CONCLUSIONES

Del análisis de resultados se puede concluir que se ha logrado el objetivo del estudio, la metodología adoptada ha permitido, conjuntamente, el aprendizaje de los contenidos y el desarrollo de diferentes dimensiones de la competencia digital. Además, estos resultados permiten pronosticar que las dificultades en la metodología se encuentran en la motivación y esfuerzo del propio alumnado, y no tanto en las competencias que se practican y desarrollan. Por ello, estos resultados de aprendizaje obtenidos por medio de los padlets animan a continuar el estudio extendiéndolo a otros contenidos de esta asignatura, a contenidos de otros cursos y a contenidos de otras asignaturas.

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Effectiveness of genetics student worksheet to improve creative thinking skills of teacher candidate students

Eficacia de la hoja de trabajo para mejorar las habilidades de pensamiento creativo de los estudiantes de genética

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Abstract

This research aimed to describe the effectiveness of a genetics student worksheet to train the creative thinking skills of teacher candidate students. The effectiveness of the worksheet was evaluated using the indicators achievement, self-assessment, and student responses. The worksheet was planned to give opportunity to develop creative thinking skills. Achievement indicators consisted of: presenting many ideas to solve the problem (fluency), formulating original idea (originality), modifying laboratory instruments, materials and experimental procedures (flexibility) and relating experiment result with theory (elaboration). Students worksheet was implemented with 15 students on the biology education program at the State University of Surabaya, Indonesia. This research was conducted using one group pre and post test. The result showed that there was creative thinking skills improvement (g score = 0.61). 93.3% of students assessed themselves as being able to practice creative thinking skills by using genetics student worksheet and 98.5% of students gave responses that the student worksheet enabled them to practice creative thinking skills. The research showed that the genetics student worksheet was effective in improving creative thinking skills.

Key words: *worksheet, genetics, creative thinking*

Resumen

Esta investigación tuvo como objetivo describir la efectividad de una hoja de cálculo para entrenar las habilidades de pensamiento creativo de los estudiantes candidatos a maestro. La eficacia de la hoja de trabajo se evaluó utilizando las respuestas de autoevaluación de estudiantes. La hoja de trabajo se planeó para desarrollar habilidades de pensamiento creativo. Los indicadores de logros consistieron en la presentacion de ideas para resolver el problema (fluidez), la formulación de la idea original (originalidad), la modificación de los instrumentos de laboratorio, materiales y procedimientos experimentales (flexibilidad), y en relación de los resultados experimentales con la teoría. Quince estudiantes elaboraron las hojas de trabajo en el programa de educación de biología. Esto se llevó a cabo mediante el uso de diseño de la investigación de prueba pre-post. El resultado mostró que hubo una mejora en habilidades de pensamiento creativo (g = 0,61). La investigación demostró que la hoja de trabajo fue eficaz para mejorar las habilidades de pensamiento creativo de los estudiantes.

Palabras clave: *hoja de cálculo, genética, pensamiento creativo*

INTRODUCTION

Curriculum that is implemented in Indonesia is curriculum of 2013. The objective of the curriculum of 2013 stated in the Policies of the Ministry of Education and Culture No. 69 is to prepare Indonesians to have life skills as individual and citizen who is religious, productive, creative, innovative, effective, and contributive to the nation (Ministry of Education and Culture, 2013). One of the essential abilities written in the Government Regulation and this seems that the challenge for the 21st century is creative thinking. Creativity is one of the main issues in all education and scientific organization that is continuously emphasized (Gholamian, 2013).

Creativity and innovation are the keys to success. Creativity is an important capacity for students to possess in order to face this fast-changing world. All individuals retain the ability to be creative (Raven, 2002). However, traditional sub-parcelling of the creativity has identified the person, the process, the products, and the environment as distinct elements that contribute to what is commonly called "creativity" (Rhodes, 1987). Several

strategies can be implemented to develop creativity. Tsai (2012) illustrated four stages of the creative process: preparation, incubation, illumination, and verification. Developing personal creativity involves the following four elements: understanding the process of creative thinking, identifying barriers to creative thinking and the skills individuals can use to increase creative response, using methods to get fresh ideas and solutions more often, and identifying a personal creative drive and life-long creative vision that will help individuals achieve their personal and professional goals (Mauzy, 2015). Each step in the process of developing personal creativity can be focused independently; and every exercise has been found to have some positive effect on a person's level of creative response. Furthermore, several researchers in the social sciences have identified contextual characteristics that improve the likelihood of being creative or arriving at a creative result (Amabile, 1983; Berry, 1999; Csikszentmihalyi, 1988; Niu & Sternberg, 2001; Raven, 2002; Rhodes, 1987).

There are many commercial products and planned programmes that improve creativity, such as books, kits, and software. Some are single activity, worksheet, or book focusing on a targeted idea or skills. It has been shown that worksheets can be planned to encourage divergent creative thinking and help record and organize ideas (Crammond et al., 1990). Therefore, it is possible to say that worksheet can be used as a strategy to encourage creativity in scientific discoveries and contribute to a country's development. It is known that those who can think creatively and critically are an important factor in the development of a country (Karsli & Sahin, 2009).

Creative thinking is a process allows/encourages gaps or disturbances to appear in conventional knowledge or ways of doing things which enable modification and reevaluation of hypotheses which have been made (Torrance, 2013). Similar to that statement, Anwar et al., (2012) explained that creative thinking is a way to raise ideas that can be applied to the world in a various new ways. Creative thinking is inseparable sense of dialogues concerning research questions and new ideas (Byron, 2012). According to Angawi (2014), creative thinking explains concepts, interprets existing data, and eventually, evaluates and criticizes various solutions. In addition, creative thinking ability is required to solve problems in everyday life (Maharani et al., 2015). Creative thinking is a multicomponent process which is mediated through social interactions that is explained by references to increasingly well-understood mental abilities such as cognitive flexibility and cognitive control that are widely distributed in the population (Dehaan, 2009).

Teachers should be attentive and creative in implementing appropriate learning process that can improve creative thinking ability. Teaching creative thinking supports the scholars by emphasising the links between environmental education and broader theoretical approaches that currently dominate research on creativity. Research in creative thinking is an actively growing field of study with a wide array of theories and perspectives. Creative thinking means posing a problem and trying to find a solution to it. Creative thinking helps the student to assess the causes and effects of a problem and apply a new way of thinking about the problem (Daskolia et al., 2011).

