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The Effect of Explicit-Embedded-Reflective Instruction on Scientific Literacy

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Abstract

The purpose of this study was to investigate the effectiveness of explicit-embedded-reflective (EER) instruction in scientific literacy levels of the ninth grade advanced science students by assessing content knowledge and scientific literacy levels. The study was conducted with 51 students by using experimental design. In the treatment group, the EER teaching was performed, while in the comparison group the instruction was conducted by lecturing, demonstration and questioning strategies in a teacher-centred context. Nature of Science Literacy Test and Cell Content Knowledge Test were used for data collection. T-tests were utilized for data analysis. The results of the study showed that the EER teaching was effective in terms of increase in scientific literacy levels and cell content knowledge in the treatment group. In addition, the approach was more effective in increasing scientific literacy levels and cell content knowledge than the regular approach.

Key words*: advanced science students; cell subject; explicit-embedded-reflective instruction; scientific literacy.*

Introduction

Being scientifically literate in today's world has been advocated in science curricula and reform documents (Project 2061, 2007; Turkish Ninth Grade Biology Curriculum, 2007). Scientific literacy can be defined as an educational aim including what people ought to know about science in general, nature of scientific knowledge, science content knowledge, scientific method, characteristics of scientists and what they ought to know to make informed decisions by using knowledge about science (Bybee, 1997, p. 69; Durant, 1993, p. 129; OECD, 2009, p. 14). A scientifically literate person should have the ability to apply scientific knowledge or concepts to his/her daily life problems in principled ways and to use the language of science for the interpretation and production of spoken and written texts (Palinscar, Anderson, & David, 1993; Miller, 2011). According to Norris and Phillips (2003), a scientifically literate person should also understand science texts by identifying whether something is an inference, hypothesis, conclusion or assumption, by distinguishing explanation from evidence, by recognizing the difference between a claim and a 'scientific result' and by expressing doubt or engaging in speculation. A more comprehensive and longer list of characteristics of a scientifically literate person regarding daily life was provided by Hurd (1998). As stated by Hurd (1998, pp. 413-414), scientifically literate individuals should understand that solutions to socio-scientific and personal-civic problems require a synthesis of knowledge from different fields including natural and social sciences, and should know that science in *social contexts* often has political, judicial, ethical, and sometimes moral dimensions, so they should have the ability to use science knowledge where appropriate in making decisions on daily life problems and social situations, forming judgments, resolving problems, and taking action. These characteristics are very important in daily life since having knowledge about science and its products and using this knowledge to solve problems are advantages when searching for a job, adapting to a new job more easily, managing technology more effectively and making informed decisions on socio-scientific issues (Khishfe, 2012).

Scientific literacy includes learning both *aspects of nature of science (NOS)* and *content knowledge* in general as an objective of education of all people in preparation for contemporary society and life (Damastes & Wandersee, 1992; Holbrook & Rannikmae, 2009; Uno & Bybee, 1994). As the first component; understanding NOS is necessary to 'help students to improve their general understanding of science' (National Research Council, 1996, p. 200). Without holding adequate views of NOS, students tend to believe that 'science is 'done' and it is a list of facts to memorize' (Akerson, Morrison, & McDuffie, 2006, p. 194). The nature of science (NOS) includes many aspects from scientific method to science in social and cultural contexts. Some aspects of NOS were found necessary to be taught at schools (McComas, 1998). These include the following aspects: 'there is no universally accepted one way to do science', 'scientific knowledge is based on evidence and observation', 'scientific knowledge is tentative', 'there is no hierarchy between theory and law', 'laws and theories have different roles in science', 'scientific knowledge is theory-laden', 'scientific knowledge is embedded in social and cultural contexts', 'creativity and imagination are important in the production of scientific knowledge', 'scientists are not objective when they begin to study because each scientist has a personal background' and 'science is a way of knowing' (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; McComas, 1998). Quoting from the study of Driver, Leach, Millar and Scott (1996), Lederman (2007) stated that understanding NOS as a component of scientific literacy is very important for utilitarian, democratic, cultural, moral and science learning aspects of life.

In spite of the emphasis on and reforms in science curricula about NOS aspects, they are still misunderstood by students and so scientific literacy levels of students are also indirectly affected by the misunderstandings (Dogan & Abd-El-Khalick, 2008; Khishfe & Abd-El-Khalick, 2002; Khisfe & Lederman, 2006). In their study, Khishfe and Lederman (2006) provided many examples of misunderstandings of ninth grade students on the NOS aspects by using Views on Nature of Science (VNOS) questionnaire plus follow-up interview approach. They found that more than half of the students in their sample presented naïve understandings on tentativeness by stating exchangeability and stability of scientific knowledge. The authors also showed the existence of naïve beliefs about the "empirical science" aspect among the majority of the students. Similarly, some of the students failed to recognize the distinction between observation and inference. In addition, the majority of the students did not appreciate "creative and imaginative science" and "subjectivity" aspects. One year later, the authors conducted a similar study with 89 ninth, 40 tenth and eleventh grade students using the Views on Nature of Science (VNOS) questionnaire and follow-up interview approach. Many of the participants in this study believed that scientific knowledge would not change and they held naïve views on "observation versus inference" and "creative/imaginative science" aspects. Similarly, the majority of the participants presented naïve understandings on subjectivity (Khisfe & Lederman, 2007). Similar results were also reported by other researchers from different countries. For example, Kilic, Sungur, Cakiroglu, and Tekkaya (2005) conducted research on 575 ninth grade students using the survey approach with Nature of Scientific Knowledge Scale (NSKS) in Turkey. They found that high school students were not certain whether scientific knowledge is absolute or not, whereas they held an informed view about "creative and imaginative science". In a similar study conducted on Turkish high school students, Dogan and Abd-El-Khalick (2008) examined tenth grade students' nature of science views using the Views on Science-Technology-Society (VOSTS) instrument. They reported that all of the participants held naïve understanding about the relationship between theories and laws, whereas the majority of them held informed views about the "tentativeness" aspect of NOS. These students also failed to understand the nature of theories and the relationship between scientific models and reality. The findings presented above indirectly show insufficiency in scientific literacy of students.

As the second component of scientific literacy, content knowledge regarding science should also be improved with NOS understandings. In this study, cell content knowledge was considered due to the fact that it is a common topic taught around the world and it is a rich subject to embed NOS aspects. In spite of the significance of the cell and cellular organization unit for science education, previous studies showed the existence of misunderstandings about the concepts of the cell among teachers and students (e.g. Flores, 2003; Kwen, 2005; Marek, 1986). For example, Dreyfus and Jungwirth (1988) showed that students did not understand 'the cell' concept appropriately (as cited in Tekkaya, 2002). Similarly, Lazarowitz and Penso (1992) defined learning difficulties among Israeli high school students about cells and organelles. In another study, Flores (2003) studied the understanding of eight topics of the cell subject with 1200 high school students. These topics were respiration, water in plants, water in animals, plant nutrition, animal nutrition, cell shapes, cell size and reproduction. By collecting data through a questionnaire and interviews, the author reported comprehension problems regarding the issues at different levels of biological organizations (cell, organ and organism). Some of the students in the sample believed that 'cell organelles are like organs' at the cell level, while they held the idea that 'structures like bones, cartilage or hair are not made up of cells' and 'nails and the pupil are made up of cells' at the organism level. They also believed that 'cells change in size along with the growth of a multi-cellular organism' and 'the cell size in an organ depends on the type and size of the organism'. In addition, some of the students, by assigning all cellular functions to nucleus, claimed that functions of organelles are not known. As a result, the author suggested teaching issues in an integrated approach and warned about anthropomorphic and isomorphic uses of biological titles. Similar to students, it was reported that teachers also held some misconceptions on this unit. For example, primary teachers believed that all cells have a nucleus (Kwen, 2005). Teachers also tended to believe that cells continue to grow as organisms mature, more clearly, that cell size is the determinant of organism size. In addition to the misconceptions about the cell and organelles, spontaneously establishing connections between the terms related to the cell and organelles was found to be problematic for junior high school biology teachers (Douvdevany, Dreyfus, & Jungwirth, 1997). Misconceptions and errors are not only limited to teachers and students since many biology textbooks also include different misconceptions and errors about the cell and its structure. Storey (1990) reported many misconceptions about cytoplasm, cytoskeleton, organelle shape, cell size, cell walls, membrane structure, extracellular matrix and cell junctions in textbooks. The problems summarized above also indicate existence of problems in terms of scientific literacy in the cell subject.

To overcome misunderstandings on NOS and problems in learning cell subject together in order to increase scientific literacy level, explicit-embedded-reflective instruction has significant potential since the approach includes teaching on both NOS aspects and content knowledge. With its potential to teach NOS aspects and content knowledge together, it has been thought that scientific literacy might also be increased by explicit-embedded-reflective instruction. Using only the explicit-reflective teaching approach where certain aspects of NOS are incorporated into science content courses has been shown to be effective in promoting informed understandings of NOS and it has been suggested by many researchers (Akerson, Abd-El-Khalick, & Lederman, 2000; Bell, Lederman, & Abd-El-Khalick, 1998). Explicit-reflective teaching means deliberately determining objectives, designing lessons and assessing the outcomes to address particular NOS issues and using pedagogical approaches that help students make connections between the activities they are doing and the NOS aspects (Clough, 2006; Lederman 1998; Khishfe & Abd-El-Khalick 2002). In addition to explicitness and reflection activities, embedding the NOS aspects into science content knowledge is another important component of NOS teaching (Clough, 2006). Embedding component includes making explicit-reflective teaching through the context of science instruction (Clough, 2006). Thus, explicit-embedded-reflective teaching includes teaching NOS aspects explicitly in science content and doing reflection by comparing their experience during teaching activities and NOS aspects in the context of science instruction. In spite of emphasis in explicit-reflective teaching on NOS aspects, embedding component also brings attention to content knowledge. Bell, Matkins, and Gansneder (2011) compared explicit and implicit teachings by using them as non-integrated and integrated contexts. Their study involved 75 elementary pre-service teachers and their findings showed that implicit teaching was not effective in increasing NOS understandings of the participants while explicit teaching was effective for teaching both content (global warming, global climate change) and NOS aspects. Along these findings, it can be expected that scientific literacy should also be increased by explicit teaching with integration or without integration to the content. Literature shows that explicit-embedded-reflective teaching has potential to increase NOS understandings and science content knowledge together and as such scientific literacy levels of students can be improved by explicit-embedded-reflective teaching.

In intervention studies including explicit-reflective teaching (e.g. Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Buzzelli, & Donnelly, 2008; Wenning, 2006), scientific literacy has not been explicitly assessed in spite of the fact that they clearly indicated the importance of scientific literacy in their theoretical frameworks and considered NOS understanding as a component of scientific literacy. As another side of scientific literacy, science content knowledge has not also been explicitly assessed with NOS aspects in the explicit-embedded-reflective (EER) teaching implications. But science content knowledge of students as a component of scientific literacy should also be taken into account in an intervention targeting to improve scientific literacy by teaching NOS aspects and content knowledge together. Because science content knowledge is an important part of scientific literacy and it also provides a context for applying NOS aspects to science, learning environments and knowing scientific theories, laws and concepts is a pre-requisite to discuss and reflect on the NOS aspects. In the present study, cell and cellular organization unit was selected as the science content because it is one of the richest subject matters to study NOS aspects. This unit includes many topics in which some of the nature of science aspects can be embedded such as change in cell theory (tentativeness), differences in membrane models (subjectivity) and difference in microscopic livings and their compartments (observation and inference). At the same time, this unit is the first one taught under the title of biology and it is a pre-requisite for further learning on important biology subjects such as biological organization, biological systems, organs and classification. The importance of the unit is also shown by the existence of the subjects of this unit in international examination studies including OECD/PISA (2003) and TIMSS (2007) science framework for eighth graders.

