Developing a constructivist proposal for primary teachers to teach science process skills: “Extended” simple science experiments (ESSE)

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Contents

Abstract

Although science experiments are the basis of teaching science process skills (SPS), it has been observed that a large number of prospective primary teachers (PPTs), by virtue of their background, feel anxious about doing science experiments. To overcome this problem, a proposal was suggested for primary school teachers (PSTs) to teach science and SPS without focusing on "structure" of experiments based on Constructivist 5E Model. Some "extended" simple science experiment (ESSE) samples were implemented to 39 PPTs according to this proposal. Then, 39 PPTs were allowed to design and to conduct several ESSE. Finally, they assessed their ESSE experiences. They stated that ESSE is not only easy and enjoyable to engage in science but also useful for teaching and learning science concepts and SPS. In this paper, ESSE process is illustrated in "Sound is a kind of energy" experiment.

Keywords: Simple science experiment; Science process skill; Constructivist 5E mode; Extended experiment.

Introduction

Turkish Ministry of National Education (MoNE) decided to revise the curriculum of primary science education due to educational and scientific developments, and unsuccessful results indicated by the international assessments (TIMSS, PISA etc.)(MoNE, 2007; Acat, Anilan, and Anagün, 2010). Curriculum was completely changed and implemented nationwide starting with the 2005–2006 academic year and revised in 2013.

The primary (3^{th}, 4^{th} graders) and secondary (5^{th} to 8^{th} graders) science education curriculum focuses on the principles of constructivism in which students actively engage in their own learning tasks by doing and experiencing (MoNE, 2007). MoNE defends that students are required to understand the basic science concepts related to daily life during the scientific process rather than struggling and memorizing more formula-based scientific knowledge (MoNE, 2007; Gömleksiz, 2012). In this education process, teachers' responsibilities are bound not only to teach science but also to focus on constructing knowledge in SPS (MoNE, 2007).

Therefore, science education curriculum draws attention to the fact that students can differently conceptualize the phenomena during the process of studying on their own acquiring scientific meanings as mentioned by other studies as well (Driver et al., 1994; Hırça, Çalık and Akdeniz, 2008). These conceptions which are different from scientific meanings are called misconceptions. To eliminate the students' misconceptions, science course books and teachers' guidebooks were prepared according to constructivist 5E instructional model (MoNE, 2007). Briefly, the purpose of Turkish science curriculum is to enable individuals to learn science by acquiring SPS considering their misconceptions (MoNE, 2007).

SPS is described as defining the problems around individuals, observing, analyzing, hypothesizing, experimenting, concluding, generalizing, and applying the information they have with the necessary skills (Aktamış and Ergin, 2008). In science education, SPS can be divided into two groups as "Basic" and "Integrated". Basic SPS refer to the following six actions, in no particular order: observation, communication, classification, measurement, inference, and prediction. The integrated SPS are complex processes that combine two or more basic SPSs such as controlling variables, interpreting data, formulating hypotheses and experimentation (Azizoğlu and Dönmez, 2010). All of these processes are connected with each other.

The important point that we need to pay attention is that students are primarily introduced science concept and SPS by PETs in 3th and 4th grades of their school life. However, researchers indicated that teachers did not have sufficient conceptual understanding of science and SPS (Nadelson et al., 2013; Aydoğdu, Erkol and Erten, 2014). Moreover, some Turkish researcher claimed that Turkish primary teachers have some difficulties in science knowledge, teaching science and inquiry learning (Ayas etal., 1994; Böyük et al., 2010; Tunç, Çam and Dökme, 2012; Koç and Bayraktar, 2013). For example, Koç and Bayraktar (2013) explored practices of PETs. They concluded that 75% of PETs have not implemented all the experiments which in science course book. According the results, The PETs asserted many reasons for the in support of their failure like lack of experience of conducting experiments. In another study, Aydoğdu, Erkol and Erten (2014) investigated PSTs' SPS understandings in two directions as follows: basic and integrated. They found that Turkish PSTs' SPS level was 55% in basic skills and 48% in integrated skills. Nadelson et al., (2013) tried to describe similar undesired results in their study. They stated that lack of PSTs' using of inquiry to teach science content may be the attributed to their limited experience in inquiry science and complacency with direct instruction.

Briefly, accommodating the goals of science curriculum not only depends on a well-designed science curriculum but also on teachers' qualifications. In that case, PSTs need to be trained to instruct practical science courses. Further, they should define and illustrate scientific concepts that they come across in daily life in a scientific way and how to teach them.