One of the creative thinking foundations is divergent thinking (Guilford, 1959). Divergent thinking requires ideational searching without directional boundaries. It is operationalized primarily by concept of *fluency*, *flexibility*, and *originality*, and secondarily by *elaboration* (Folley, 2006). Therefore, creative thinking has four indicators: (1) *fluence*, as ability to raise many ideas, (2) *flexibility*, as ability to raise various kinds of ideas, (3) *originality*, as ability to raise new ideas, and (4) *elaboration*, as ability to develop or add ideas in order to produce more detailed ideas (Baer in Aryana, 2007). Indicators of creative thinking can be implemented in the learning process by using a student worksheet. Karkockiene (2005) described that the realization of creative ability is not only dependent on knowledge and skills, but also on the usage of different information found in the tasks that need this kind of ability. This worksheet contains a manipulative task load because combining and juxtaposing ideas through trial and error processes has been thought to be a hallmark of creativity (Boden, 2004; Simonton, 2003). Jeffrey & Craft (2004) also explained that creative learning and creative teaching need to be defined, marked, and assessed. However, current student worksheet have not developed creative thinking ability

In biology, creative thinking is very important aspect to answer various questions, solve problems related to life, and to communicate the results of student work. One of the topics in biology that seems fit to develop creative thinking is genetics. Nowdays, students live in an era of ever-greater explosion of information, thus, the coverage of genetics becomes larger and the course curriculum expands (Griffiths & Mayer-Smith, 2000). The students are able to practice creative thinking by raising many ideas to solve the problem (*fluency*), developing the original idea (*originality*), modifying equipments, materials, and experimental procedures (*flexibility*), and relating the experimental result with theory (*elaboration*) through the student worksheet. In order to have effective results from laboratory practices, students should benefit from using worksheets.

The worksheets are developed to meet needs in the learning environment and also used for different purposes according to researchers needs or aims. The worksheet is also used for teaching science concepts (Karsli & Sahin, 2009). Using student worksheets in the learning process help the students to understand the material by themselves. Student worksheets also give a large opportunity for the students to demonstrate their ability and develop thinking process through discovery, observation and logic. The main goal of learning is to change behavior because of an experience. Therefore, this student worksheet was aimed to enrich creative thinking skills. The worksheet provided a suitable variety of opportunities for students to be creative in multiple ways by creating a poster, essay about science problem solving that correlated with environmental education, or other art-works.

The objective of this research was to describe the effectiveness of a genetics' student worksheet to develop creative thinking skills based on the indicator achievement, self-assessment, and student responses. Genetics education is essential for preparing society to engage in an informed debate about the future of genetics research and how its applications affect human health and the environment (Susane, 2006). Genetics is an essential part of biology that requires creative thinking skills to solve existing problems in society.

METHODS

Subject and research design

The sample of this research was 15 students from an advanced placement class, Department of Biology, Biology Education Program, Faculty of Mathematics and Natural Science, The State University of Surabaya. The research was applied using one group pre-post test design (Creswell, 2005). It was carried out at even semester 2013/2014 academic year, from January to May 2014, at Genetics Laboratory, The State University of Surabaya.

Learning objectives

The genetic worksheet expected the students to construct the flow of genetic information using DNA isolation. Students would also be able to correctly order the stages of gene expression and explain a genetic mutation and bacteria mutation.

Teaching strategies

The genetics student worksheet which covered two subtopics, i.e. deoxyribose nucleic acid (DNA) isolation and bacterial mutation, were supplemented with lab practices (experiment) in groups. Students were lectured about the general overview of the material. They were asked to answer a pre-test afterwards. After the lab practice had ended, the students were required to turn in lab report and answered a post-test. They were also asked to communicate their experiment result using creative presentation aids.

The first worksheet which related to the DNA isolation subtopic and asked the student to creatively modify the sample and reagent used (summarized in **Appendix A**). The worksheet explained the basic principle of DNA isolation and asked the student to conduct the experiment using various samples and reagents that could be chosen by their own decision. The samples included plant organs and animal organs, i.e. young leaf, mature leaf, chicken liver, and chicken epidermis. The reagents were replaced by various household chemicals to promote the usage of accessible lab materials in teaching. Most chemicals were provided to replace physiological buffer and sodium dodecyl sulphate (SDS) which would be needed in DNA extraction stage. There were also several questions stated in the worksheet to challenge the students to critically think the reason they chose particular sample and reagents in their experiment.

The second worksheet dealt with bacterial mutation which was induced by UV light (summarized in **Appendix B**). The worksheet explained the concept of mutation and detailed laboratory instruments and materials. However, the students were asked to creatively apply various exposure times and exposure distances of UV light to the bacteria culture. The worksheet also taught the students to calculate mutation rate based on their experimental

result. Critical thinking was promoted by several questions which asked student to present empirical evidence to explain the effect of UV intensity, exposure time, and exposure distance to the bacteria mutation rate.

Evaluation

The students answered the written pre-test before the lecturer introduced the genetics student worksheet. The pre-test consisted of two essay questions about DNA isolation and three essay questions about bacterial mutation. At the end of the session, they were asked to answer other two essay questions about DNA isolation and three questions about bacterial mutation in the post-test. The tests were assessed by rubric criteria and scored in a scale from 1 to 100 points (Table 1). All of the test questions were constructed based on achievement indicators (Table 2).

All students had the opportunity to assess their own learning capabilities using a self-assessment sheet that covered creative thinking indicators (Table 3). Comments were also invited on the content so that the material could be refined to improve student's learning capability. An attempt was also made to assess student response to the learning activities by closed questionnaire. Assessed aspects of this questionnaire was determined by the researchers based on the creative thinking indicators (Table 4).

Data analysis

Data collection was conducted using an essay test and questionnaire method with a self-assessment sheet and learning activities response sheet. The test score analyzed using average normalized gain (g) which is defined as the ratio of the actual average gain to the maximum possible average gain, i.e. $(g)=\frac{S_f-S_i}{100-S_i}$, where S_f and S_i are the final (post) and initial (pre) class average (Hake, 1999). Hake (1999) defined g score >0.7 as highly engaged activity to promote particular understanding; 0.7>g>0.3 as medium-engaged activity; and g<0.3 as poor-engaged activity. The self-assessment sheet and rhe learning activities response sheet were analyzed descriptively.

RESULT AND DISCUSSION

The result of this research consisted of indicator achievement, self-assessment of creative thinking training through genetics student worksheet, and student responses about lecturer's ability to develop creative thinking skills. The result showed that there was an improved indicator achievement with average g score = 0.6 (medium-g) (Table 1). This score indicated that genetics student worksheet could fairly engage students to conduct creative thinking skills.