As a summary, NOS understandings and cell content knowledge components of scientific literacy should be assessed together to get more complete picture of the effectiveness of the EER teaching in increasing scientific literacy levels by changing the levels of NOS understanding and cell content knowledge. Another important point in literature on explicit-reflective teaching is that the majority of the studies using the explicit-reflective instruction were conducted with pre-service teachers (Akerson, Abd-El-Khalick, & Lederman, 2000; Kucuk, 2008). However, there is a lack of studies conducted with a sub-group of high school students such as advanced science students. They are special cases for scientific literacy studies due to their experiential differences, more exposure to science content and assessment situations. These students generally take more science courses; therefore, they are more experienced in science content than regular students are. Moreover, they are selected for science high schools and their programmes on the basis of the assessment of their results in special tests on science content. They are at the top of the distribution of students taking science content test and IQ tests (Ozaslan, Yildiz, & Cetin, 2009). Furthermore, these students will probably have a high status that will cause them to make important decisions for other people due to their success in science content and they are also future citizens of the society. As a result, these special students, as well as other students, should be studied in the EER teaching in terms of NOS understandings and content knowledge components of 'scientific literacy'.

After considering all of the points aforementioned, the purpose of the present study was determined as the investigation of the effectiveness of the explicit-embedded-reflective (EER) instruction on scientific literacy components including NOS understandings and content knowledge of ninth grade advanced science students about 'cell and cellular organization' subject. The findings on the NOS aspects of the study were reported elsewhere (Koksal, Cakıroglu, & Geban, 2013), so the findings on scientific literacy and cell content knowledge will be reported in this study. The basic assumption of the study is that "the improvement in NOS understandings and cell content knowledge will lead to an increase of scientific literacy". The research questions of the study are:

1 Is there any statistically significant difference between scientific literacy scores of the advanced science students who took explicit-embedded-reflective instruction on NOS and cell content, and those who took regular teaching on NOS and cell content?

2 Is there any statistically significant difference between content knowledge scores of the advanced science students who took explicit-embedded-reflective instruction on NOS and cell content, and those who took regular teaching on NOS and cell content?

Research Methodology

In this study, a non-equivalent quasi-experimental design was utilized. For the purpose of the study, a comparison group pretest-posttest design was used with quantitative data collection tools (Cohen & Manion, 1994; Fraenkel & Wallen, 2006).

The design has advantages of the use of comparison groups and pre-test over the pre-experimental designs (Shadish & Luellen, 2006). The design of the study is the most appropriate design as long as the true experimental conditions such as random assignment were not provided (Cohen & Manion, 1994). Due to the formal restrictions, a random assignment of the students could not be applied.

Participants

This study was conducted on 51 ninth grade academically advanced science students (15 years old; 28 female, 23 male) enrolled in two different intact classes of a science high school in Turkey. The students in the classes are similar to each other because they have taken biology course from the same biology teacher and they also have similar scores on the national examination for selection to Science High Schools. In addition, students at the same educational level must take the same content of the courses suggested by the Ministry of Education due to the fact that a common biology curriculum prepared by the Ministry of Education is applied in the whole country. None of the participants were enrolled in any activity or course regarding philosophy, history of science and scientific methods. The education levels of their mothers and fathers are 'high school' and 'university' levels. Science high schools have more time and a denser content for science courses than other types of high schools (6 course-times per week for ninth grades, 12 course-times per week for tenth, eleventh and twelfth grades). Science high schools, which are supported by the state and located only in the province capitals (the number of provinces is over 80), offer advanced science courses. Advanced science students in the country are selected according to their results at a nation-wide examination known as Student Selection Examination for Secondary Schools (SSE). According to the 2007 records of the Ministry of Education, 818,359 students took this examination (Turkish Ministry of Education, 2007). The students need to get higher scores on the science and mathematics part of the examination in order to be selected for science high schools. The majority of the students in science high schools are in the 5% highest scorers of the nation-wide examination and the range for the participants of this study is from 0.73% to 1.79%. Teachers are also selected for these schools by a formal evaluation process and examination.

Instruments

Data were collected by means of two instruments: Nature of Science Literacy Test and Cell Content Knowledge Test.

Nature of Science Literacy Test

For the purpose of the study, the Nature of Science Literacy Test, developed by Wenning (2006) was adapted for ninth grade advanced science students. The aspects to be assessed in this study were nature of scientific knowledge, scientific method, scientists and making informed decisions by using knowledge about science. The test was developed to assess scientific literacy levels. In the EER approach nature of scientific knowledge (tentativeness, etc.), scientific methods (one way to do science, etc.), characteristics of scientists (subjectivity, etc.) and making informed decisions (discussing examples including empirical basis of science, etc.) were taught by embedding them into cell content (see Table 2). As such, the test items were in line with the applications in EER approach. The author's permission was given via e-mail. Before piloting the test, all items (n=35), including 27 multiple-choice with four choices and 8 true-false items, were translated into Turkish by the researchers using direct translation. Then, the translated version of the items and the original version were evaluated by two bilingual experts both on science education and test development in the field of science education. Based on their recommendations, the corrections about wording and meaning were done by the researchers. In addition to the experts' opinions, one biology teacher examined the test with respect to its appropriateness and applicability for the level focused on in the study. After the corrections, the final form of the test including 35 items was administered to the 189 ninth grade advanced science students (73 female, 114 male and 2 missing data) for piloting the test items. Students completed the test in 20 minutes. Content validity was provided in reference to Wenning (2006) and two experts' opinions on the consistency between the purpose and content of the test.

To examine discrimination and difficulty indexes, ITEMAN programme was utilized. The elimination of items based on discrimination and difficulty values was conducted after three runs of the discrimination and difficulty analyses. The final form of the test included 25 items (19 multiple choice, 6 true-false) with higher discrimination values than 0.20. The reliability coefficient for the final form of the test was found to be 0.83. According to Gronlund and Linn (1990), this is an indicator of very acceptable internal consistency because the interval of 0.60-0.85 for reliability is useful for instructional decisions. In addition, the difficulty of the test was found to be appropriate for the level of the students due to the approximation of 0.60 value to 0.625 that is reference value of appropriate difficulty (Gronlund & Linn, 1990). One example question can be seen below:

Which of the following statements would a scientist consider false?

a) Established laws of science are universal and not merely local.

b) The natural laws in operation today can account for physical events past, present, and future.

c) Science allows for the existence of physical objects that cannot be directly observed, but that can be shown to exist through reason and experiment.

d) Misleading – All of the above would be considered true by a scientist.

There was only one correct answer for this question, while the remaining three choices were accepted as incorrect. For example, choice "D" was correct for this question. The participants who selected "D" got 1 point for the correct answer, while the others got "0" for their incorrect answer. Another item of the test can be seen below:

A teacher asks students, "What do you think will happen next?" The teacher is asking for a(n):
a) hypothesis
b) explanation
c) principle
d) prediction.

Cell Content Knowledge Test

The cell content knowledge test on the unit of 'cell and cellular organization' was developed by the researchers. The researchers wrote the items taking into consideration all of the objectives in the biology curriculum through an investigation of national examination test questions on the unit. As a result, 35 multiple-choice items with five choices were formed. All the questions and their corresponding objectives were analysed by two experts from the science education department by means of an evaluation form. The evaluation form consisted of items on 'understandability', 'difficulty of words', 'number of items', 'language of items', 'appropriateness to objective' and 'reading load'. Additional comments were also asked for in order to find out other points to consider. The agreement between these two experts on the aspects of the form was found to be very high except for wording of some sentences in the test.

After the discrimination and difficulty analyses by ITEMAN, the final form of the test included 25 items with higher discrimination values than 0.20 except for item 32 and nearly equal rate of items with high and low difficulty values. The reliability coefficient of the scores on the final form test was found as 0.75. It is an indicator of very acceptable internal consistency (Gronlund & Linn, 1990). The difficulty of the test was appropriate for the level of the students due to the approximation of 0.56 value to 0.60 as expected reference value (Gronlund & Linn, 1990). By inspecting purpose, objectives, validity parameters, reliability, difficulty and discriminating power of the test, it was concluded that the test is useful and appropriate for the purpose of this study. One example question can be seen below:

When you think of a cell as a city, which of the choices includes units of a cell which correspond to the town refuse and management unit of the city respectively?
A) Lysosome-Cell membrane
B) Centrosome-Endoplasmic reticulum
C) Vacuole-Nucleus
D) Mitochondria-Ribosome
E) Golgi apparatus-Nucleus membrane

In this question, the correct answer was "C". The participants who selected the correct answer were given "1" point, while "0" point was given to the participants who selected any of the remaining three choices.

Data Analysis

For the analysis of data in this study, paired samples t-tests and independent t-tests were used since there was no covariant associated with outcome variables. To test the effectiveness of the methods for both groups separately, paired samples t-tests on two dependent variables (content knowledge and scientific literacy level) were conducted by considering each group as a unit of analysis, while independent t-tests were used to compare two groups. To keep 0.05 alpha level constant throughout the analyses, Bonferroni adjustment was conducted, so 0.006 was set as alpha for the analyses. In the situations requiring more analysis techniques than one rather than using one comprehensive test such as ANCOVA due to insufficiency in providing the assumptions of the test, multiple comparison analysis application are applied. However, the inflation of alpha level for one test should be prevented by Bonferroni adjustment before starting the analysis (Gordon-Larsen, Nelson, & Popkin, 2004).

Treatment

In the study, Nature of Science Literacy Test, Cell Content Knowledge Test and personal information questionnaire were administered to the participants in all of the groups before the treatment. All the activities were prepared by the researchers except *the cube activity* which was adapted from Lederman and Abd-El-Khalick (1998). After the intervention, Nature of Science Literacy Test and Cell Content Knowledge Test were administered as post-tests. In this study, the following NOS aspects have been examined: 'tentativeness', 'empirical basis of science', 'distinction between observation and inference', 'role of creativeness and imagination', 'subjectivity', 'existence of no hierarchy between theory and law' and 'existence of no universally accepted one way to do science' (Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006). These aspects were frequently cited as problematic for high school students (Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; McComas, 1998). The sequence of the intervention entitled 'the explicit-embedded-reflective instruction' can be seen in Table 1.

In the study, teaching activities were conducted in two different stages: science content teaching and NOS teaching. In the process of teaching the cell and cellular organization unit as the first stage of teaching, the teacher who was female (45 year-old) and had 20-year teaching experience, and took NOS courses, used regular teaching strategies such as lecturing, questioning and demonstration. In both groups the same teacher applied EER instruction. These strategies were also indicated as regular ways of teaching biology by biology teachers in Turkey (Atici & Bora, 2004).

As presented in Table 1, the EER based instruction included conducting planned and purposeful activities in which NOS aspects were embedded in the content by using examples from the content for explaning NOS aspects, asking some discussion questions about the aspects, and then, doing a reflection activity on the aspects embedded in the content by comparing previous and current understandings on NOS, and explicitly explaining the NOS aspects to the students in collaborative groups. In the reflection activity, the participants compared their previous and current understandings on the NOS aspects and combined the content knowledge

Table 1

Content and sequence of 'explicit-embedded-reflective instruction'

Sequence/Time	1 /2 hr	2/1 hr	3/1 hr	4/2 hr	5/2 hr	6/2 hr	7/1 hr	8/2 hr	9/1 hr
Subject of the 'Cell' Unit	Basic compounds in livings	History of liveliness and views on it	Common characteristics of livings	Organic and inorganic compounds in livings	Cell theory	Cell model	Cell membranes	Prokaryotic and Eukaryotic cells and Plant and Animal cells	One cell, colony, multicellular organisms
Sequence	1 hr for content 1 hr for NOS	25 min. for content 20 min. for NOS	30 min. for content 15 min. for NOS	60 min. for content 30 min. for NOS	60 min. for content 30 min. for NOS	60 min. for content 30 min. for NOS	20 min. for content 25 min. for NOS	60 min. for content 30 min. for NOS	25 min. for content 20 min. for NOS
NOS Activity	Introduction of content knowledge and NOS aspects	1. Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content	1. Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content	1. Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content 5. Explicit evaluation of the learners on the aspects	1. Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content	1.Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content	1. Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content	1. Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content	1. Giving NOS examples from content with activities 2. Making discussion 3. Explicitly explaining the aspect 4. Reflection on examples on the content 5. Explicit evaluation of the learners on the aspects
Target NOS Aspects	All seven aspects	One way to do science	Observation and inference	Empirical basis	Hypothesis, theory and law	Creativeness and imagination	Tentativeness	Subjectivity	Observation and inference

and what they were doing on the NOS aspects. In other words, the participants in the treatment group were asked to compare their understandings on a NOS aspect after the NOS actvity regarding the aspect was completed and to connect their cell content knowledge and NOS aspect by evaluating content knowledge from NOS perspective. One sample reflection question asked after the activity was "*Could you compare your understandings on "tenativeness of scientific knowledge" before and after the instruction*?". In the process of the treatment, the first researcher made two assessments through open-ended questions in order to explicitly evaluate the understandings on the aspects of NOS and to check whether the situation was in line with the objectives determined at the beginning. The assessments were made during the lessons in the fourth and seventh weeks after the NOS activities.