Theoretical Framework of the "Extended" Simple Science Experiments(ESSE)

Constructivism is a theory of learning. It is not an instructional method (Cobb, 1994). The 5E Model (Table 1) is one of the instruction methods of constructivist model which is often used in Turkish science curriculum. Moreover, course books, workbooks and teachers' guidebooks of science lessons were prepared according to the 5E instruction model.

Constructivist 5E instruction model can be enriched by using different teaching methods and techniques together in each stage of it (Ürey and Çalık (2008; Hırça, Çalık and Seven, 2011). For example, Hırça, Çalık and Seven (2011) used worksheets, science experiments, conceptual change texts and computer software; Ürey and Çalık (2008) combined analogy, conceptual change text and worksheet in 5E model. Based on this goal, Hırça has embedded simple experiment and SPS into 5E model for PSTs in this paper. Constructivist 5E Model and embedding SPS into 5E Model is described in Table 1.

Table 1. Embedding SPS into phases of 5E Model

Phases of 5E Model (Bybee et al, 2006)		**Integrated Science Process Skills (Gilbert, 2011)**
Engagement phase	Teacher asks some questions or presents an event to get students mentally engaged in the concept or process to be explored. S/he also identifies and notes students' prior knowledge about the concept.	In this phase, teacher encourages students to discuss (communicating skills) the subject by using their prior knowledge
Explore phase	Students actively identify and develop current concepts by exploring their environment or manipulating materials.	In this phase, teacher wants students to formulate their hypotheses of what will happen in the investigation. To verify the hypotheses, students' goal is to identify variables, to define variables operationally, to describe relationships between variables, to design investigations, to conduct experiment, to acquire data, to organize data in tables and graphs by discussing each other (communicating skill)
Explanation phase	Students present their findings and explain what they have learned guided by the teacher	In this phase, students explain the relation between cause and effect, they analyze their investigations and their data by

		discussing each other communicating skill).
Elaboration phase	Teacher helps students to correct their misconceptions and, help them develop a deeper and broader understanding and to acquire more information.	In this phase, teacher tries to correct students' prior knowledge that s/he meets in the engagement phase and s/he encourages students to transfuse their understanding (formulating models) into a new situation, context or daily life. Teacher also wants students to repeat the "explore phase" to apply their understanding of the concept by conducting additional activities.
Evaluation phase	Teacher encourages students to assess their understanding and provides opportunities toward achieving the educational objectives	In this phase, teacher encourages students to communicate again

Method

I have implemented Science and Technology Laboratory Applications (STLA) course to PPTs for three years. Hovewer, I met PPT having low self-confidence to conduct science experiments by virtue of their poor practice as mentioned in some studies (Appleton 1995; Pell and Jarvis 2003; Nadelson et al., 2013). They have always claimed that they got science courses including only theoretical concepts of science at first years of both high school and undergraduate degree. Then, they were intensively engaged in science experiments in their second year of undergraduate degree. To overcome this undesired problem, I needed a method to get PPTs to teach SPS and science concepts without focusing on "structure" of experiments.

Constructivist learning approach already enabled me to change the objectives by considering the learning needs of students (Brooks, 1987). I focused on getting them to acquire SPS rather than dealing with complicated experiments. I embedded SPS into the simple science experiments based on Constructivist 5E Model. I designed several "extended" science experiments (ESSE) which were known as "experiment that you can do at home" by expanding the content as well.

In the first four weeks of the Action research study, I introduced SPS and 5E model to PPTs. In the following weeks, I implemented ESSEs to 39 PPTs (25 male, 14 female) who were enrolled in STLA course in the 2013-2014 academic year. Then, I wanted them to conduct several ESSEs using the same method. The ESSE process is illustrated in "Sound is a kind of energy" experiment in Appendix A. Finally, I asked their views about the applications. Qualitative methods were used to collect data. Data collection was carried out by a focus group interview with 7 PPTs (4 female and 3 male). Data were analyzed using qualitative content analysis method by coding and creating categories and themes.

The Perceptions and the Experiences of PPTs about ESSE Process

This title should not be considered as "findings section" of the study. Under this title, I tried to present the perceptions and the experiences of PPTs to provide a viewpoint to the readers about ESSE process.