Table 1. Pre-test and post-test result of DNA isolation and bacteria mutation

Student	Score		g	Category
	Pre-test	Post-test		
1	37.5	83.0	0.73	medium
2	46.3	77.5	0.58	medium
3	38.8	90.0	0.84	high
4	46.3	75.0	0.54	medium
5	48.8	82.5	0.66	medium
6	43.8	84.5	0.72	medium
7	27.5	76.5	0.68	medium
8	48.8	87.5	0.76	high
9	52.5	65.0	0.26	low
10	35.0	62.5	0.42	medium
11	48.8	58.0	0.18	low
12	38.8	72.5	0.55	medium
13	42.5	90.0	0.83	high
14	35.0	89.5	0.84	high
15	60.0	82.5	0.56	medium
Average	43.3	78.4	0.61	medium

Table 2. Achievement indicators in pre- and post-test

Topic	Indicators	Pre-test	Post-test
DNA Isolation	Analyzing the most suitable sample of experiment	34.2	100
	Modifying the experiment procedure of DNA isolation	19.4	65.9
Average Achievement (%)		25.3	79.5
Bacteria Mutation	Analyzing the most suitable sample used in bacteria mutation experiment	77.8	100
	Analyzing manipulation treatment toward bacteria mutation experiment	26.7	45.7
	Modifying the experiment procedure of bacteria mutation	74.7	100
Average Achievement (%)		61.3	80.7

Average achievement percentage of DNA isolation gained 25.3% to 79.5%. Meanwhile, average achievement percentage of bacteria mutation increased from 61.3% in pre-test to 80.7% in post-test (Table 2). This indicated that both of DNA isolation and bacterial mutation showed an improvement in test score after the genetics student worksheet was implemented. The worksheet provides a suitable variety of opportunities for students to be creative in multiple ways. Using the student worksheet in learning helps students to understand the material by themselves. Worksheets are also used for different purposes according to researchers' needs or aims, especially for teaching science concepts (Karsli & Sahin, 2009). There has been shown that well-planned worksheetss encourage divergent creative thinking and help to record and organize ideas (Crammond, et al., 1990).

Table 3. Student self-assessment of self-capability

No.	Aspects	Answer Percentage (%)	
		Negative	Positive
1.	I acquire opportunity to create many ideas to solve the problem (fluency)	0	100
2.	I acquire opportunity to create original idea to solve the problem (originality)	13.3	86.7
3.	I acquire opportunity to modify equipments, materials, procedures of experiment (flexibility)	0	100
4.	I acquire opportunity to relate experiment result with the theory of DNA isolation/bacteria mutation (elaboration)	13.3	86.7
Total		26.6	373.4
Total Percentage (%)		93.3	

The capability/behavior that students want to be improved:
Most of students wanted to improve their ability to conduct experiment by raising original and creative ideas. Students also wanted to improve honesty, discipline, carefulness, and thoroughness in learning and to operate laboratory instruments and materials including from the simple to complex technology.

Table 4. Student response in the learning activities of DNA isolation and bacteria mutation

No.	Aspects	Answer Percentage (%)	
		No	Yes
1.	The capability of lecturer to improve student's ability conducting problem analysis.	0	100
2.	The capability of lecturer to improve student's ability raising many ideas to solve the problem (fluency)	0	100

3.	The capability of lecturer to improve student's ability raising original ideas to solve the problem (originality)	0	100
4.	The capability of lecturer to improve student's ability modifying instruments, materials, and experiment procedures (flexibility)	0	100
5.	The capability of lecturer to improve student's ability relating experiment result and theory of DNA/bacteria mutation (elaboration)	6.7	93.3
Total		6.7	493.3
Total Percentage (%)		98.5%	

Average gain in pre-test and post-test affected learning outcomes. Increased learning outcomes were indicated from the increased achievement percentage. First pre-test achievement indicator that represented student's ability to analyze correct sample in DNA isolation increased from 34.2% to 100% (Table 2). Since the students had never been involved in isolating DNA before, the low score in the pre-test is caused by inadequate prior knowledge to determine which sample that was most suitable in experiment. The correct sample of DNA isolation experiment was chicken liver because the texture was easy to be disrupted and did not have cell wall; therefore this sample was easier to be treated. Most of the students answered young leaf and chicken liver. Even though all of the samples could be categorized as correct sample in DNA isolation, the accuracy of the answer that asked the most suitable sample was also important aspect in creative thinking assessment.

Second achievement indicator in DNA isolation topic that was covered student's ability to modify DNA isolation experiment showed improvement from 19.4% to 65.9% (Table 2). Many students overcame difficulties to modify DNA isolation experiment. Although some student groups failed to conduct the experiment, there was a group that could modify the procedure well so they could obtain the correct result. Modifying DNA isolation procedure could be conducted in these steps: 1) the application of vortexer was replaced by continuous filtration; 2) the usage of SDS solution was replaced by using detergent because this chemical household was colorless and contained high concentration of active SDS that led to easier DNA extraction step. This second indicator allowed the students to gain opportunity to modify laboratory instruments, materials, and procedures (*flexibility*) to promote creative thinking learning. According to Crammond et al., (1990), in order to improve creativity, there are many commercial products and programmes planned, including worksheet that encourages divergent creative thinking and help record and organize ideas.

In the bacterial mutation experiment, the achievement percentage increased from 61.3% to 80.7% (Table 1). This high achievement was represented by the increased achievement indicator. First indicator gained 77.8% to 100%, second indicator gained 26.7% to 45.7%, and third indicator improved from 74.7% to 100% (Table 2). The first indicator in the bacterial mutation was about analyzing the most suitable sample for the bacterial mutation experiment. The students did not overcome any difficulties to analyze the sample regarding to the their earlier experiment in microbiology lectures. The suitable sample for the experiment was *E. coli* or *Sigella*. Both of these bacteria were easier to take from environment and safe to be kept in laboratory. Even though these bacteria were not malignant, the students were aware to conduct safety procedures to maintain their own health. The second indicator was about analyzing behavior or manipulating bacteria mutation experiment. Student's creative thinking could be seen based on the their fair modification in the experiment. This modification consisted of applying various exposure distances to the UV light, various colchicine concentrations and various exposure times to the UV light. This creatively modified step produced highly variable experiment results that could enrich student's learning experiences. The second indicator provided opportunity to raise many ideas to solve the problem (*fluency*) and raise the original idea to solve the problem (*originality*); therefore this learning activities triggered creative thinking skills. Similar to this current result, Maharani et al. (2015) stated that creative thinking ability is required to solve problems in everyday life. The third indicator was about the procedure of bacteriai mutation increased from 74.7% to 100%. This indicator taught the students to conduct experiment by using the correct procedure. Experiment that was conducted by the students was very good because the technique had been applied in the microbiology lab session. This prior laboratory experiences made the students familiar with the procedure used in the bacterial mutation experiment. The third experiment developed the students' ability to think creatively by providing opportunity to modify laboratory instruments, materials, and procedures (*flexibility*). Furthermore, after the students discovered the experimental result, they had the opportunity to present and relate the result of experiment with theory that had been learned (*elaboration*) which was also one of the critical thinking learning aspects. Angawi (2014) explained that creative thinking expands the student to explain concepts, interpret spectral data, and eventually, evaluate and criticize various solutions. All of the test result improvement was consistent with student self-assessment that showed the students were capable of creative thinking skills (Table 3).

