education, 38(3),* 321-341.

Yalçın, F. A., & Bayrakçeken, S. (2010). The effect of 5E learning model on pre-service science teachers' achievement of acids-bases subject. *International Online Journal of Educational Sciences, 2(2),* 508-531. www.iojest.net

Yaman, S., & Yalçın, N. (2005). Fen bilgisi öğretiminde probleme dayalı öğrenme yaklaşımının yaratıcı düşünme becerisine etkisi [Effectiveness on creative thinking skills of problem based learning approach in science teaching]. *İlköğretim Online*, *4(1),* 42-52. http://ilkogretim-online.org.tr

Yıldırım, B., Altun, Y. (2015). STEM eğitim ve mühendislik uygulamalarının fen bilgisi laboratuar dersindeki etkilerinin incelenmesi. *El-Cezeri Journal of Science and Engineering*, *2*(2), 28-40.

Yıldırım, B., & Türk, C. (2018). Sınıf öğretmeni adaylarının STEM eğitimine yönelik görüşleri: Uygulamalı bir çalışma [Pre-service primary school teachers' views about STEM education: An applied study]. *Trakya University Journal of Education Faculty*, *8(2),* 195-213.

Yıldırım, A. & Şimşek, H. (2011). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*, 8. Baskı, Seçkin Yayıncılık, Ankara.

Zion, M., Michalsky, T. ve Mevarech, Z. R. (2005). The Effects of Metacognitive Instruction Enbedded Within an Asynchronous Learning Network on Scientific Inquiry Skills. *International Journal of Science Education, 27(8),* 957-983.