Although the entire group had taken an introductory science course previously, PPTs expressed that they had fear, anxiety and worry about experiments before the implementations. One of the PPT framed that "*I have learnt science theoretically*", another pre-service teacher established "*I had fear of science*", another one expressed that "*I have not conducted experiment until this course*", one PPT pointed that "*I thought that I have a trouble conducting experiment*". After the implementations, although PPTs encountered several difficulties, most of all expressed their satisfaction. One of the PPTs expressed that "*I think that it is a successful implementation for teaching and learning science*". One of the PPTs pointed that "*I have learned how science subjects can be popularized and concretized. Hereafter, I can easily develop and implement several simple science experiments to teach science and SPS to my prospective students in the future*". Another pre-service teacher acknowledged that "*my science fear has decreased during the course due to simple science experiment that I can do anywhere*". When a female PPT pointed that "*the implementation allowed me to learn science without memorizing*" the other one stated that "*Although I have trouble in telling the difference between dependent and independent variables, I have gained ability to apply theoretical knowledge into practice*". One PPT expressed that "*Although I had some difficulty in providing material in my hostel, I have learned that any object can be used as a material for conducting an experiment*". A male PPT summarized the benefits of ESSE. He stated that "*I have learned that simple facts or events may contain complex scientific knowledge. Therefore, I have a trouble in explaining the result of the some experiments*".

Discussion and conclusion

Before the implementations, it was found that the PSTs have a fear of science experiments. The findings of this study support the results of previous studies reporting that PPTs had limited experience with science experiment and SPS (Ayas etal., 1994; Böyük et al., 2010; Tunç, Çam and Dökme, 2012; Koç and Bayraktar, 2013; Nadelson et al., 2013) and low self-confidence to teach science (Appleton 1995; Pell and Jarvis 2003; Tunç, Çam and Dökme, 2012). To overcome this problem, this paper suggested an easy way of teaching SPS for PSTs which was verified by experiences of PPTs. The applications are called as ESSE.

The ESSEs are simple science experiments which were developed and extended including SPS based on constructivist 5E Model. Constructivist 5E model was used in this study because it enables variety in teaching and it provides opportunities for the rich learning environments to be organized considering students' misconceptions (Ürey and Çalık, 2008; Hırça, Çalık and Seven, 2011). Each "E" represents part of the process of assisting students' learning sequence and experiences in linking prior knowledge with new concepts (Karslı and Ayas, 2011). This process is gradually illustrated in "Sound is a kind of energy" experiment in appendix A.

Another marking part of this study is the materials of experiments. Some studies indicated that most of experienced teachers have difficulties in doing experiment or they prefer not to do experiment due to lack of specific apparatus and adequate laboratory equipment (Ayas et al., 1994; Böyük et al., 2010; Tunç, Çam and Dökme, 2012; Koç and Bayraktar, 2013) and teachers complained preparing and guiding such activities which takes too much time and effort (Ateş and Eryılmaz, 2011). According the views' of PPTs, these undesired results can be eliminated during the ESSE process. Because, PPTs who were afraid of doing experiments due to focusing on structure of science experiments stated that any object can be used as a material for conducting an experiment. This finding shows similarities to the results of Aktamış and Ergin (2008) who determined that the SPS skills education increased the students' achievements and scientific creativities and to the results of Ateş and Eryılmaz, (2011) who indicate that teaching science do not need a special laboratory environment or complicated apparatus, everyday gadgets, simple set-ups or low-cost items can make better realize science and students physically active.

Although Ürey and Çalık (2008) indicate that one conceptual change method don't remedy students' misconceptions completely, PPTs stated that ESSEs process taught science concepts them in relation to real-life experiences and practiced SPS by having fun during the implementations. This finding is similar to findings of Karslı and Ayas (2011) who explained that student-centered learning environments which are enriched by effective methods and techniques are needed in order to help the students understand the challenging concepts. Moreover, prospective teachers stated that they can easily develop and implement several simple science experiments to teach science and SPS to their students in the future. Based on the results of the applications, all of the PPT pointed out that "*experiments are not the aim of the science lessons, experiments are a method for teaching science and Scientific Process Skills*". Based on this findings, I have considered the ESSE beneficial for engaging PPTs who feel anxious about science experiments in the process of teaching and learning SPS without focusing on "structure" of experiments, as well as meeting state and national standards.

In recent years, some courses were have been implemented to familiarize prospective teachers with linking Hands on science activities in some education faculties in Turkey (Ateş and Eryılmaz, 2011). It is expected that these courses might be evolved to familiarize prospective teachers with linking science with SPS. Jaus (1975) reiterates the vital message that teachers must be equipped with the science process skills because they design activities for teaching these skills to their students. In-service trainings, workshops or projects should be organized for PPTs and PSTs allowing them to gain practical science experience and proficiency, and to acquire SPS without focusing on "structure" of experiments. In that time teachers, when they need, can design and implement science experiments for improving their students' SPS.