Student self-assessment that assessed student's capabilities indicated that most students were able to do creative thinking during their learning activities. However, the percentage of students that could not create original ideas to solve the problem (*originality*) and relate experimental result with the theory of DNA isolation/bacteria mutation (*elaboration*) was 13.3% (Table 3). Student response also showed that 6.7% of students negatively assessed that their lecturer was able to improve their ability to relate experiment result with the theory (Table 4). This result showed that the learning activities involving the genetic worksheet should be refined to help student to improve their capability in *originality* and *elaboration* aspects. Open comments in the self-assessment revealed that most students wanted to improve their honesty, discipline, carefulness, and thoroughness in the learning activities, and be able to use simple and complex laboratory technology.

Student worksheet as a part of teaching resources can foster students to generate their own thinking, ask questions, make connections, evaluate outcomes, so that the autonomy of the students increases as well (Chappell & Craft, 2009). Although an improvement in test was observed in the students, average gain of student worksheet engagement was only detected at medium level with positive self-assessed creative thinking indicators. As noted by McCormack (1971), creative-training may affect very little the actual ability of a person to be creative, but have much more impact on the attitudes and values regarding creativity. Therefore, creative training should include evaluation instruments that involve higher level of thinking, including creative thinking skills. Teacher candidate students should also possess broad understanding of creativity because they will teach mainstream classroom that needs positive impact of creative teaching (Seo et al., 2005).

However, any student worksheets cannot be generalized to improve creative thinking skills in the same way because the sample size was too small. The result of this research tentatively showed that student worksheet which emphasizes creative thinking indicators could be effective to develop creative thinking skills until the future researches with larger sample size confirm and strengthen the findings. These further researches will be needed to study the correlation effect of creative teaching, creative learning resources, and developed creative thinking skills that will provide more information about creative thinking skills improvement of teacher candidate students. Evaluation instrument that facilitate creative thinking assessment would be also helpful.

CONCLUSIONS

Genetics student worksheet was fairly effective to develop creative thinking skills regarding to the increased test score and creative thinking achievement indicator, positive self-assessed creative thinking capability from the students, and positive student response to lecturer's ability to develop creative learning activities. It is recommended that creative thinking-student worksheet should be also supported by creative teaching to increase *originality* and *elaboration* aspects.

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Appendix A

Title: DNA Isolation (Susantini, et al, 2014)

Introduction: Genetics research has been directed to molecular research. Deoxyribose Nucleic Acid (DNA), the genetic material of living organisms that acts as blueprint of genetic information, is important research object in molecular genetics. DNA analysis can be conducted when the DNA has been isolated or extracted from the sample. DNA isolation consists of three stages: 1) extraction, to separate the DNA from the cell using SDS/ CTAB/Triton-X as active detergent and concentrated NaCl, 2) purification, to separate extracted DNA from any contaminants, cell debris, protein, and RNA using phenol: chloroform: isoamylalcohol, and 3) precipitation, to precipitate the DNA as transparent or white fiber using cold 96% alcohol. DNA isolation technique is determined by the character of the sample used. Simple DNA isolation steps are as follows:

1. Prior to homogenization, 0.5 gram of sample was placed in the sterile mortar and added with physiological buffer
2. Homogenate was filtered using filter paper and placed in the sterile centrifuge.
3. Filtrate was mixed with 5 ml of SDS 20% and 5 ml of 5M NaCl using vortexer
4. Suspension was centrifuged to separate cellular components with cell debris
5. Supernatant was removed into new tube
6. Cold 96% ethanol was carefully added to the new tube through its wall
7. Please observe whether a white or transparent fiber occurred on the suspension surface

DNA isolation can be taught to high school students using materials around us. Try to conduct DNA isolation experiment by modifying provided instruments and materials

Objective: To modify the procedure of DNA isolation using available materials in the environment

Materials and instruments: mortar and pestle, tube and rack, filter paper, beaker glass, pipette, spatula, mineral water, raw water, young leaf, mature leaf, chicken epidermis, chicken liver, salt, sugar, detergent, dishes soap, liquid soap, alcohol

Discussion:

1. Create flow sheet procedure of your experiment
2. What is your sample? why do you choose that?
3. What is the material can be used to replace physiological buffer? Why do you choose that?
4. What is the material can be used to replace 20% SDS and 5M of NaCl? Why do you choose those?
5. What are the steps you modify to the existing standard procedure?

Please create presentation about your experiment result and attach the picture of your DNA

Appendix B

Title: Bacteria Mutation (Susantin, et al., 2014)

Introduction: Research in mutation is more effective to be conducted in prokaryotes. All of the prokaryotes genomes are exons that encodes functional protein. Therefore, little change in prokaryote's gene causes change in the produced protein. This change that is inherited to the offspring called mutation. Mutation can be caused by mutagen like ultraviolet (UV) radiation or colchicines. Mutation is defined as a permanent change in DNA and can be seen in the phenotype. Mutation can be classified into two groups: 1) spontaneous mutation, which is

caused by one or more unknown factors, and 2) artificial mutation, which is artificially made by known factor. This experiment asks you to learn about spontaneous mutation in *Escherichia coli* and calculate the mutation rate.

What are the possible research questions of this experiment?