In the comparison group, NOS aspects were implicitly taught to the students undergoing the regular approach including lecturing, demonstration and questioning. During lecturing, mostly "what and which" questions, which are not reflection questions, were directed towards the students. The time for each lecturing on the aspects of NOS in the comparison group was the same as the time for NOS activities done in the treatment group. Different from the experimental treatment, no specific instructional objectives on the aspects of NOS were determined and no assessment on the aspects was made in the comparison group. Since implicit teaching involves lack of explicit references (assessment, objectives, etc.) to NOS, it is included as a secondary component of the teaching process (Khishfe & Abd-El-Khalick, 2002). First, the content was explained, and then, the aspects of NOS were explained with the same approach used for the content. In line with implicit teaching, it was expected that only lecturing about NOS aspects without any reference to cell content in a limited time after lecturing, demonstration and questionining on cell subject was enough to learn NOS aspects.

In "Giving NOS examples from content with activities" section of NOS teaching, one NOS aspect such as "difference between observation and inference" was presented by embedding the NOS aspect into cell content knowledge. In one section of the unit, characteristics of living things were presented as content knowledge, so the aspect of "difference between observation and inference" was presented in this part of the unit. The cube activity can be given as an example of NOS activities used in the treatment group for the difference between observation and inference. In the activity, on the one side of the cube a characteristic of living things (e.g. stimulation) and a number (e.g. number 1) are written, and on the opposite side another characteristic of living things (e.g. movement) following the first characteristic and a number (e.g. number 2) showing the sequence of the characteristics are located. For example, 'stimulation (1^{st} characteristic) might cause movement (2^{nd} characteristic)' are presented on the opposite sides of the cube as shown in Figure 1.

In all of the opposite sides of the cube, two related items (cause-effect pair) were placed. The cube was placed in front of the students and they could see five sides of the

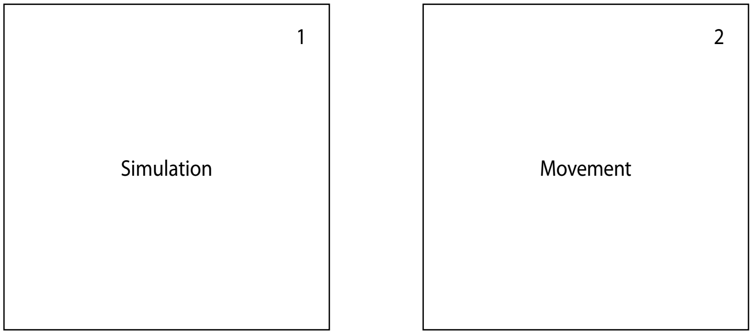

Figure 1. Two opposite sides of the cube used in the study

cube, except for the bottom side. They were asked to observe and examine the five sides, and find a pattern explaining the relationship between the cube's sides (cause-effect pairs in opposite sides), and then, make inferences about number and characteristic on the bottom side of the cube by using the pattern. During the activity, students found different characteristics and numbers after their observation. Following the activity, a whole-class discussion was initiated by the teacher by asking 'How do scientists reach their conclusions? By direct observation or by other ways? Is there any difference between inference and observation?'. Then, the teacher explicitly explained the target NOS aspect and students were given time to make their reflections on this aspect.

Another example of the activities was about "creativity and imagination in all stages of science". In the activity, the task of investigating an onion cell under the microscope to explain the structure of a cell was done by the students. During the investigation, the students were asked "how can you prepare a more efficient sample of onion cell to examine under the microscope?", "what can you use to examine onion cells more effectively under the microscope?", "what is the more effective way to draw onion cell images seen through the microscope?", "how can you make a model of an onion cell" and "which way do you prefer to introduce your cell model to a greater number of people?". These questions provoked the students to think imaginatively and creatively in order to find different alternatives during all the stages of a scientific study from the pre-investigation stage to the presentation stage of results.

Integrative learning was provided by making explicit references to cell content activity during discussion and reflection on NOS aspects. For example, cell content knowledge was provided by an investigation activity under microscope, discussion and questioning as presented in the previous paragraph and then the teacher presented explicit NOS examples from the content activity by showing every stage in their investigation required creativity and imagination. Explicit NOS examples presented by the teacher were discussed by the students and the teacher summarized the discussion and made explicit explanations on the NOS aspect. After the explicit explanations, students completed their reflection forms asking them about comparing their pre and post understandings on the NOS aspect.

All the lessons were conducted in a biology laboratory where students were seated in their chairs and there was one table for each group. The laboratory also has a computer, projector and a television for use, but the teacher did not prefer to use these means. After the lessons, it is expected that both content knowledge and NOS understandings will be improved and the improvement will lead to increase in scientific literacy.

Treatment Fidelity

In the study, the researchers prepared a handout explaining the theoretical foundations of the applications and a guide to proceed through the instructions to increase treatment fidelity. In addition to these applications, an observation checklist for the EER teaching was prepared to provide evidence for treatment fidelity by using the definitions of Khishfe and Abd-El-Khalick (2002), Khishfe and Lederman (2006), Lederman (2007),

Table 2

The ratings of the independent observers on the activities conducted in the treatment and comparison groups

Expected Components of EER Instruction	Ratings on Comparison Group Activities	Ratings on Treatment Group Activities
The objectives about the nature of science are explicitly included in lesson plans	-	++
The subjects of the nature of science aspects are taught as separate titles from the unit content in lessons	++	++
The development of the students on the aspects of nature of science is deliberately evaluated	+	++
The aspects of nature of science are taught by incorporating them into the unit content taught in the same lesson	-	++
The students have been studying the activities on the nature of science aspects as if studying the activities on unit content	+	++
The teacher has been explicitly informing the students that he or she has been teaching the nature of science aspects	+	++
During the lesson, students have been asking questions about the nature of science aspects	++	++
During the lesson, students have been taking notes about the nature of science aspects	-	+
During the lesson, students have been making explanations about the nature of science aspects	++	++
During the lesson, students have been discussing the nature of science aspects	++	++
During the lesson, the teacher has been making explanations about the nature of science aspects	++	++
At the end of the lesson, the students made a 'reflection' on their previous understandings and current understandings about the nature of science aspects	-	++

Note= - = No, + = Not Enough, + + = Yes.

Lederman (1998) and Akerson and Volrich (2006) on the EER teaching. Then, two other individuals as independent observers were asked to observe the teaching on the NOS aspects by the teacher. In total, six hours (85%) for the comparison group were observed, while a total of eight hours (57%) of experimental group studies were observed during the study. The duration of instruction for these two groups was equal but the observation times for each group were different due to the fact that the observers could participate in the observations only in these limited time intervals because of their individual programmes. The results on the ratings of the observers showed that important components of the EER teaching in the treatment group were implemented (see Table 2). One important point in these observations was that the participants in the comparison group also made explanations and participated in the discussions on the NOS aspects similarly to the participants in the treatment group. However, there was no reflection activity in the comparison group. Preventing explanations and discussions is very hard to control, especially in groups of advanced students because asking challenging questions, engaging in discussions and providing explanations are the most important characteristics of these students in science classrooms (Park & Oliver, 2009).

Results

Based on the results of t-tests for both paired and independent variables, the change in the scores of the students in each group prior to and after the study was investigated and the scores were also compared in order to determine the effectiveness of the EER approach. Descriptive values regarding the scores are given in Table 3.

Table 3

Descriptive values regarding the scores of the participants in the groups

Group	Variables	Measurement	Mean	n	SD	Skew.	Kur.	Std. Error of Mean
Comparison group	Content Knowledge	Pre-test	10.39	24	2.34	0.20	0.03	0.48
		Post-test	12,04	24	3.09	-0.14	-0.27	0.63
	Scientific Literacy	Pre-test	17.83	24	3.47	-0.60	-0.65	0.71
		Post-test	19.57	24	1.79	-0.12	0.96	0.37
Treatment group	Content Knowledge	Pre-test	10.93	27	2.60	-0.38	0.83	0.50
		Post-test	14.61	27	2.45	-0.77	0.42	0.47
	Scientific Literacy	Pre-test	19.60	27	1.78	0.13	-0.30	0.34
		Post-test	20.75	27	2.12	-0.30	1.00	0.41

Note: Skew=skewness, Kur= kurtosis

Before the main analysis, assumptions of the analyses were checked. The results on assumptions on normality and equality of variance showed that there was no violation of the assumptions. Table 4 presents the results on the normality assumption of the analyses.

After checking the assumptions of the analyses, independent t-tests were conducted to compare the groups on the dependent variables prior to and after the treatment period. There were no statistically significant differences in the other pre- and post-test scores of the comparison and treatment group participants in terms of both content knowledge and scientific literacy (p>0.006). However, the results of the independent t-tests showed that there were statistically significant differences between the post-test scores of the participants in treatment and comparison groups in terms of content knowledge (p<0.006). The effect size value regarding the difference was large. The difference was in favour of the participants in the treatment group. The results regarding independent t-tests can be seen in Table 4.

Table 4
Results on independent t-tests of the scores of the participants

Variables	Measurement	Mean Difference	t	df	p	d
Content Knowledge	Pre-test	0.53	0.77	49	0.45	0.22
Scientific Literacy	Pre-test	1.77	2.25	49	0.03	0.64
Content Knowledge	Post-test	2.56	3.30	49	0.00*	0.92
Scientific Literacy	Post-test	1.18	2.14	49	0.04	0.60

Note: '*' refers to statistically significant difference at the level of 0.006

The results of paired samples t-tests showed that there were statistically significant differences between the pre and post-test scores of the participants in the treatment group in terms of both content knowledge (large effect) and scientific literacy (medium effect) (p<0.006). Nevertheless, there were no statistically significant differences in the pre- and post-test scores of the comparison group participants in terms of both content knowledge and scientific literacy (p>0.006). Results regarding paired samples t-tests are presented in Table 5.

Table 5
Results on paired samples t-tests of the scores of the participants

Group	Variables	Pairs	Mean Difference	t	Df	p	d
Comparison group	Content Knowledge	Posttest-Pretest	1.65	2.18	23	0.04	0.60
	Scientific Literacy	Posttest-Pretest	1.73	2.18	23	0.04	0.63
Treatment group	Content Knowledge	Posttest-Pretest	3.68	6.32	26	0.00*	1.46
	Scientific Literacy	Posttest-Pretest	1.15	3.10	26	0.00*	0.59

Note: '*' refers to statistically significant difference at the level of 0.006

Discussion and Implications

The results on the t-tests provided some important insights into the effectiveness of the EER approach. It was determined that the EER approach was more effective than the regular approach to increase content knowledge of the advanced science students, and there was also an advantage of the EER approach over the regular way of teaching to increase scientific literacy among advanced science students. The positive effect of the approach on NOS understandings; another component of scientific literacy was also considerably clear but the findings on NOS understandings were reported elsewhere (Koksal, Cakıroglu, & Geban, 2013). Despite the fact that independent t-test results showed a non-significant difference between the groups in terms of scientific literacy, the paired samples t-test indicated a significant gain on scientific literacy in the treatment group, while there was no significant gain in the comparison group.

The possible reason for the increase in content knowledge level could be explained by the fact that EER teaching helps students get the opportunity to elaborate on science content knowledge during the teaching on NOS aspects. In other words, the embedding strategy provides a way to elaborate not only on NOS aspects but also on the cell unit content related to NOS aspects by the way that students might see use of the concepts, facts or other contents in scientific context. This might provide an opportunity to see the association between the content including facts and concepts and their use with their epistemological meanings. Elaboration includes establishing associations between two unconnected titles in a meaningful context. Making these associations might have increased the learning on cell unit during the treatment group activities. There have been some studies showing the effectiveness of elaboration in the literature. For example, Sahari (1997) in his meta-analysis study indicated that elaboration enhanced higher-order learning and its effectiveness is related to explicit teaching. Bell, Matkins, and Gansneder (2011) also focused on another biology topic; global climate change and global warming, they used explicit teaching by embedding NOS into the content. Their findings supported effectiveness of explicit teaching with integration on increasing NOS understandings and content knowledge levels of pre-service teachers.