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Appendix A

Designing and Implementing of an ESSE: "Sound is a Kind of Energy" sample

When we listen to music loudly, we notice that any material which is in front of the speaker moves. With reference to moving objects by loud sound, we designed "Sound is a kind of energy" experiment which is presented as a sample in this paper. Physical Science Content Standard of "Sound is a kind of energy" experiment is given in Table 2.

Table 2. The goals of science and technology curriculum

Grade	Lesson	Subject	Goals
4-5	Science and technology	Release of Lights and Sounds/ How does sound occur?	• S/he produces sound with (different) object *(SPS)* • S/he notices that (different) vibrating objects produce (different) sounds • S/he notices that the pitch of the sound can be varied by changing the rate of vibration.
5-8	Science and technology	Release of Lights and Sounds/ Sound	• S/he produces sound with musical instruments *(SPS)* • S/he changes the volume of sound on musical instruments *(SPS)* • S/he defines frequency, amplitude, and phase shift • S/he defines the relations between frequency, amplitude and phase shift

			• S/he defines sounds that can be varied in pitch and volume • S/he produces sounds that can be varied in pitch and volume by musical instruments *(SPS)* • S/he notices that sound is a kind of energy • S/he notices that sound energy is transferred in many ways.
6	Science and technology	Light and sound	• S/he notices that sound moves in waves • S/he defines the interaction of sound waves with matter • S/he gives an example about using sound in science and technology • S/he defines why sound needs substantial matter for moving

Material: Computer, Computer speaker, A few lentils, Ruler

Phase 1: Engagement *(5–10 Min)*

- First you must call the students attention to "sound is a kind of energy" topic. Breaking a glass by an opera singer using only his/her voice is a very interesting phenomenon. Start with a whole class discussion by asking *"Can any opera singer break a glass using his/her voice"* based on their prior knowledge *(SPS: communicating).*
- After having the students brainstorm for a couple of minutes in the class, record and list the students' prior knowledge about the concept without attracting the students' attention. (You will correct the misconception in elaboration phase). Don't answer your question or students questionsto get the students mentally engaged in the concept and process to be explored.

Phase 2: Explore *(15–20 Min)*

- Have them hypothesize whether sound sways any material or not based on their prior knowledge *(SPS: Formulating hypotheses).* The students' hypotheses come about in two types; *"We can sway any material with our voice"* or *"We can't sway any material with our voice"*.
- Divide the students into groups of four or five to solve the problem by manipulating materials. Make a copy of Appendix A and deliver them to

student teams. Distribute the lentils to student teams. Get the students to start to the experiment in this section to test their hypotheses.

- Tell the student teams to lay the speaker-woofer look upside and put the lentils on it and to switch on the volume on their PC *(SPS: experimenting)*. Have them note their observations on worksheets. They will most likely respond that the lentils on the speaker began to jump *(SPS: identifying of dependent variables)*.
- Have them note the cause of jumping of lentils on worksheet. *(SPS: identifying of independent variables)*. They will also most likely respond that the lentils began to jump due to intensity of vibration (sound volume) *(SPS: designing investigations)*
- Get the students to turn up the volume on PC and to observe the effect of changing the volume of sound (independent variables) on moving lentils (dependent variables) *(SPS: describing relationships between variables)*. Have them note their observations on worksheets.
- Get the students to turn up volume gradually and have them measure the highest altitude jump of lentil in each case *(SPS: defining variables operationally)*. Have them repeat this process five times for accurate results *(SPS: acquiring data)* and fill in the worksheet *(SPS: organizing data in tables)*.

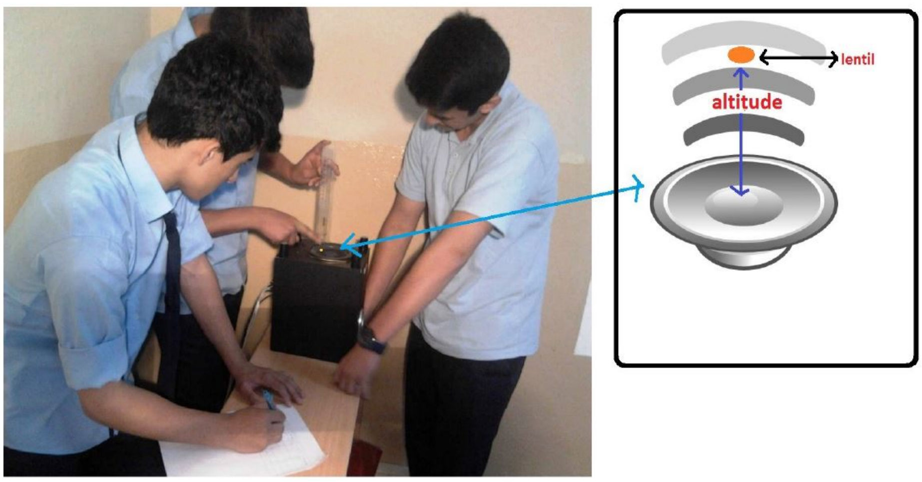

Figure 1. While a student is measuring altitude of lentil, the other one is writing their findings in data table