Materials and instruments: culture of *E. coli*, nutrient broth, nutrient agar, sterile 0.1 M $MgSO_4$, 40 watt of UV light, sterile Erlenmeyer, 9 tubes which are filled with 9.9 ml of sterile nutrient broth and labeled as K 10^{-2}, K 10^{-4}, K 10^{-6}, L 10^{-2}, L 10^{-4}, L 10^{-6}, D 10^{-2}, D 10^{-4}, and D 10^{-6}, 3 tubes which are filled with sterile nutrient broth and labeled as K 10^{-7}, L 10^{-7} and D 10^{-7}, 6 Petri dishes which are filled with nutrient agar and labeled as NA-1, NA-2, NA-3, and NA-4, 6 Petri dishes which are filled with nutrient agar and 30 mg/l of penicillin (or another antibiotics) and labeled as NAA-1, NAA-2, NAA-3, NAA-4, NAA-5, and NAA-6, sterile tubes, cotton buds, 1 ml and 0.1 ml sterile syringes, 70% alcohol, antibiotics, and tin foil.

Please construct the experiment procedures related to the bacteria spontaneous mutation by using the materials and instruments above

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Science student teachers' ideas about the structure of the ear

Ideas de los estudiantes de licenciatura sobre la estructura del oido

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Abstract

The ear is of great importance for human beings when considered as a sense organ which fulfils the functions of hearing and balance in itself. The purpose of this research was to introduce the learning levels of science student teachers about the structure of ear. The learning levels of science student teachers about the structure of ear were researched by using a drawing technique in line with this purpose. In this research, 125 science student teachers were asked to draw the structure of ear and show the organs on it. Upon the analysis of the drawings made by the science student teachers one by one, it was concluded that most of them had partial understanding of the anatomic structure of ear (45%). However, it was found that some of them had some misconceptions and missing knowledge about where the malleus was found, where the auditory canal was found and what the internal ear, middle ear and external ear organs were in relation to the structure of the ear. It was important to reveal those findings from the science student teachers. The importance of the findings was analysed in detail in the light of the literature. Suggestions were presented in the light of these results.

Key words: ear structure, students' ideas, drawing methods.

Resumen

El objetivo de este estudio es exponer el nivel de comprensión de los candidatos para profesor en ciencias físicas en cuanto a la estructura de la oreja así como las estructuras que se encuentran en ella. Con este motivo se llevó a cabo un estudio sobre el nivel de comprensión de los candidatos respecto a la estructura de la oreja. En este estudio se pidió a 125 candidatos para ser profesor en ciencias físicas, dibujar la estructura de la oreja e indicar los órganos comprendidos en ella. Cuando fueron analizados los dibujos hechos por los candidatos uno por uno, se reveló el resultado de que la mayoría tenía conocimiento parcial de la estructura anatómica de la oreja (45%). Pero se constató que algunos de ellos tenían conceptos erróneos en lo que se refiere a la estructura de la oreja; a la ubicación del martillo, del canal auditivo, y no sabían identificar los órganos del oído interno, medio y externo así como les faltaba ciertos conocimientos. La constatación de estos datos ha sido reveladora. La implicación de estos datos se analizó a la luz de la literatura. Se ofrecieron las propuestas con el fin de ayudar a estructurar la información con vista a eliminar los problemas.

Palabras clave: *estructura de la oreja, ideas de los estudiantes, métodos para dibujar*

INTRODUCTION

It is expected to turn knowledge into behaviour in the meaningful structuring of knowledge. Meaningful learning of the concepts is the process of structuring learning and settlement. Meaningful learning becomes much easier when teachers and students add their own comments. Recently, most of the studies on learning have focused on active learning. The constructivist approach is one of these approaches. During this process, students establish a connection between the knowledge that they have obtained before and the knowledge they have obtained later. The knowledge of each of the students may be different from the others when their past experiences and knowledge are taken into account (Gagnon & Collay, 2001; Michael, 2006). The mental models of the students are of importance in structuring the knowledge (Hatano & Inagaki, 1997). Learning concepts and establishing relations with other concepts is also of great importance in obtaining meaningful learning (Novak & Gowin, 1984). According to Gagnon and Collay (2001), constructivism highlights learning rather than teaching. It takes the mental moulds of the learners into account. It gives importance to the content of the constructed learning. It gives the learners a chance to create new knowledge and comprehension from real experience. Some of the reasons which complicate learning and teaching biological science related topics are listed as: the topic involves invisible biological events and abstract concepts; there are too many interconceptual relations; the concepts in the topic are pronounced very similarly; the topic remains beyond the cognitive levels of the students; and the topic is not suitable for performing tests (Bahar, Johnstone & Hansel, 1999).

In the research which has been done recently about understanding, many techniques are used to set forth the conceptual understanding of the students. Open-ended questions (Eisen & Stavy, 1988), two-tier diagnostic tests (Maier, Wolf & Randler, 2016; Haslam & Treagust, 1987), interviews (Abdullah & Scaife, 1997), concept maps (Novak & Gowin, 1984), word association tests (Bahar, Johnstone & Sutcliffe, 1999) and drawings (Cardak, 2015; Prokop & Fancovicova, 2006) might be given as examples of these techniques. Using drawings to access a student's thinking has been a feature of educational research. Students can present a broad spectrum of ideas through drawings (Rennie & Jarvis, 1995). This is in contrast to what is exposed by standard written texts, where students can repeat what they learned in class without revealing their misconceptions (Scherz & Oren, 2006). Drawings introduce many dimensions of understanding rather than a single dimension. Whether or not the change which is expected during learning occurs can be set forth through the drawings made by the students. The drawing technique is used in order to determine whether the knowledge is meaningfully learned. Research also shows that the drawings of the students are a useful means to reveal the understanding of the students in studies in the science field. (Bahar, Ozel, Prokop & Usak, 2008; Cardak, 2009, 2015; Dikmenli, 2010a; Dikmenli, 2010b; Kose, 2008; Prokop & Fancovicova, 2006).

As a technique for exploring ideas, drawing taps holistic understanding and prevents students from feeling constrained by attempting to match their knowledge with that of the researcher (White & Gunstone, 1992). Thus, science researchers use the drawing technique in order to reveal the understanding of the students. The drawing technique could have some disadvantages besides some advantages just like every technique. Strommen (1995) found that children's drawings of forests yielded less information than interviews. In this study, the researcher found that the students drew a limited number of animal and plant examples rather than different species. It had a limited value in setting forth the species diversity of the living things according to the drawings of the students (Dove, Everett & Preece, 1999). Several researchers used children's drawings to examine their ideas about the digestive system (Cardak, 2015), cell division (Dikmenli, 2010a), carbon cycle (Dikmenli, 2010b), the water cycle (Cardak, 2009), the heart (Bahar et al., 2008), the functioning of plant organs (McNair & Stein, 2001) and the internal structure of animals (Prokop, Prokop, Tunnicliffe & Diran, 2007) in order to reveal the understandings of the students.