The increase of content knowledge level in this study might also be related to the increase in content knowledge recall rate due to explicit exposure to the content and following elaboration both on the content and relationship between the content and NOS aspects. By focusing on the recall of facts, Wood (1989) studied the effectiveness of elaboration on the acquisition of facts such as facts about animals with fourth and eighth grade students. The author indicated that elaborative interrogation facilitated the acquisition of facts by children. Therefore, recall of the facts was also facilitated by elaboration. Similarly, Gallimore et al. (1977) stated that elaboration is an important process in increasing retention and recall of the names of objects. The authors studied the recall of shape names with 24 kindergarten children and they found that elaboration is very effective in long-term recall of the participants.

Another side of this research is that the benefits of the EER approach on scientific literacy might be related to its components including discussion and reflection. Studies reported in the literature show the effectiveness of discussion and reflection in promoting scientific literacy. For example, Gibson, Bernhard, Kropf, Ramirez, and Van Strat (2001) studied fourteen pre-service teachers to test the effectiveness of reflective journal application accompanied with cooperative group work in an introductory college science course. The reflection journals, at the same time, included discussion questions on the subject. The authors showed that the participants increased their scientific literacy levels by making reflections. They also added that making reflections provided the participants with an opportunity to see the relevance between science concepts and daily life and the application of these concepts to daily life. Another research study which was conducted by Lee (2007) focused on decision-making skills as a component of scientific literacy using the topic 'banning smoking in restaurants' as an issue. The study included 160 fifteen and sixteen year-old students. The author used discussion activities on smoking and cancer rates. He indicated that discussion activities provided benefits in decision-making skills. It was also effective for the increase of students' scientific literacy levels. As seen in the studies, discussion and reflection are two important components of the approach to increase scientific literacy. In addition to these studies, Millar (2006) studied 15 and 16-year-old students and their teachers in 78 schools to implement a scientific literacy approach developed by himself. Similar to the two previous studies, the author also used discussion and debate as the main components of his scientific literacy approach. According to the results of his pilot study, the interviewed teachers reported that the students reacted positively to the approach. Yacoubian and Boujaoude (2010) also showed in their study that discussion and reflection activities in an inquiry context were effective in the increase of scientific literacy levels of eighth grade students. This study also supported the finding of the current study that discussion and reflection are effective components of EER teaching on improving scientific literacy.

The findings of this study are important due to their contribution to simultaneously teaching NOS and cell content knowledge to academically advanced science students in order to increase their scientific literacy levels. The results of this study on scientific literacy and content knowledge have provided evidence for the efficiency of the EER approach, so the applications provided in the study might be used for further purposes to increase scientific literacy in advanced science courses. Therefore, the results of this study might be useful to develop the programmes on scientific literacy about biology issues in advanced classrooms. The results of this study provide a frame to increase advanced science students' scientific literacy levels in an integrative way between NOS and content knowledge components of scientific literacy. In this way, sophisticated knowledge of advanced science students on science might be used in making informed decisions. At the same time, the approach presented in this study might give insights into how to design a more balanced instruction on NOS aspects and cell content knowledge to increase scientific literacy. This study has also provided experimentally comparable results. This is important to establish a cause-effect relationship between treatment and change in dependent variables. Therefore, the results of this study contribute to the existing literature with its experimental nature and importance of the group studied for science education.

In this study, experimental design with non-equivalent groups was utilized. However, there is a need to conduct this study using true experimental approaches to control more threats. In addition to the attention given to internal validity threats, external validity should also be increased by replicating the study with a greater number of academically advanced science students. Moreover, discussion activities were conducted in the form of whole class discussion in the current study, but future studies should extend the approach by using more effective ways of discussion such as small group discussions or expert-novice discussions. The effectiveness of the approach has not been tested for different genders in this study, therefore, future studies should focus on the gender variable.

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Učinak eksplicitnog uključujućeg refleksivnog poučavanja na znanstvenu pismenost

Sažetak

Svrha ovoga rada bila je istražiti učinkovitost eksplicitno-uključujuće-refleksivne metode poučavanja (dalje u tekstu EER) na znanstvenu pismenost naprednih učenika devetih razreda iz prirodoslovlja procjenjujući poznavanje sadržaja i razinu znanstvene pismenosti. U istraživanju je sudjelovao 51 učenik, a provedeno je uz pomoć eksperimentalnog nacrta. U eksperimentalnoj skupini primijenjeno je poučavanje metodom EER, a u kontrolnoj skupini poučavanje je provedeno u obliku predavanja, demonstracija i strategija ispitivanja u kontekstu koji je orijentiran na nastavnika. Za prikupljanje podataka korišteni su Test znanstvene pismenosti i Test o poznavanju stanice. Za analizu podataka korišteni su T-testovi. Rezultati ovoga istraživanja pokazali su da je primjena EER metode u poučavanju učinkovita s obzirom na povećanje razina znanstvene pismenosti i znanja o stanici u eksperimentalnoj skupini. Nadalje, taj je pristup bio učinkovitiji kod podizanja razine znanstvene pismenosti i znanja o stanici od uobičajene metode poučavanja.

Ključne riječi: *eksplicitno-uključujuće-refleksivno poučavanje; napredni učenici prirodoslovlja; stanica; znanstvena pismenost.*

Uvod

Znanstvena pismenost u današnjem društvu promovira se posredstvom znanstvenih kurikula i reformskih dokumenata (Project 2061, 2007; Turkish Ninth Grade Biology Curriculum, 2007). Znanstvena pismenost definira se kao obrazovni cilj koji uključuje ono što bi ljudi općenito trebali znati o znanosti, znanje o prirodi znanosti, znanje o sadržaju znanosti, znanstvene metode, karakteristike znanstvenika i ono što bi oni trebali znati kako bi donijeli pravilne odluke koristeći se znanjem o znanosti (Bybee, 1997, str. 69; Durant, 1993, str. 129; OECD, 2009, str.14). Znanstveno pismena osoba morala bi imati sposobnost primjene, na principijelan način, znanstvenoga znanja ili pojmova kod svakodnevnih životnih problema te koristiti se jezikom znanosti u interpretaciji i produkciji govorenoga ili pisanoga teksta (Palinscar, Anderson, i David, 1993; Miller, 2011). Prema Norris i Phillips (2003), znanstveno pismena osoba također bi trebala razumjeti znanstveni tekst iz kojega bi mogla prepoznati je li nešto inferencija, hipoteza, zaključak ili pretpostavka, razlikovati objašnjenje od dokaza, tvrdnju od „znanstvenoga rezultata“ te izraziti sumnju ili se upustiti u spekulaciju. Detaljan i dulji opis karakteristika znanstveno pismene osobe u svakodnevnom životu dao je Hurd (1998). Hurd (1998, str. 413-414) je izjavio da bi znanstveno pismeni pojedinci morali moći razumjeti kako rješenja za društveno-znanstvene i osobno-građanske probleme nalažu sintezu znanja iz različitih područja koja uključuju prirodne i društvene znanosti, te da bi trebali znati da znanost u društvenom kontekstu često ima političke, pravne, etičke, a ponekad i moralne dimenzije, pa tako moraju imati sposobnost koristiti se znanjem o znanosti gdje je to važno za donošenje odluka u svakodnevnim životnim i društvenim situacijama kao što je prosuđivanje, rješavanje problema i poduzimanje mjera. Te karakteristike vrlo su bitne u svakodnevnom životu jer posjedovanje znanja o znanosti i njezinim proizvodima, te korištenje toga znanja za rješavanje problema prednosti su prilikom zapošljavanja, prilagodbe novom poslu, prilikom učinkovitog korištenja tehnologijom, kao i kod donošenja pravilnih odluka vezanih uz društvenu i znanstvenu problematiku (Khishfe, 2012).

Znanstvena pismenost uključuje oba *aspekta prirode znanosti (NOS)* i *znanja sadržaja* općenito kao cilj obrazovanja svih ljudi koji se pripremaju za život u modernome društvu (Damastes i Wandersee, 1992; Holbrook i Rannikmae, 2009; Uno i Bybee, 1994). Ponajprije je razumijevanje NOS-a (prirode znanosti) potrebno da bismo „pomogli učenicima kako bi poboljšali svoje opće razumijevanje znanosti“ (National Research Council, 1996, str. 200). Bez određenoga promišljanja o NOS-u, učenici teže vjerovanju da se „znanost radi, te da je ona skup činjenica koje se uče napamet“ (Akerson, Morrison, i McDuffie, 2006, str. 194). Priroda znanosti (NOS) uključuje mnoge aspekte, od znanstvene metode u znanstvenom društvenom i kulturnom kontekstu. Neki aspekti NOS-a smatraju se nezaobilaznima u poučavanju u školi (McComas, 1998), primjerice: ‘ne postoji jedan univerzalno prihvaćen način znanstvenoga rada“, „znanstvena spoznaja utemeljena je na činjenicama i promatranju“, „znanstvena spoznaja je provizorna“, „ne postoji hijerarhija između teorije i zakona“, „zakoni i teorije imaju različite uloge u znanosti“, „znanstvena je spoznaja teorijski opterećena“, „znanstvena spoznaja ugrađena je u socijalne i društvene kontekste“, „kreativnost i mašta važni su u stvaranju znanstvene spoznaje“, „znanstvenici nisu objektivni kada počnu učiti jer svaki znanstvenik ima osobnu povijest“ i „znanost je način znanja“ (Lederman, Abd-El-Khalick, Bell, i Schwartz, 2002; McComas, 1998). Citirajući istraživanje Driver, Leach, Millar, i Scott (1996), Lederman (2007) je ustvrdio da je razumijevanje NOS-a kao komponente znanstvene pismenosti vrlo važno za korisno, demokratsko, kulturno, moralno i znanstveno učenje aspekata života.

Unatoč naglasku na reforme u znanstvenim kurikulima o aspektima NOS-a, studenti ih još uvijek pogrešno tumače pa su i razine znanstvene pismenosti studenata neizravno posljedica pogrešnih shvaćanja (Dogan i Abd-El-Khalick, 2008; Khishfe i Abd-El-Khalick, 2002; Khisfe i Lederman, 2006). U svome istraživanju Khishfe i Lederman

(2006) ponudili su mnoge primjere pogrešnoga shvaćanja aspekata NOS-a kod učenika devetih razreda korištenjem upitnika Views on Nature of Science (Pogledi na prirodu znanosti) (u tekstu VNOS) uz prateći intervju. Saznali su da više od polovine učenika u uzorku ima naivno shvaćanje provizornoga pokazujući zamjenjivost i stabilnost kao znanstvenu spoznaju. Autori su također ukazali na postojanje naivnih shvaćanja aspekata „empirijske znanosti" kod većine učenika. Slično tome, neki učenici nisu uspjeli prepoznati razliku između opažanja i zaključivanja. Nadalje, većina učenika nije uvažila znanstvenu kreativnost, maštu i aspekt subjektivnosti u znanosti. Nakon godine dana autori su proveli slično istraživanje nad 89 učenika devetih razreda i 40 učenika desetih i jedanaestih razreda koristeći se upitnik VNOS-om i intervjuom. Velik broj ispitanika u ovome istraživanju vjerovao je da se znanstvena spoznaja neće promijeniti i imali su naivne poglede na aspekte znanosti „opažanje nasuprot zaključivanju" i „kreativna i maštovita znanost". Slično tome, većina ispitanika pokazala je naivno shvaćanje subjektivnosti (Khisfe i Lederman, 2007). Slični rezultati također su zabilježeni u istraživanjima iz drugih zemalja. Na primjer Kilic, Sungur, Cakiroglu, i Tekkaya (2005) proveli su istraživanje nad 575 učenika devetih razreda koristeći se metodom ankete i skale znanja o prirodi znanosti (NSKS). Zabilježili su da učenici srednjih škola nisu bili sigurni je li znanstvena spoznaja bezuvjetna ili nije, a imali su prilično informiran stav o „kreativnoj i maštovitoj" znanosti. U sličnome istraživanju srednjoškolaca u Turskoj, Dogan i Abd-El-Khalick (2008) proučavali su učenike desetih razreda o pogledima na znanstvenu spoznaju koristeći se instrumentom Views on Science-Technology-Society (Pogledi na znanost-tehnologiju-društvo) (dalje u tekstu VOSTS). Izvijestili su da svi ispitanici pokazuju naivno shvaćanje odnosa između teorija i zakonitosti, a da je većina imala prilično informirane poglede o aspektu „provizornosti" NOS-a. Ti učenici također nisu razumjeli samu prirodu teorija i odnos između znanstvenih modela i realnost. Navedeni primjeri indirektno ukazuju na nedovoljnu znanstvenu pismenost kod učenika.