- Remind the students that a well-organized table also enables the readers to visualize the relationship between dependent and independent variables and helps them draw a graph.
- Have them draw a graph according to their results. (However, we all know that primary students and primary prospective teachers are not experienced in drawing graphs. Therefore, we advised them using any spreadsheet software to draw a graph.)
- Have the students open spreadsheet software and enter the results into rows and columns as the results appear in the worksheet. Warn the students to choose "a scatter (X-Y)" (and not Line graphic, even though it looks similar. This is the most common error people make). Have the students choose the version which shows points and connects them by smoothed lines. This will convert their highlighted data into a graph *(SPS: organizing graphic)*. Have them draw the graph on worksheet.

Phase 3: Explanation *(10–15 Min)*

- Get the students to explain what they understand from the data table and graph *(SPS: communicating)*. Infact, we expect students to describe the fact that the relationship between two variables is directly proportional to each other. In other words, they must explain the findings as; "when we turn up volume, it increases the altitude of lentil" *(SPS: understanding cause and effect relationships)*.
- Encourage and help the students to analyze their findings until correct definitions come out *(SPS: analyzing investigations and their data)*. At the end of this phase, the students must explain the results as: *"When examining speaker system and jumping lentils, we can say that speaker converts electrical energy into sound energy and sound energy vibrates lentil. In other words, sound energy is converted into kinetic energy. So, sound is produced by vibrating objects and then sound vibrates lentils. So, the pitch of the sound can be varied by changing the rate of vibration."*

Phase 4: Elaboration *(15–20 Min)*

- Encourage and help the students to illustrate their new understandings (*SPS: communicating)*. For example, you can remind them that sound waves are used for removing stones from kidney *(SPS: formulating models)*. Ask them whether they present various examples.

- Have the students to correct their misconceptions which were listed and recorded in engagement phase.
- Clarify the misconceptions indicated in literature according to the results such as; *"sound moves between particles of matter (in empty space) and then 'bumps into' the next matter particle"* and *"As sound waves move, the air moves along with them"*.

***Phase 5: Evaluation** (5–10 Min)*

- In this phase, have the students discuss what they actually did during the activity and ask them *(SPS: communicating);*

  1. Which types of energy have you learned in this experiment?
  2. How is sound produced? (please use energy conversion)

- At the end of the lesson, request the students to investigate and to prepare a report about "how to remove stones with sound waves from kidney" for next lesson.

Appendix B: Student Worksheet

Please answer the question: *"can the opera singer break a glass using her voice"*

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• What is your hypothesize whether the opera singer break a glass by her voice? ……………………………………………………………………………………………………
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• Take the lentils, lay the speaker down and put the lentils on it and to switch on the volume on PC. What do you observe? *(What is dependent variable)*. ………………………………………………………………………
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• What is the cause of jumping of lentils? *(what is independent variables).*

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• Turn up volume on PC and observe the effect of changing volume on moving lentils. Write your observation *(Describe relationships between dependent and independent variables).*

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• When you turn up volume gradually, measure highest altitude of lentil and write your findings in the data table in below. Repeat this process five times for accurate results.

Volume	**Altitude of Lentils**			
	trial 1	**trial 2**	**trial 3**	**Average (cm)**
20				
40				
60				
80				
100				

• Draw your graphic according to your data. (Open spreadsheet software. Copy and paste your results on spreadsheet. Use "a scatter (X-Y)" graphic and choose the version which shows points and connects them by smoothed lines.)

• What do you understand from the data table and graph? (Describe the effect of independent variable on dependent

variable.) ……………………………..……………………………………………………………… ………… ………………………………..………………………………………………………………………….
• Give an example of levitating and moving object by sound? Can we use the effect of sound in technology? ……………………………………………………………………………………………………….…… …….
• Which types of energy have you learned in this experiment? ……… ……….…… ………. • How is sound produced? (please use energy conservation) …… ………..…… ………….