In his research on science student teachers understanding about the digestive system and organs in 2015, Cardak revealed some misconceptions about the fact that digestive system learning levels and digestive system organs are disconnected structures and which organs are responsible for digestion. In their study, Bahar et al. (2008) revealed insufficient knowledge and misconceptions about the internal structure of the heart based on the drawings made by the science student teachers. Prokop and Fancovicova (2006) also revealed that a maximum of 47.4% of prospective primary school teachers had such misconceptions about the function of the heart as "heart beating prolongs life".

Recent research has emphasized the importance of teaching anatomy and physiology topics. The preliminary knowledge of the students was of importance while teaching these topics. A limited amount of research has been made about face-to-face, hands-on, constructive laboratories in relation to teaching anatomy and physiology. Many studies were located which explore the use of online or virtual laboratories versus hands-on (Hilbelink, 2009; Johnston & McAllister, 2008; O'Byrne, Patry & Carnegie, 2008). Drawing technique was used not only to reveal the understanding of the students but also as a means of teaching in anatomy and physiology lessons (Clavert, Bouchaib, Duparc & Kahn, 2012; Kotzé, Mole & Greyling, 2012; Naug, Colson & Donner, 2011).

We perceive our environment through our sense organs. We see most things through our sense organs such as eyes, ears, nose, tongue and skin. When considered in this regard, the sense organs in the human body are important. The human body receives alerts from the external environment through the receptors in the sense organs and transmits them to the brain. Being one of our sense organs, the ear is of great importance as it is related to hearing and balance. There are several topics in biology which students have difficulty in understanding. Human anatomy and physiology related topics are among them. Research about ear structure and hearing is limited. In the Turkish education system curriculum, ear structure is taught in several lessons in elementary, middle and high school. Additionally, university science students learn about ear structure in general biology and human anatomy and physiology lessons.

This research aims to reveal the science student teachers' state of understanding the structure of ear. What are the levels of understanding of the science student teachers regarding the structure of ear? Moreover, an answer was sought for the question: What are the misconceptions of the science student teachers about the structure of the ear?

METHODOLOGY

In this study, drawing technique was used in order to reveal the understanding levels of the science student teachers about the internal structure of ear.

Participants

A total of 125 student teachers who are studying at Necmettin Erbakan University Ahmet Kelesoglu Education Faculty participated in this study in Turkey. University science student teachers voluntarily participated in the study. The age average of the student teachers who participated in the research was 20.7 (range = 18–25). Approximately 78% of the participant students were female. However, gender differences were not taken into account in this study. This research was carried out in March 2015. The participants of the research gained their knowledge about the structure of the ear in elementary, middle and high school, social studies, science and technology as well as biology lessons. Additionally, science student teachers learned their knowledge about the internal structure of ear in general biology, human anatomy and physiology and teaching technologies and material design lessons. The ear topic was taught in teaching technologies and material design lessons through model and material design.

Data collection and analysis

The students who participated in the research were asked to draw and show the structure and sections of ear in the human being in an empty A4 paper. The science student teachers were given 30 minutes to draw and show the internal structure of ear. The drawing technique allows the students to reveal their understanding levels deeply and in a detailed manner (Rennie and Jarvis, 1995). There is evidence that student science teachers' drawings may serve as a useful tool for probing their level of understanding of natural phenomena and for identifying the gap between students' misconceptions and scientific ideas (Reiss & Tunnicliffe, 2001; Tunnicliffe & Reiss, 1999). The student science teachers' answers to the drawing activity were analysed using a coding framework prepared by Kose (2008) and Reiss and Tunnicliffe (2001). And then, the drawings were given scores one by one by the researchers. Moreover, the drawings were also evaluated by two different biology and science education experts. The results were compared; score differences about a few cases were opened for discussion, and then a final decision about the scoring was made. The drawings were addressed as a whole and analysed through a scoring method that took the units on the drawing into consideration. The elements on the ear drawings were taken into account rather than the drawing capacities in the evaluation of the drawings. Five understanding levels were determined for the student teachers: no drawing, non-representational drawings, drawings with misconceptions, partial drawings and comprehensive representation drawings. Details of the levels are as follows (Cardak, 2009; Dikmenli, 2010a; Kose, 2008):

Level 1: No Drawing: Students replied, "I don't know," or no response was given to the statement.

Level 2: Non-Representational Drawings: These drawings included identifiable elements of the structure of the ear. In addition, the answers which included diagrams or formulations instead of the drawings were evaluated in this category. This category is illustrated by examples in Figure 1.

Level 3: Drawings with Misconceptions: These types of drawings showed some degree of understanding of the structure of the ear but also demonstrated some misconceptions; however, these were misconceptions held by scientists or stated in science texts. This category is illustrated in Figures 2a and 2b.

Level 4: Partial Drawings: The drawings in this category demonstrated partial understanding of the concepts. Drawings of the structure of the ear were included (Figure 3).

Level 5: Comprehensive Representation Drawings: Drawings in this category were the most competent and realistic drawings of the ear's internal structure (Figure 4). Drawings showing sound understanding contained seven or more elements of the validated response for that particular statement (Table 1).

RESULTS

In this research, in order to reveal the conceptual understandings of the student science teachers from their drawings, levels were created as follows: no drawing, non-representational drawings, drawings with misconceptions, partial drawings and comprehensive representation drawings (e.g. Bahar et al., 2008; Dove, Everett & Preece1999; Reiss & Tunnicliffe, 2001; Simpson & Marek, 1988; Usak, 2005); regarding the knowledge about anatomy of the researchers and the outcomes regarding ear structure mentioned in the Turkish biology/ science curricula. These five categories proved useful for classifying the science student teachers' responses in this study. The categories are shown in Table 1.