Druga komponenta znanstvene pismenosti, odnosno sadržaj vezan uz znanost, također bi se trebao poboljšati razumijevanjem NOS-a. Ovo istraživanje bavi se znanjem o stanici s obzirom na činjenicu da je to uobičajena tema koja se poučava diljem svijeta i dovoljno je bogata za uvrštavanje aspekata NOS-a. Unatoč važnosti nastavne jedinice stanica i stanična organizacija, prijašnja istraživanja ukazala su na postojanje nesporazuma vezanih uz koncepte stanice među nastavnicima i učenicima (na primjer Flores, 2003; Kwen, 2005; Marek, 1986). Dreyfus i Jungwirth (1988) pokazali su da učenici ne razumiju, na odgovarajući način, koncept „stanice" (citirano u Tekkaya, 2002). Slično tome, Lazarowitz i Penso (1992) definirali su poteškoće u učenju izraelskih srednjoškolaca u vezi sa stanicom i organelima. U drugome istraživanju Flores (2003) proučava razumijevanje osam tema vezanih uz temu stanice na uzorku od 1200 srednjoškolaca. Teme su bile disanje, voda u biljkama, voda u životinjama, prehrana biljaka, oblici stanice, veličina stanice, reprodukcija. Prikupljajući podatke putem upitnika i intervjua, autor je izvijestio o problemima razumijevanja tema na različitim razinama biološke organizacije (stanica, organ, organizam). Neki učenici iz uzorka vjerovali su da su „stanični organeli isto što i organi" na staničnoj razini, a drugi su smatrali da „strukture kao što su kosti, hrskavice ili kosa „nisu sačinjeni od stanica", kao i da su „nokti i zjenice" sačinjeni od stanica na razini organizma. Također su vjerovali da se „stanice mijenjaju veličinom u istom odnosu kao i višestanični organizam" i „da veličina stanice u organu ovisi o vrsti i veličini organizma". Nadalje, neki učenici, pridajući stanične funkcije jezgri, smatraju da funkcije organela nisu poznate. U skladu s tim autor predlaže poučavanje tema na integriran način te upozorava na antropomorfne i izomorfne primjene nazivlja u biologiji. Slično kao i učenici, nastavnici su također imali neke zablude u ovoj jedinici. Primjerice, učitelji su vjerovali da stanice imaju jezgru (Kwen, 2005). Nastavnici su također vjerovali da stanice rastu sazrijevanjem organizma, točnije, da veličina stanice određuje veličinu organizma. Uz pogrešno shvaćanje stanica i organela, spontano povezivanje termina vezanih uz stanicu i organela bilo je problematično za nastavnike biologije (Douvdevany, Dreyfus, i Jungwirth, 1997). Pogrešno shvaćanje i pogreške nisu samo ograničene na nastavnike i učenike jer mnogi udžbenici iz biologije također sadrže različite zablude i pogreške o stanici i njezinoj strukturi. Storey (1990) ukazuje na mnoge zablude o citoplazmi, citoskeletonu, obliku organela, veličini stanice, staničnim stijenkama, strukturama membrane, izvanstaničnim matricama i spajanjima stanica u udžbenicima. Navedeni problemi također ukazuju na postojanje problema u znanstvenoj pismenosti kada je riječ o stanici.

Kako bi se prevladala pogrešna shvaćanja o NOS-u i problemima učenja o stanici te povećale razine znanstvene pismenosti eksplicitno-uključujući-refleksivni način poučavanja ima važan utjecaj i potencijal s obzirom na to da takav pristup podrazumijeva učenje aspekata NOS-a i sadržaja. S potencijalom zajedničkog poučavanja aspekata NOS-a i sadržaja smatra se da se znanstvena pismenost može poboljšati upravo primjenom eksplicitno-uključujuće-refleksivne metode poučavanja. Primjena samo eksplicitno-uključujuće-refleksivne metode, koja uključuje aspekte NOS-a u sadržaj znanosti, pokazala se kao puno učinkovitija u promidžbi informiranih shvaćanja NOS-a pa je predlažu mnogi znanstvenici (Akerson, Abd-El-Khalick, i Lederman, 2000; Bell, Lederman, i Abd-El-Khalick, 1998). Eksplicitno-refleksivno poučavanje podrazumijeva promišljeno određivanje ciljeva, stvaranje nastavnih jedinica i mjerenje ishoda uzimajući u obzir određene teme NOS-a, a koristeći se pedagoškim pristupima koji pomažu učenicima da nastoje stvoriti veze između aktivnosti koje rade i aspekata NOS-a (Clough, 2006; Lederman 1998; Khishfe i Abd-El-Khalick 2002). Uz aktivnosti koje su eksplicitne i refleksivne uvrštavanje aspekata NOS-a u sadržaj znanosti drugi je važan dio poučavanja NOS-a (Clough, 2006). Uključivanje podrazumijeva eksplicitno i refleksivno poučavanje putem konteksta poučavanja znanosti (Clough, 2006). Prema tome, eksplicitno-uključujuće-refleksivno poučavanje sadrži aspekte NOS-a eksplicitno u sadržaju znanosti i refleksije (osvrta) putem usporedbe iskustava iz drugih aktivnosti i aspekata NOSa u kontekstu poučavanja znanosti. Unatoč naglasku na eksplicitnom refleksivnom poučavanju aspekata NOS-a, komponenta uvrštavanja također usmjerava pažnju na znanje sadržaja. Bell, Matkins, i Gansneder (2011) usporedili su eksplicitno i implicitno poučavanja koristeći se njima kao odvojenim i integriranim kontekstima. Njihovo istraživanje uključivalo je 75 budućih učitelja, a rezultati su pokazali da implicitno poučavanje nije bilo učinkovito kod povećavanja shvaćanja NOS-a kod ispitanika, a da je eksplicitno poučavanje bilo učinkovito i za poučavanje sadržaja (globalno zatopljenje, globalne klimatske promjene) i aspekata NOS-a. Uz te pokazatelje može se očekivati da se znanstvena pismenost povećava putem eksplicitnog poučavanja i integracijom ili bez integracije sadržaja. Iz literature se vidi da eksplicitno-uključujuće-refleksivno poučavanje ima potencijal u poboljšanju shvaćanja NOS-a i znanja znanstvenog sadržaja. Razine znanstvene pismenosti učenika također se mogu poboljšati primjenom eksplicitno-uključujuće-refleksivnog poučavanja.

U istraživanjima koja su uključivala eksplicitno-refleksivno poučavanje (npr. Abd-El-Khalick, Bell, i Lederman, 1998; Akerson, Buzzelli, i Donnelly, 2008, Wenning, 2006) znanstvena pismenost nije bila eksplicitno ispitivana unatoč činjenici da su istraživanja jasno upućivala na važnost znanstvene pismenosti u svojim teorijskim okvirima i da je shvaćanje NOS-a smatrano sastavnim dijelom znanstvene pismenosti. Druga strana znanstvene pismenosti, znanje o znanstvenom sadržaju, također nije bila eksplicitno ispitivana aspektima NOS-a u eksplicitno-uključujućem-refleksivnom (EER) poučavanju. Međutim, znanje učenika o znanstvenom sadržaju kao komponenti znanstvene pismenosti također treba uzeti u obzir u intervenciji koja za cilj ima poboljšati znanstvenu pismenost istodobno poučavajući aspekte NOS-a i sadržaj. Upravo zato što je znanje znanstvenog sadržaja važan dio znanstvene pismenosti te nudi kontekst za primjenu aspekata NOS-a, okolina za učenje, poznavanje znanstvenih teorija, zakonitosti i koncepata preduvjeti su za promišljanje i refleksiju o aspektima NOS-a. U ovome istraživanju stanica i stanična organizacija odabrani su kao znanstveni sadržaj jer je to jedna od najbogatijih tema na kojoj se mogu primijeniti aspekti NOS-a. Ta nastavna jedinica sadrži mnoštvo tema u koje se mogu uključiti neki aspekti prirode znanosti kao što su promjene u teoriji stanice (provizornost), razlike u modelima membrana (subjektivnost) i razlika u mikroskopskim životima i njihovim odjeljcima (opažanje i zaključivanje). Istodobno, ta jedinica je prva koja se poučava pod nazivom biologija i preduvjet je za daljnje učenje o važnim predmetima iz biologije poput biološke organizacije, bioloških sustava, organa i klasifikacije. Važnost te jedinice vidljiva je u postojanju predmeta iz te jedinice u nacionalnim ispitima uključujući OECD/PISA (2003) i TIMSS (2007) znanstveni okvir za učenike osmih razreda.

Ukratko, znanstvenu pismenost i njezine sastavnice, shvaćanje NOS-a i znanje o stanici trebalo bi procijeniti zajedno kako bi se dobila cjelovita slika učinkovitosti EER poučavanja za povećanje razine znanstvene pismenosti promjenom razina razumijevanja NOS-a i znanjem o stanici. Druga važna stavka u literaturi vezanoj uz eksplicitno-refleksivno poučavanje jest da je većina istraživanja u kojoj se primijenilo eksplicitno-refleksivno poučavanja provedena na budućim učiteljima (Akerson, Abd-El-Khalick, i Lederman, 2000; Kucuk, 2008). Međutim, nedostaju istraživanja provedena na podskupinama srednjoškolaca poput primjerice naprednih učenika u prirodoslovnim školama. Oni su posebni slučajevi za proučavanje znanstvene pismenosti upravo zbog svojih iskustvenih razlika, veće izloženosti sadržaju iz znanosti te situacija provjere znanja. Ti učenici općenito imaju više znanstvenih predmeta pa tako imaju i više izloženosti sadržaju znanosti od ostalih učenika. Nadalje, oni su odabrani za programe prirodoslovnih srednjih škola putem provjera rezultata na specijalnim testovima znanstvenog sadržaja. Upravo ti učenici dolaze iz redova najboljih učenika na testovima prirodoslovlja i IQ testovima (Ozaslan, Yildiz, i Cetin, 2009). Nadalje, ti učenici vrlo će vjerojatno imati visok status koji će im u budućnosti omogućiti donošenje bitnih odluka za druge ljude, s obzirom na vlastitu uspješnost u znanstvenom sadržaju. Posebni učenici, kao i ostali učenici, trebali bi biti poučavani metodom EER s obzirom na „znanstvenu pismenost" i njezine sastavnice; shvaćanje NOS-a i sadržaj.

Uzevši u obzir sve prethodno spomenute detalje, svrha ovoga istraživanja bila je proučiti učinkovitost eksplicitno-uključujuće-refleksivne (EER) metode poučavanja u znanstvenom opismenjavanju, razumijevanje NOSa i znanje sadržaja „stanice i stanične organizacije" naprednih učenika devetoga razreda. Rezultati aspekata NOS-a iz istraživanja objavili su i drugi (Koksal, Cakıroglu, i Geban, 2013) pa su pronalasci o znanstvenoj pismenosti i znanju sadržaja o stanici prikazani i u ovome istraživanju. Osnovna pretpostavka istraživanja je da će „napredak u razumijevanju NOS-a i znanja sadržaja o stanici dovesti do poboljšanja znanstvene pismenosti".

1.Postoji li statistički značajna razlika između rezultata znanstvene pismenosti naprednih učenika prirodoslovlja koji su bili poučavani metodom eksplicitno-uključujućeg-refleksivnog poučavanja o NOS-u i stanici i onih koji su imali uobičajenu nastavu o NOS-u i stanici?

2. Postoji li statistički značajna razlika između rezultata o znanju sadržaja naprednih učenika prirodoslovlja koji su bili podvrgnuti poučavanju NOS-a i stanici putem eksplicitno-uključujuće-refleksivne metode i onih koji su poučavani NOS-u i stanici uobičajenom metodom?