Table 1. Levels of science students' conceptual understanding of the structure of the ear

Level	Understanding	N(125)	%
Level 1	No drawing: Students replied, "I don't know," or no response was given to the statement.	4	2
Level 2	Non-representational drawings: These drawings were without identifiable elements of the ear structure. Answers, which included diagrams instead of the drawings, were also evaluated in this category. This category is illustrated in Figure 1.	11	9
Level 3	Drawings with misconceptions (These types of drawings showed some degree of understanding of the structure of ear but also demonstrated some misconceptions Figures 2a and 2b.)	17	14
Level 4	Partial drawings (The drawings in this category demonstrated partial understanding of the concepts. This category is illustrated in Figure 3.)	56	45
Level 5	Comprehensive representation drawings (Drawings in this category were the most competent and realistic drawings of the ear structure. This category is illustrated in Figures 4.)	37	30
Total		125	100

Based on the drawings of the student teachers, the most dominant level was level 4 where partial drawings were made as seen in Table 1 (45%). A total of 45% of the science student teachers made drawings with partial understanding. The category with comprehensive understanding drawings was 30%. The representative drawings of the student teachers were very few (9%). Student teachers know the structure of the ear partially. Additionally, it was clearly revealed that there were some misconceptions and missing information in some drawings (14%). The percentage of the science student teachers who had misconceptions was important. It is necessary to focus on them when we consider the fact that they will become teachers in the forthcoming years. All these results show that the student teachers had some insufficient information about the structure of the ear. Only four of the student teachers did not make drawings.

Drawings were analysed one by one, and the frequency of the organs which were drawn by the student teachers with regard to the structure of ear is shown in Table 2. In the drawings, there were mainly ear structure organs which are mostly responsible for hearing such as pinna, eardrum, ear canal, cochlea, malleus, incus, stapes, eustachian tube, semicircular canals, oval window, hearing nerves and vestibule. Most of the student teachers (82.4%) drew pinna; 62.4% of them drew the eardrum; 56.8% drew the ear canal. Other percentages are shown respectively in Table 2. It was found that student teachers drew the external ear, middle ear and internal ear organs in their drawings.

Figure 1 shows a non-representational level 2 drawing by a science student teacher. The science student teacher drew a diagram instead of a drawing. Figures 2a and 2b show the drawing samples of level 3 student teachers with misconceptions. As is seen in Figures 2a and 2b, the student teachers have misconceptions about the structure and location of the organs of the ear which are responsible for hearing. In Figure 2a, the student teacher thinks malleus, anvil and stapes bones are found in the internal ear. Moreover, the student teacher who made this drawing did not draw the nerves which are responsible for hearing and the semicircular canals in the internal ear. In Figure 2b, on the other hand, the science student teacher thinks the ear path is the eustachian tube. Moreover, this science student teacher drew only malleus which is found in the middle ear. He did not draw the anvil and the stapes bones. Likewise, this student teacher did not draw all the organs in the internal ear which are responsible for hearing. He only drew the cochlea. He did not draw the semicircular canals and hearing nerves.

Table 2. The most frequent structure drawn by students

	N(125)	% from total
Pinna	103	82.4
Eardrum	78	62.4
Ear canal	71	56.8
Cochlea	55	44.0
Malleus	51	40.8
Incus	41	32.8
Stapes	40	32.0
Eustachian tube	33	26.4
Semicircular canals	32	25.6
Oval window	29	23.2
Hearing nerves	19	15.2
Vestibule	17	13.6

In Figure 3, there is a partial drawing (level 4). The student teacher drew the pinna, the eardrum and cochlea in the internal structure, the semicircular canals and the Eustachian tube. However, there are some missing things. This science student teacher had a partial understanding of the structure of the ear (Figure 3). In Figure 4, there is a drawing by the student teacher with comprehensive understanding who did not have any misconceptions. The student teacher drew and wrote the names of more than seven organs. The student teacher fully drew all the organs of the external ear, middle ear and internal ear. All the organs of the ear were in their correct place. In Figure 5, on the other hand, the student teacher only drew the pinna. He did not draw the organs in the middle ear and the internal ear (Figure 5).

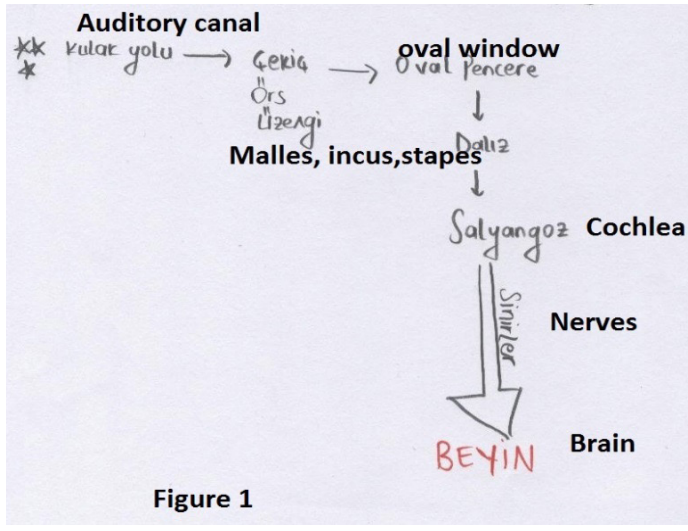
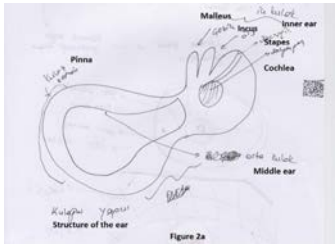
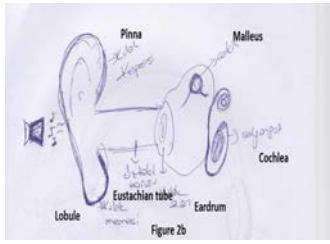


Figure 1. Example of level 2 (non-representational drawing) (Student 35)





Figures 2a and 2b. Examples of level 3 (drawing with misconception) (Student 61 and Student 70)

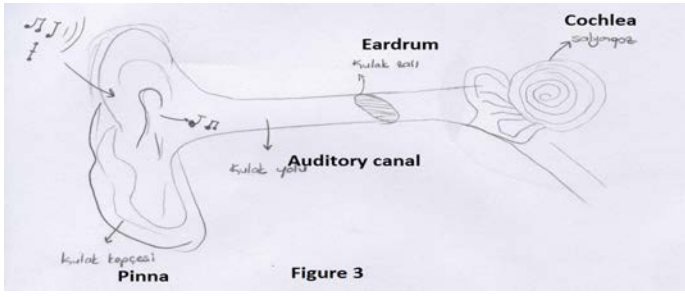


Figure 3. Example of level 4 (partial drawing) (Student 18)

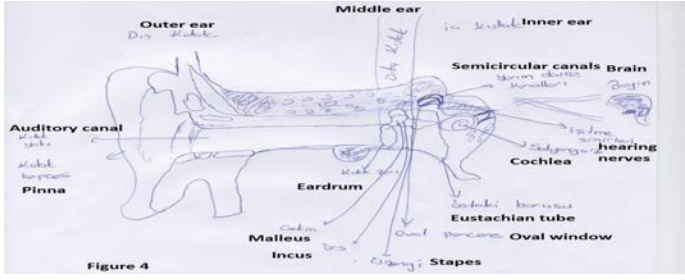


Figure 4. Example of level 5 (comprehensive representation drawing (Student103)

In Figure 6, the student teacher drew the malleus which is in the middle ear on the pinna. And, he did not draw the stapes. The student teacher also had misconceptions about the location of the organs in the structure of ear (Figure 6).

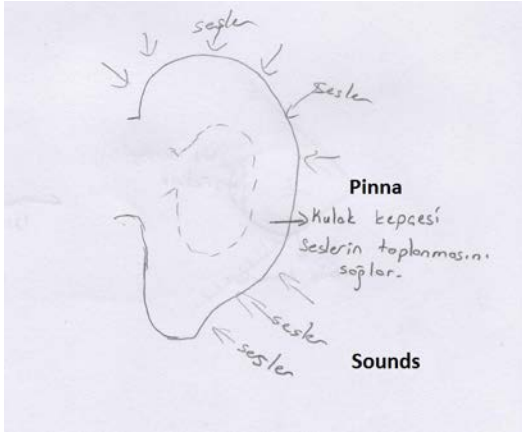


Figure 5. Drawing with misconceptions in relation to the internal structure of ear (Student 42)

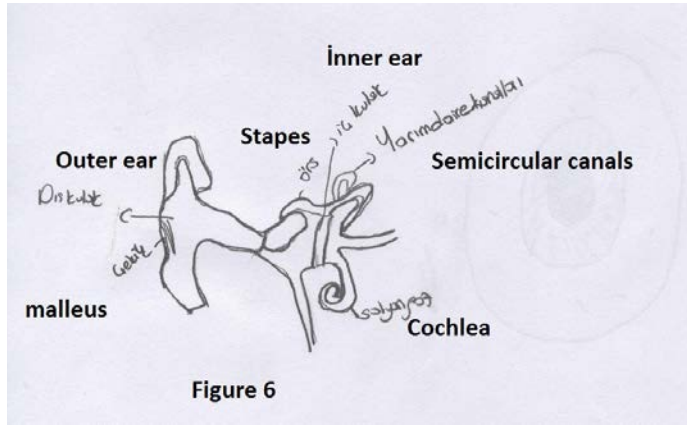


Figure 6. Drawing with misconceptions in relation to the internal structure of ear (Student 56)

DISCUSSION AND IMPLICATIONS

The purpose of this study was to determine the understanding of the science student teachers about the structure of the human ear by using the drawing technique. In general, the findings of this study showed that science student teachers had knowledge with partial understanding. And, they also had some insufficient knowledge and misconceptions about the structure of the ear and the location of the organs. One of the misconceptions of the student teachers was that the malleus is located on the pinna. Another one was that the ear path was shown as the Eustachian tube. Also, some of the student teachers drew the malleus, anvil and stapes bones within the internal structure borders. Additionally, another student drew sound entering from the internal ear and hearing starting from the internal ear. In this research, nearly half of the student teachers (45%) had partial understanding (Figure 3). The student teachers with partial understanding were those who could not fully draw all the elements which are scientifically acceptable. They showed less than seven organs in the structure of the ear. A total of 30% of the student teachers made comprehensive drawings. These student teachers were those who showed at least seven of the organs of the ear. The results of this study showed that the drawing technique was effective in revealing the understanding conditions as in the other studies (Bahar et al., 2008; Cardak, 2015; Dikmenli, 2010a; Kose, 2008; Prokop et al., 2007).

As we have previously mentioned, the drawing method had some advantages as well as disadvantages in revealing the understanding levels of the student teachers (Dove et al., 1999).In this study, the science student teachers were informed about the drawing method, and a practice session was done. However, it seems that the limitations of the method may have caused difficulties since the drawing of the structure of the inner ear may require more skills than drawing an ordinary concept.

One reason why the science student teachers had all these misconceptions and insufficient knowledge could originate from the teaching methods and techniques used, for misconceptions are quite resistant to change (Bahar, 2003; Pfundt & Duit, 2004). Wandersee, Mintzes and Novak (1994) state that misconceptions cannot be removed by traditional teaching strategies. Additionally, forming and correcting mental maps and models through constructivism and hands-on learning is extremely advantageous (Wandersee, Mintzes & Novak, 1994). In most of the education level in Turkey, teachers and lecturers use mainly teacher-centred strategies that promote memorization and reproduction of knowledge on the day of examination where the multiple choice format is mainly used (Bahar et al, 2008; Bahar, 2003). Recently, there has also been research about the effectiveness of the of use of face-to face, hands-on, constructive laboratories, drawing technique in teaching anatomy and physiology topics (Clavert et al., 2012; Kotzé, Mole & Greyling, 2012; Naug, Colson, & Donner, 2011). Some research even revealed that online and virtual laboratories should be used (Hilbelink, 2009; Johnston & McAllister, 2008; O'Byrne, Patry & Carnegie, 2008).

The teaching strategies in which student teachers will be more active should be used in order to avoid the misconceptions about the internal structure of the ear and minimize and change the missing knowledge and

misconceptions of the student teachers. Learning by doing and through experience, face-to-face, hands-on learning strategies will be effective in preventing and changing misconceptions. Primarily, it is necessary to determine the misconceptions in order to change the misconceptions of the students. Moreover, teaching technologies and virtual reality techniques are certainly effective in teaching internal ear structure topics and providing conceptual change in order to assist meaningful learning. Missing knowledge and misconceptions can also be eliminated by using exploring creative constructivist approach strategies where students are active during teaching. When we consider science student teachers as teachers of the future, the importance of misconceptions becomes greater and misconceptions should be eliminated. Being an important source of knowledge for students and to be most effective, teachers should teach by using face-to-face, hands-on, virtual laboratory, online laboratory etc. activities in teaching anatomy and physiology lessons.

CONCLUSION

In general, the findings of this study showed that science student teachers had knowledge with partial understanding. And, they also had some insufficient knowledge and misconceptions about the structure of the ear and the location of the organs. One of the misconceptions of the student teachers was that the malleus is located on the pinna. Another one was that the ear path was shown as the Eustachian tube. Also, some of the student teachers drew the malleus, anvil and stapes bones within the internal structure borders. Additionally, another student drew sound entering from the internal ear and hearing starting from the internal ear. In this research, nearly half of the student teachers (45%) had partial understanding (Figure 3). The student teachers with partial understanding were those who could not fully draw all elements which are scientifically acceptable.

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