Metodologija istraživanja

U ovome istraživanju koristila se metoda polueksperimentalnog – nejednakog pristupa. Za potrebe istraživanja nad kontrolnom skupinom proveden je predtest i posttest kako bi se dobili kvantitativni podaci (Cohen i Manion, 1994; Fraenkel i Wallen, 2006). Taj pristup ima prednosti u korištenju usporedbe kontrolne skupine i predtesta nad metodama predistraživanja (Shadish i Luellen, 2006). Nacrt ovoga istraživanja uistinu je najprimjereniji sve dok stvarni uvjeti za eksperiment poput nasumičnog odabira nisu osigurani (Cohen i Manion, 1994). Zbog formalnih ograničenja nasumična raspodjela učenika nije bila primjenjiva.

Ispitanici

Istraživanje je uključilo 51 učenika naprednoga prirodoslovnoga programa (15-godišnjaci; 28 ženskih, 23 muških) uključenog u dva različita razreda prirodoslovne srednje škole u Turskoj. Učenici u razredima vrlo su slični jer su pohađali nastavu biologije kod istog nastavnika biologije i imali su slične rezultate na nacionalnim testovima za odabir u prirodoslovnu srednju školu. Nadalje, učenici na istoj obrazovnoj razini moraju imati isti sadržaj predmeta koji predlaže Ministarstvo obrazovanja s obzirom na činjenicu da zajednički kurikul za biologiju priprema Ministarstvo obrazovanja i on se primjenjuje u cijeloj zemlji. Nitko od ispitanika nije bio uključen u aktivnosti ili predmet vezan uz filozofiju, povijest ili znanost i znanstvene metode. Obrazovna razina njihovih majki i očeva je „srednja škola" i „sveučilišna" razina. Prirodoslovne srednje škole imaju više vremena i opširniji sadržaj u predmetima prirodoslovlja od ostalih srednjih škola (6 nastavnih sati tjedno za učenike devetih razreda, 12 nastavnih sati tjedno za učenike desetih, jedanaestih i dvanaestih razreda). Državno poticane prirodoslovne srednje škole smještene su samo u županijskim centrima (postoji više od 80 županija) te nude napredne prirodoslovne predmete. Napredni učenici iz prirodoslovlja odabiru se na državnoj razini na osnovi rezultata nacionalnog testa poznatog kao Student Selection Examination for Secondary Schools (SSE). Prema podacima iz 2007. Ministarstva obrazovanja, 818.359 učenika bilo je podvrgnuto testu (Turkish Ministry of Education, 2007). Za upis u prirodoslovnu srednju školu učenici moraju imati bolje rezultate iz prirodoslovlja i matematike. Većina učenika iz prirodoslovnih srednjih škola ubraja se u 5 % najviših postignutih rezultata na nacionalnome ispitivanju, a raspon ispitanika u ovome istraživanju je od 0,73 % do 1,79 %. Za rad u takvim školama nastavnici su također podvrgnuti formalnim evaluacijskim procesima i ispitima.

Instrumenti

Podaci su prikupljeni korištenjem dva instrumenta: Test pismenosti prirode znanosti (Nature of Science Literacy Test) i Test znanja o stanici (Cell Content Knowledge Test).

Test pismenosti prirode znanosti (Nature of Science Literacy Test)

Za potrebe ovoga istraživanja Test pismenosti prirode znanosti, koji je razvio Wenning (2006), prilagođen je za napredne učenike prirodoslovlja u devetome razredu. Aspekti koji su se proučavali u ovome istraživanju jesu priroda znanstvene spoznaje, znanstvena metoda, znanstvenici i donošenje informiranih odluka koristeći se znanjem o znanosti. Test je razvijen kako bi se procijenile razine znanstvene pismenosti. U EER pristupu poučavanju priroda znanstvene spoznaje (promjenjivost itd.), karakteristike znanstvenika (subjektivnost itd.) i donošenje informiranih odluka (raspravljanje o primjerima koji uključuju i empirijsku osnovu znanosti itd.) poučavaju se njihovim uvrštavanjem u sadržaj stanice (vidi Tablicu 2). S obzirom na navedeno čestice u testu bile su u skladu s primjenama u EER pristupu. Autorovo odobrenje dobiveno je putem e-pošte. Prije samoga pilotiranja testa sve čestice (n=35), uključujući 27 pitanja višestrukog izbora s četiri izbora i 8 čestica točno-netočno, izravno su prevedene na turski jezik. Prevedenu inačicu čestica i originalnu verziju procijenila su dva dvojezična stručnjaka iz područja obrazovanja u znanosti i razvijanju testova u području obrazovanja u znanosti. U skladu s njihovim preporukama istraživači su proveli određene preinake u odabiru riječi i značenja. Uz mišljenja stručnjaka jedan je nastavnik biologije proučio test s obzirom na primjerenost i primjenjivost za razinu koja bi se proučavala u ovome istraživanju. Nakon ispravaka završni oblik testa za pilotiranje uključivao je 35 čestica te je primijenjen na 189 naprednih učenika prirodoslovlja (73 ženskih, 114 muških i 2 za koja su nedostajali podaci). Učenici su test riješili za 20 minuta. Valjanost sadržaja dobivena je referirajući se na Wenning (2006), a mišljenja dva stručnjaka ukazala su na konzistentnost između namjere i sadržaja testa.

Za ispitivanje indeksa diskriminacije i težine koristio se program ITEMAN. Eliminacija čestica na osnovi vrijednosti diskriminacije i težine provedena je nakon tri kruga analiza diskriminacije i težine. Konačni oblik testa sastojao se od 25 pitanja (19 pitanja višestrukog izbora, 6 točno – netočno) s vrijednostima diskriminacije većim od 0,20. Koeficijent pouzdanosti za konačni oblik testa bio je 0,83. Prema Gronlund i Linn (1990), to je pokazatelj vrlo prihvatljive unutarnje konzistentnosti jer je interval 0,60 – 0,85 za pouzdanost koristan za obrazovne odluke. Nadalje, težina testa bila je prikladna za razinu učenika s obzirom na vrijednost aproksimacije od 0,60 na 0,625, što je referentna vrijednost primjerene težine (Gronlund i Linn, 1990). Navodimo primjer pitanja:

Koju od sljedećih tvrdnji bi znanstvenik smatrao netočnom?
a) Utemeljene znanstvene zakonitosti su univerzalne, a ne samo lokalne.
b) Prirodne zakonitosti koje danas djeluju mogu objasniti fizičke događaje u prošlosti, sadašnjosti i budućnosti.
c) Znanost dopušta postojanje fizičkih predmeta koji se ne mogu izravno promatrati, ali njihova postojanost može se prikazati kroz prosuđivanje i eksperiment.
d) Zavaravajuće – Znanstvenik bi sve navedeno smatrao točnim.

Samo je jedan točan odgovor na navedeno pitanje, a tri su odgovora netočna. Primjerice, odgovor „D“ je točan odgovor na ovo pitanje jer je nakon uzorkovanja i testiranja opaženo da postoje i kisele i slatke zelene jabuke, ali da su sve jabuke u uzorku zelene i tvrde. Ispitanici koji su izabrali odgovor „D“ dobili su jedan bod, a ostali su dobili „0“ bodova za netočan odgovor. Druga čestica u testu glasi:

Nastavnik pita učenike: „Što mislite, što će se dogoditi sljedeće?“ Nastavnik traži:
a) hipotezu
b) objašnjenje
c) princip
d) predviđanje

Test znanja o stanici (Cell Content Knowledge Test)

Test znanja o stanici vezan uz nastavnu jedinicu "stanica i stanična organizacija" razvili su istraživači. Istraživači su napisali čestice uzimajući u obzir sve ciljeve kurikula biologije i proučavajući ispitna pitanja iz nacionalnih testova vezanih uz tu jedinicu. Slijedom toga oblikovali su 35 pitanja višestrukoga izbora s 5 mogućih odgovora. Sva pitanja i njihove ciljeve analizirala su dva stručnjaka iz odsjeka za prirodoslovlje putem evaluacijskih obrazaca. Evaluacijski obrasci sadržavali su stavke „razumljivost", „težina riječi", „broj čestica", „jezik čestica", „primjerenost cilju" i „složenost čitanja". Zatraženi su i dodatni komentari kako bi se razmotrile i druge pojedinosti. Slaganje među dva stručnjaka u aspektu forme bilo je vrlo visoko u gotovo svim segmentima osim kod odabira riječi u nekim rečenicama.

Nakon analize diskriminacije i težine ITEMAN-om, konačni oblik testa sadržavao je 25 čestica s vrijednostima diskriminacije većim od 0,20 osim kod čestice 32 i gotovo identičnu procjenu teških i laganih vrijednosti. Koeficijent pouzdanosti za rezultate u konačnom testu bio je 0,75. To je pokazatelj vrlo prihvatljive unutarnje konzistentnosti (Gronlund i Linn, 1990). Težina testa bila je primjerena razini učenika s obzirom na aproksimaciju vrijednosti 0,56 prema 0,60 kao očekivanoj referentnoj vrijednosti. (Gronlund i Linn, 1990). Ispitujući svrhu, ciljeve, parametre valjanosti, pouzdanosti, težinske i diskriminatorne snage testa, zaključeno je da je test koristan i primjeren za svrhu ovoga istraživanja. Jedan primjer ispitnoga pitanja je sljedeći:

Kada zamislite stanicu kao grad, koji od navedenih odgovora najbolje opisuje jedinicu stanice koja se podudara s gradskom jedinicom za zbrinjavanje i upravljanje otpadom?

A) lizosomi – stanična membrana
B) centrosomi – endoplazmatski retikulum
C) vakuola – nukleus
D) mitohondrij – ribosom
E) Golgijev aparat – nukleus membrane

Točan odgovor na ovo pitanje je "C". Ispitanici koji su dali točan odgovor dobili su "1" bod, a ispitanici koji su odabrali neki od ostala tri odgovora dobili su "0" bodova.

Analiza podataka

Za analizu podataka u ovome istraživanju koristio se t-test za zavisne uzorke i t-test za nezavisne uzorke s obzirom na to da nije postojala kovarijanca povezana s varijablama. Za ispitivanje učinkovitosti metoda za obje skupine zasebno koristio se t-test za zavisne uzorke na dvije zavisne varijable (znanje sadržaja i razina znanstvene pismenosti) uzimajući svaku grupu kao jedinicu analize, a dvije su grupe uspoređene nezavisnim t-testom. Kako bi se održala razina alfa na 0,05 tijekom analize, napravljena je Bonferronijeva korekcija, pa je 0,006 postavljena kao alfa u analizama. U slučajevima koji su zahtijevali više od jedne metode analize umjesto korištenja jednog sveobuhvatnog testa poput ANCOVA, zbog nedostatka pretpostavki testa, rađene su višestruke usporedne analize. Međutim, nedostatak alfa razine za jedan test trebala bi spriječiti Bonferronijeva korekcija prije početka same analize (Gordon-Larsen, Nelson, i Popkin, 2004).

Eksperiment

U ovome istraživanju, prije samoga eksperimenta, primijenjeni su Test znanstvene pismenosti, Test znanja o stanici i upitnik o osobnim podacima za sve ispitanike u svim grupama. Sve aktivnosti pripremili su istraživači osim *aktivnosti kocke* koja je prilagođena od Lederman i Abd-El-Khalick (1998). Nakon intervencije, primijenjeni su Test znanstvene pismenosti i Test znanja o stanici kao posttestovi. U ovome istraživanju, proučavani su sljedeći NOS aspekti: „promjenjivost", „empirijska osnova znanosti", „razlike između opažanja i zaključivanja", „uloga kreativnosti i mašte", „subjektivnosti", „nepostojanje hijerarhije između teorije i zakona" i „nepostojanje univerzalno prihvaćenog načina na koji znanost radi" (Khishfe i Abd-El-Khalick, 2002; Khishfe i Lederman, 2006). Ti aspekti često se navode kao problematični za učenike srednjih škola (Khishfe i Abd-El-Khalick, 2002; Khishfe i Lederman, 2006; Lederman, Abd-El-Khalick, Bell, i Schwartz, 2002; McComas, 1998). Slijed intervencije naslovljen „eksplicitno-uključujuće-refleksivno poučavanje" može se vidjeti u tablici 1.

U ovome istraživanju nastavne aktivnosti provedene su u dvije faze: poučavanje sadržaja prirodoslovlja i poučavanje NOS-a. U procesu poučavanja jedinice o stanici i građi stanice kao prvoj fazi poučavanja, nastavnica (45 god.) s 20 godina iskustva i NOS obrazovanjem, koristila se uobičajenim strategijama poučavanja poput predavanja, ispitivanja i demonstriranja. U obje grupe isti je nastavnik primijenio i EER metodu poučavanja. Te su strategije također prikazane kao uobičajeni načini poučavanja biologije nastavnika biologije u Turskoj (Atici i Bora, 2004).

Kao što je prikazano u tablici 1, poučavanje metodom EER uključuje izvođenje planiranih i svrsishodnih aktivnosti u koje su aspekti NSO-a uvršteni u sam sadržaj koristeći se primjerima iz sadržaja za objašnjavanje aspekata NOS-a. Postavljaju se pitanja za raspravu o aspektima, a putem refleksije o uvrštenim aspektima u sadržaj uspoređuju se prijašnja i trenutna shvaćanja NOSaa, te se NOS aspekti eksplicitno objašnjavaju učenicima putem suradničkog rada. U aktivnosti refleksije učenici uspoređuju svoje prijašnje i trenutno razumijevanje aspekata NOS-a te povezuju znanje sadržaja s aspektima vezanim uz NOS. Drugim riječima, ispitanici u eksperimentalnoj skupini morali su usporediti svoje shvaćanje aspekata NOS-a nakon što su odradili aktivnosti NOS-a sa znanjem sadržaja stanice vrednujući svoje znanje sadržaja iz perspektive NOS-a. Primjer refleksivnog pitanja nakon odrađivanja aktivnosti je sljedeći: „*Možeš li usporediti svoje shvaćanje „promjenjivosti znanstvenih spoznaja" prije i nakon poučavanja*?". Za vrijeme eksperimenta prvi je istraživač proveo dvije procjene putem pitanja otvorenoga tipa kako bi eksplicitno vrednovao razumijevanje aspekata NOS-a i kako bi provjerio odgovaral li situacija inicijalno postavljenim ciljevima. Procjene su napravljene za vrijeme nastavnoga sata u četvrtom i sedmom tjednu nakon NOS aktivnosti.

Tablica 1

Sadržaj i slijed "eksplicitnog-uključujućeg-refleksivnog poučavanja"

Slijed/Vrijeme	1 /2 sat	2/1 sat	3/1 sat	4/2 sat	5/2 sat	6/2 sat	7/1 sat	8/2 sat	9/1 sat
Tema jedinice „Stanica"	Osnovne sastavnice živih bića	Povijest života i pogledi na nju	Zajedničke karakteristike živih bića	Organski i anorganski spojevi kod živih bića	Teorija stanice	Model stanice	Stanične membrane	Prokarioti i eukarioti i biljne i životinjske stanice	Jedna stanica, kolonija, višestanični organizmi
Slijed	1 sat za sadržaj 1 sat za NOS	25 min za sadržaj 20 min za NOS	30 min za sadržaj 15 min za NOS	60 min za sadržaj 30 min za NOS	60 min za sadržaj 30 min za NOS	60 min za sadržaj 30 min za NOS	20 min za sadržaj 25 min za NOS	60 min za sadržaj 30 min za NOS	25 min za sadržaj 20 min za NOS
NOS aktivnost	Uvođenje sadržaja i aspekata NOS-a	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3.Eksplicitno objašnjavanje aspekta 4.Refleksija na primjere sadržaja	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3. Eksplicitno objašnjavanje aspekta 4. Refleksija na primjere sadržaja	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3. Eksplicitno objašnjavanje aspekta 4. Refleksija na primjere sadržaja 5. Eksplicitno vrednovanje učenika o aspektima	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3. Eksplicitno objašnjavanje aspekta 4. Refleksija na primjere sadržaja	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3. Eksplicitno objašnjavanje aspekta 4. Refleksija na primjere sadržaja	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3. Eksplicitno objašnjavanje aspekta 4. Refleksija na primjere sadržaja	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3. Eksplicitno objašnjavanje aspekta 4. Refleksija na primjere sadržaja	1. Davanje NOS primjera iz sadržaja s aktivnostima 2. Rasprava 3. Eksplicitno objašnjavanje aspekta 4. Refleksija na primjere sadržaja 5. Eksplicitno vrednovanje učenika o aspektima
Ciljani NOS aspekti	Svih sedam aspekata	Jedan način rada znanosti	Opažanje i zaključivanje	Empirijska osnova	Hipoteza, teorija i zakon	Kreativnost i mašta	Promjenjivost	Subjektivnost	Opažanje i zaključivanje

U referentnoj skupini aspekti NOS-a implicitno su poučavani uobičajenom metodom predavanja, demonstracije i ispitivanja. Za vrijeme predavanja učenicima su se uglavnom postavljala „što i koje" pitanja, što nisu refleksivna pitanja. Vrijeme predavanja o aspektima NOS-a za referentnu skupinu bilo je isto kao i vrijeme za izvođenje NOS aktivnosti u eksperimentalnoj skupini. Za razliku od eksperimentalne skupine u referentnoj skupini nisu bili određeni specifični ciljevi poučavanja o aspektima NOS-a niti su rađene procjene vezane uz aspekte. Implicitno poučavanje podrazumijeva nedostatak eksplicitnih podataka (vrednovanje, ciljevi itd.) za NOS, a NOS je prihvaćen kao sekundarni dio nastavnog procesa (Khishfe i Abd-El-Khalick, 2002). Prema tome, najprije je objašnjen sadržaj, a nakon toga su objašnjeni aspekti NOS-a koristeći se jednakim pristupom u poučavanju kao i za sadržaj. U skladu s implicitnim poučavanjem očekivalo se da je puko poučavanje o aspektima NOS-a bez poveznice na sadržaj nastavne jedinice stanice u ograničenom vremenu nakon predavanja, demonstracije i ispitivanja o stanici dovoljno za učenje aspekata NOS-a.

U dijelu poučavanja NOS-a „Davanje NOS primjera iz sadržaja s aktivnostima" jedan aspekt NOS-a, kao što je „razlika između promatranja i zaključivanja", bila je prikazana uključivanjem aspekta NOS-a u znanje sadržaja stanice. U jednom dijelu nastavne jedinice prikazane su karakteristike živih bića kao sadržajno znanje, pa je aspekt „razlika između opažanja i zaključka" prikazan u tome dijelu nastavne jedinice. Aktivnost kocke primjer je NOS aktivnosti u eksperimentalnoj skupini kako bi se uočile razlike između opažanja i zaključivanja. Na jednoj stranici kocke zapisana je jedna karakteristika živih bića (npr. stimulacija) i broj (npr. broj 1), a na suprotnoj strani druga karakteristika živih bića (npr. kretanje) i broj (npr. broj 2) ukazujući na slijed karakteristika. Na primjer „stimulacija (prva karakteristika) može uzrokovati kretanje" (druga karakteristika) prikazani su na suprotnim stranicama kocke, kao što se vidi na Slici 1.

Slika 1

Na svim suprotnim stranicama kocke dva su povezana elementa (uzrok – posljedica), odnosno jedan je uzrok i jedna posljedica. Kocka je stavljena pred učenike koji su mogli vidjeti pet stranica kocke, osim donje stranice. Učenici su morali promatrati i proučiti pet stranica i pronaći uzorak na način da objasne odnose između stranica kocke (uzrok – posljedica na suprotnim stranama), a nakon toga su morali zaključiti nešto o broju i karakteristikama na donjoj stranici kocke koristeći se tim uzorkom. Za vrijeme aktivnosti učenici su pronašli različite karakteristike i brojeve nakon promatranja. Nakon aktivnosti nastavnik je potaknuo raspravu u razredu postavljanjem pitanja: „Kako znanstvenici dolaze do zaključaka? Opažanjem ili nekim drugim načinima? Postoji li razlika između opažanja i zaključivanja?" Nakon toga je nastavnik eksplicitno objasnio aspekt NOS-a, a učenicima je dano dovoljno vremena da refleksivno promisle o tome aspektu.

Drugi primjer aktivnosti vezan je uz „kreativnost i maštu na svim stupnjevima znanosti". U toj aktivnosti zadatak učenika bio je proučiti stanicu luka pod mikroskopom kako bi se objasnila struktura stanice. Za vrijeme ispitivanja učenicima su postavljena sljedeća pitanja: „Kako možeš pripremiti učinkovitiji uzorak stanice luka kako bi je proučio pod mikroskopom?“, „Čime se možeš koristiti kako bi učinkovitije proučio stanicu luka pod mikroskopom?“, „Koji je učinkovitiji način crtanja stanice luka viđene pod mikroskopom?“, „Kako možeš izraditi model stanice luka?“ i „Koji način prikazivanja svoga modela stanice ljudima preferiraš?“ Ta pitanja potaknula su učenike na maštovito i kreativno razmišljanje kod pronalaženja alternativa u svim fazama znanstvenoga istraživanja, od predistraživanja do faze prezentacije rezultata.

Integrativno učenje omogućeno je ukazivanjem na eksplicitne reference na sadržaj nastavne jedinice „stanica“ za vrijeme rasprave i refleksije o aspektima NOS-a. Na primjer, znanje o stanici omogućeno je putem aktivnosti istraživanja pod mikroskopom. Nakon rasprave nastavnik je pokazao eksplicitne primjere NOS-a iz aktivnosti sadržaja ukazujući na to da je svaka faza u njihovom istraživanju tražila i kreativnost i maštu. Učenici su raspravljali o eksplicitnim primjerima NOS-a, a nastavnik je sažeo raspravu i dao eksplicitna objašnjenja o aspektima NOS-a. Nakon objašnjenja učenici su popunili obrasce u kojima se tražila usporedba razumijevanja NOS aspekata prije i nakon poučavanja.

Sva nastava održavala se u laboratoriju za biologiju. Učenici su sjedili u stolcima, a svaka je skupina učenika imala jedan stol. Laboratorij ima računalo, projektor i televizor, ali se nastavnik nije služio tim uređajima. Nakon održanih sati očekivalo se da će znanje sadržaja i shvaćanje NOS-a biti poboljšano i da će to dovesti do povećanja znanstvene pismenosti.

Vjerodostojnost eksperimenta

U ovome su istraživanju istraživači pripremili letak u kojemu su objasnili teorijsku podlogu primjene i vodič kroz upute kako bi se povećala vjerodostojnost eksperimenta. Uz to, pripremili su i kontrolni obrazac opažanja za poučavanje EER metodom kako bi osigurali vjerodostojnost eksperimenta koristeći se definicijama o poučavanju EER metodom (vidi Khishfe i Abd-El-Khalick, 2002; Khishfe i Lederman, 2006; Lederman, 2007; Lederman, 1998; Akerson i Volrich, 2006). Nakon toga, dva neovisna pojedinca zamoljena su da promatraju poučavanje o aspektima NOS-a. Za vrijeme trajanja istraživanja ukupno je šest sati promatrano u kontrolnoj i ukupno 8 sati u eksperimentalnoj skupini. Trajanje poučavanja u te dvije skupine bilo je jednako, međutim vrijeme promatranja bilo je drukčije za svaku skupinu s obzirom na činjenicu da su promatrači mogli sudjelovati u promatranjima u ograničenim vremenskim intervalima, s obzirom na njihove pojedinačne obaveze. Rezultati procjene promatrača pokazali su da su u eksperimentalnu skupinu uvršteni važni dijelovi poučavanja EER metodom (vidi Tablicu 2). Jedna bitna stavka u opažanjima bila je da su ispitanici iz referentne skupine također davali objašnjenja te da su sudjelovali u raspravama o aspektima NOS-a na vrlo sličan način kao i učenici u eksperimentalnoj skupini. Međutim, u referentnoj skupini nije zabilježena aktivnost refleksije. Onemogućavanje objašnjavanja i rasprava vrlo je teško kontrolirati, posebno u skupinama naprednih učenika jer su postavljanje izazovnih pitanja, upuštanje u rasprave i davanje objašnjenja najvažnije karakteristike tih učenika u nastavi prirodoslovlja (Park i Oliver, 2009).

Tablica 2

Procjena neovisnih promatrača vezana uz aktivnosti koje su provedene u kontrolnoj i eksperimentalnoj skupini

Očekivane sastavnice EER poučavanja	Procjena aktivnosti kontrolne skupine	Procjena aktivnosti eksperimentalne skupine
Ciljevi o prirodi znanosti eksplicitno su uvršteni u nastavne planove	-	++
Teme aspekata prirode znanosti poučavaju se kao zasebni naslovi od sadržaja jedinice poučavanja	++	++
Razvoj učenika vezan uz aspekte prirode znanosti namjerno je vrednovan.	+	++
Aspekti prirode znanosti poučavaju se njihovim uključivanjem u sadržaj nastavne jedinice za isti nastavni sat	-	++
Učenici uče o aspektima prirode znanosti putem aktivnosti kao da uče putem aktivnosti o sadržaju jedinice	+	++
Nastavnik eksplicitno informira učenike o tome da poučava aspekte prirode znanosti	+	++
Za vrijeme sata učenici su postavljali pitanja o aspektima prirode znanosti	++	++
Za vrijeme sata učenici su vodili bilješke o aspektima prirode znanosti	-	+
Za vrijeme sata učenici su pokušavali objasniti aspekte prirode znanosti	++	++
Za vrijeme sata učenici su raspravljali o aspektima prirode znanosti	++	++
Za vrijeme sata nastavnik je objašnjavao aspekte prirode znanosti	++	++
Na kraju sata učenici se osvrću na prethodno razumijevanje i trenutno razumijevanje aspekata prirode znanosti	-	++

Napomena= - = Ne, + = Nedovoljno, + + = Da.

Rezultati

Na osnovi rezultata t-testova za zavisne i nezavisne varijable ispitana je razlika u rezultatima učenika u svakoj skupini, prije i nakon istraživanja, a rezultati su uspoređeni kako bi se odredila učinkovitost EER metode poučavanja. Deskriptivne vrijednosti vezane uz rezultate prikazane su u tablici 3.

Tablica 3

Prije same analize provjerene su analize pretpostavki. Rezultati pretpostavki o normalnosti i jednakosti varijance ukazali su na to da ne postoji narušavanje pretpostavki. Tablica 4 prikazuje rezultate normalnosti pretpostavki iz analiza.

Nakon provjere pretpostavki iz analiza primijenjen je nezavisni t-test kako bi se usporedile skupine za zavisne varijable prije i nakon eksperimenta. U ostalim rezultatima predtestova i posttestova usporedbe kontrolne i eksperimentalne skupine u vezi sa znanjem sadržaja i znanstvene pismenosti nije uočena statistički značajna razlika ($p>0,006$). Međutim, rezultati nezavisnih t-testova pokazali su da postoji statistički značajna razlika između rezultata posttesta ispitanika u kontrolnoj i eksperimentalnoj skupini koja je povezana sa znanjem sadržaja ($p<0,006$). Vrijednost učinka veličine vezana uz razliku bila je velika. Razlika je bila u korist ispitanika iz eksperimentalne skupine. Rezultati vezani uz t-testove mogu se vidjeti iz tablice 4.

Tablica 4

Rezultati t-testa za zavisne uzorke pokazali su statistički značajne razlike između rezultata predtesta i posttesta ispitanika u eksperimentalnoj skupini s obzirom na znanje sadržaja (velik učinak) i znanstvenu pismenost (srednji učinak) ($p<0,006$). Međutim, statistički značajnih razlika u rezultatima predtestova i posttestova u kontrolnoj skupini s obzirom na znanje sadržaja i znanstvenu pismenost nije bilo ($p>0,006$). Rezultati vezani uz zavisne t-testove prikazani su u tablici 5.

Tablica 5

Rasprava i implikacije

Rezultati t-testova dali su neke važne uvide u učinkovitost EER pristupa poučavanju. Zaključeno je da je EER pristup učinkovitiji od uobičajenog načina poučavanja za povećanje znanja sadržaja kod naprednih učenika prirodoslovlja i da postoji prednost EER pristupa u odnosu na uobičajen način poučavanja da bi se povećala znanstvena pismenost među naprednim učenicima u prirodoslovlju. Pozitivan učinak pristupa na razumijevanje NOS-a, druga komponenta znanstvene pismenosti, također je vrlo uočljiva, ali su rezultati o shvaćanju NOS-a objavljeni i u drugim radovima (Koksal, Cakıroglu, i Geban, 2013). Unatoč činjenici da su rezultati nezavisnoga t-testa ukazali na neznačajnu razliku među skupinama s obzirom na znanstvenu pismenost zavisni t-test pokazao je značajnu dobit u pitanju znanstvene pismenosti u eksperimentalnoj skupini, a ona nije zabilježena u kontrolnoj skupini.

Mogući razlog za povećanje razine znanja sadržaja mogao bi se objasniti činjenicom da poučavanje EER metodom daje učenicima mogućnost razrade sadržaja iz prirodoslovlja za vrijeme poučavanja o aspektima NOS-a. Drugim riječima, strategija uključivanja omogućuje razradu ne samo aspekata NOS-a nego i sadržaja nastavne jedinice o stanici povezane s aspektima NOS-a na način na koji učenici mogu uvidjeti primjenu koncepata, činjenica ili drugih sadržaja u znanstvenom kontekstu. Taj način nudi mogućnost uviđanja poveznica između sadržaja koji uključuje činjenice i pojmove i njihovu primjenu putem epistemološkog značenja. Elaboriranje podrazumijeva stvaranje poveznica između dva nepovezana naslova u smisleni kontekst. Stvaranje tih poveznica možda je poboljšalo učenje nastavne jedinice o stanici putem aktivnosti u eksperimentalnoj skupini. Postoje istraživanja koja su ukazala na učinkovitost razrade. Primjerice, Sahari (1997) u svom istraživanju metaanalize ukazuje na to da razrada unaprjeđuje učenje na višoj razini, a njezina je učinkovitost povezana s eksplicitnim poučavanjem. Bell, Matkins i Gansneder (2011) usredotočili su se na drugu temu iz biologije: globalne klimatske promjene i globalno zatopljenje u kojoj su primijenili eksplicitno poučavanje uključivanjem NOS-a u sadržaj. Njihovi pronalasci idu u prilog učinkovitosti eksplicitnog poučavanja s integracijom na povećanje razumijevanja NOS-a i razine znanja sadržaja kod budućih učitelja.

Povećanje razine znanja sadržaja u ovome istraživanju također se može povezati s povećanjem stope prisjećanja sadržaja s obzirom na eksplicitnu izloženost sadržaju i prateću razradu sadržaja i odnosa između sadržaja i aspekata NOS-a. Usmjerenošću na prisjećanje činjenica, Wood (1989) je proučavao učinkovitost razrade na usvojenost činjenica poput činjenica o životinjama s učenicima četvrtih i osmih razreda. Autor je pokazao da su razrađeni upiti omogućili usvajanje činjenica. Prema tome, razrada je također pospješila i prisjećanje činjenica. Slično tome, Gallimore i sur. (1977) ustvrdili su da je razrada važan proces kod povećanja zadržavanja i prisjećanja naziva predmeta. Autori su proučavali prisjećanje naziva oblika kod 24 djece predškolskoga uzrasta te su ustanovili da je razrada vrlo učinkovita za dugoročno prisjećanje kod ispitanika.

Drugi aspekt ovoga istraživanja je taj da koristi EER pristupa na znanstvenu pismenost mogu biti povezane s elementima poput rasprave i refleksije. Istraživanja navedena u literaturi ukazuju na učinkovitost rasprave i refleksije u promidžbi znanstvene pismenosti. Primjerice Gibson, Bernhard, Kropf, Ramirez, i Van Strat (2001) proučavali su četrnaest budućih učitelja kako bi provjerili učinkovitost primjene vođenja refleksivnog dnevnika uz suradnički grupni rad za vrijeme uvodnih prirodoslovnih kolegija na fakultetu. Refleksivni dnevnici u isto su vrijeme uključivali pitanja za raspravu o određenoj temi. Autori su pokazali da su putem refleksije ispitanici povećali svoju razinu znanstvene pismenosti. Također su primijetili da je refleksija ispitanicima omogućila uvid u važnost povezanosti znanstvenih koncepata i svakodnevnoga života, kao i uvid u primjenu tih koncepata u svakodnevnome životu. Drugo istraživanje koje je proveo Lee (2007) bilo je usmjereno na vještine donošenja odluka kao sastavnice znanstvene pismenosti koristeći se problemom „zabrane pušenja u restoranima". Istraživanje je uključilo 160 učenika u dobi od petnaest i šesnaest godina. Autor se koristio raspravom o pušenju i stopi oboljelih od raka. Ukazao je na to da su aktivnosti rasprave bile korisne za vještine donošenja odluka. Isto je također bilo učinkovito i za povećanje razine znanstvene pismenosti učenika. Kao što su istraživanja pokazala, rasprava i refleksija dva su važna elementa pristupa kojima se povećava znanstvena pismenost. Uz ova istraživanja Millar (2006) proučava učenike u dobi od 15 i 16 godina i njihove nastavnike u 78 škola u primjeni pristupa znanstvenoga opismenjavanja koji je sam razvio. Slično kao i u prethodna dva istraživanja autor je upotrijebio raspravu i polemiku kao glavne elemente svog pristupa znanstvenom opismenjavanju. Prema rezultatima njegova probnoga istraživanja intervjuirani nastavnici izvijestili su da su učenici pozitivno reagirali na pristup. Yacoubian i Boujaoude (2010) također su u svome istraživanju pokazali da su aktivnosti rasprave i refleksije u kontekstu propitkivanja bile učinkovite u povećanju razine znanstvene pismenosti učenika osmih razreda. Navedeno istraživanje također je potvrdilo nalaz ovoga istraživanja da su rasprava i refleksija učinkoviti elementi EER poučavanja za poboljšanje znanstvene pismenosti.

Nalazi ovoga istraživanja važni su zbog svojega doprinosa usporednoga poučavanja NOS-a i znanja o stanici naprednih učenika prirodoslovlja kako bi se povećale razine njihove znanstvene pismenosti. Rezultati ovoga istraživanja na znanstvenu pismenost i znanje sadržaja dali su dokaz za učinkovitost EER pristupa. Zbog toga primjena opisana u ovome istraživanju može biti od koristi za daljnje pokušaje poboljšanja znanstvene pismenosti učenika u naprednim predmetima prirodoslovlja. Rezultati ovoga istraživanja mogu biti korisni za razvoj programa znanstvene pismenosti tema iz biologije za napredne učenike. Oni daju okvir prema kojemu se mogu povećati razine znanstvene pismenosti naprednih učenika iz prirodoslovlja integrirajući elemente NOS-a i znanja sadržaja. Na taj bi se način sofisticirano znanje naprednih učenika prirodoslovlja o znanosti moglo koristiti za donošenje informiranih odluka. Istodobno, pristup prikazan u ovome istraživanju mogao bi dati uvid u način kako stvoriti uravnoteženo poučavanje aspekata NOS-a i sadržaja stanice za bolju znanstvenu pismenost. Ovo istraživanje također je ponudilo eksperimentalno usporedive rezultate, što je važno kod stvaranja uzročno-posljedičnih odnosa između eksperimenta i promjene kod zavisnih varijabli. Stoga rezultati ovoga istraživanja mogu doprinijeti postojećoj literaturi svojom eksperimentalnom prirodom i važnošću proučavanje skupine za obrazovanje iz znanosti.

U ovome istraživanju koristili smo se eksperimentalnim pristupom s nejednakim skupinama. Međutim, uočena je potreba za provedbom ovoga istraživanja korištenjem autentičnog eksperimentalnog pristupa s ciljem kontroliranja prijetnji. Uz pažnju koja je posvećena prijetnjama interne valjanosti, eksterna valjanost također bi trebala biti povećana ponavljanjem istraživanja na većem uzorku akademski naprednih učenika prirodoslovlja. Nadalje, aktivnosti rasprave provedene su u obliku razredne rasprave, pa bi buduća istraživanja trebala proširiti pristup koristeći se učinkovitijim načinima raspravljanja poput rasprave u manjim skupinama ili rasprave stručnjak – učenik. U istraživanju nije bila ispitivana učinkovitost navedenog pristupa s obzirom na različite spolove, pa bi buduća ispitivanja trebala uključiti i varijablu spola.