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"WHAT COLOUR IS OUR BLOOD?" EVALUATION OF STUDENTS' AND PROSPECTIVE TEACHERS' OPINIONS IN TERMS OF ALTERNATIVE CONCEPTS

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ABSTRACT

The main purpose of this study is to identify alternative concepts that students possess on the colour of blood and determine the strength of those concepts as well as the reasons for why students constructed them. The sample of the study consisted of participants who were selected from three different cohorts of students (i.e. middle-school, high-school and university). 233 participants were recruited from two middle-schools, 207 students from two high-schools, and 181 third year pre-service teachers from a public university in Kars, Turkey. The study followed the survey method and the data was collected using the "What colour is our blood?" questionnaire. Content analysis was used to analyse the data collected from the questionnaire which consisted of open-ended questions. Analysis of the data indicated that students possessed various alternative concepts on the colour of blood. Furthermore, results suggested that the numbers of students holding the alternative concept with regards to the colour of blood being blue increases day by day. It was found that information sources such as school, teacher, family, friends, media and various visual elements play a role in the emergence of those alternative concepts.

Keywords: Blood, Alternative Concept, Biology Teaching

INTRODUCTION

Everybody thinks that they know what the colour of their blood is. However, a number of different answers may emerge after careful considerations. Although the question "What colour is our blood?" seems to be an easy one, various answers have been to it have been by researchers in daily as well as educational life. Certain studies identified that not only students but also prospective teachers perceived blood to be blue rather than red (Koç and Yager, 2016; Metty, 2013; Özgür, 2013; Schoon and Boone, 1998).

All of the visual elements in our surrounding portray blood as red and, in fact, when we bleed, blood can be seen to have red colour. More specifically, blood cells known as erythrocytes are depicted in red in visual elements. The reason for why -in spite of the above information- people perceiving blood to be blue exists has become a topic of interest. A conversation held between one of the authors and a child in a kindergarten constituted the starting point of the present investigation. In the conversation, the child explained that they answered the above question asked by their teacher correctly. In that incident, the pupil's teacher asked them which blood was venous and which one was clean, and the pupil answered that the red blood was clean and the blue one was venous. That answer was accepted

as the correct answer by the teacher and the pupil was awarded a red ribbon. Following this surprising and sad incident, the authors asked "What colour is our blood?" to a cohort of pre-service science teachers and, unfortunately, prospective teachers' responses indicated that there were a number of students who thought that blood was blue. Thus, the authors decided to investigate the extent of such thinking among pre-service teachers as well as the reasons for its existence.

The average adult has about five litres of blood circulating in their body. Slightly more than half of this amount consists of plasma (i.e. water, dissolved salts, proteins, hormones, and waste materials) and the remaining part consists of cellular elements that are suspended in the plasma. Those cellular elements include erythrocytes, thrombocytes, and leukocytes (Simon, Dickey, Hogan and Reece, 2016/2017). Erythrocytes are the most common blood cells and there are approximately 25 trillion erythrocytes cells in five litres of blood. Those cells' main function is to transport oxygen. Each erythrocyte cell contains an iron-rich protein which binds oxygen and is called hemoglobin (Simon, Dickey, Hogan and Reece, 2016/2017; Wong-Staal, 2001/2006). Hemoglobin contains four polypeptide chains and four heme groups. There is an iron atom in the centre of each heme group and each iron atom can hold an O_2 molecule. Therefore, a single hemoglobin molecule can carry four O_2 molecules the most. This way, hemoglobins transport the oxygen from our lungs to other cells in our body. Hemoglobin turns the colour of blood into red. Oxygen-rich blood which is also known as clean blood has a bright cherry red colour. On the other hand, without oxygen connected to it, blood has a darker red colour (burgundy) (Simon, Dickey, Hogan and Reece, 2016/2017). Additionally, it should be noted that the colours we see are the colours that are reflected by the objects in our surrounding. Regardless of being rich or poor in oxygen content, the hemoglobin in our blood not only reflects the red colour in the light spectrum but also absorbs green and blue light to a great extent (Gratzer and Kollias, 1998; Sauter 1988). Nevertheless, it should be underlined that erythrocytes are labelled as red blood cells in related literature.

Although we grow up observing and being taught that blood is red, there are cases where some students have different opinions on this matter. Rozenblit and Keil (2002) highlighted that science is generally directed by intuition and gut feelings. Based on the ideas they develop through their interactions with their environment (i.e. school, family, friends), students can sometimes provide explanations that do not match scientific facts. This situation is referred to as preconceptions, misconceptions, alternative conceptions, alternative frameworks, alternative conceptual frameworks, intuitive theories, and mini-theories in the literature (Taber, 2015). While few researchers referred to students' conceptions that were different than scientific facts as misconceptions (Helm, 1980; Novick and Menis, 1976; Sanders, 1993), others argued that the use of the term "mistake" to refer to such conceptions would not be right. Nevertheless, research literature suggests that such conceptions are also referred to as alternative concepts by many researchers (Driver and Easley, 1978; Gilbert and Swift, 1985). Abimbola (1988) suggested that some concepts are strongly and continuously accepted as correct by students and, therefore, argued that such concepts could no longer be treated as mistakes and should be renamed as alternative concepts. In line with above explanations, the present study replaces the use of the term "misconception" with "alternative concepts".

The analysis of related literature on the colour of blood suggests that both "misconceptions" and "alternative concepts" are used to refer to students' explanations that do not match scientific facts. In addition, research findings suggest that both teachers and students possess various concepts on the topic of circulatory system that are not scientific (Özgür, 2013; Yeşilyurt and Gül, 2012; Yip, 1998). Yip (1998) underlined that teachers possessed alternative concepts on the topic of circulatory system as well as conceptual mistakes in their content knowledge. This suggests that the students such teachers will teach are more likely to possess the same alternative concepts. Moreover, in their study with children of various age groups, Reiss and Tunnicliffe (2001) found that students were most successful in depicting respiratory and digestive systems. And only two per cent of the students were able to draw the circulatory system successfully. Güneş and Güneş (2005) noted that 25 % of middle-school students reported that the circulatory system was a difficult subject but they understood it, and 10-14 % of the students stated that they did not understand the subject. Güneş and Güneş (2005) argued that the

reason for why students did not understand the contents of the circulatory system was the lack of experiments during the teaching of this subject. The above information indicates that circulatory system is not a subject that can be easily understood by everyone and that students might possess alternative concepts on this subject. An in-depth analysis of those studies suggested that researchers did not focus on any alternative concepts on the colour of blood.

In their study, De Leeuw (1993) investigated 8th grade students' beliefs regarding the circulatory system utilizing mind maps. De Leeuw stated that there were also a number of misbeliefs such as "blood has blue colour" among students, but added that they were mapped in that way. In their study conducted with pre-service teachers, Pelaez, Boyd, Rojas and Hoover (2005) highlighted that pre-service teachers possess alternative concepts regarding circulatory system. They underlined that pre-service teachers specifically experienced difficulties in the following topics; systemic circulation and pulmonary circulation, blood vessels, and gas exchange. Furthermore, in the interviews, the researchers identified that few prospective teachers possessed the following alternative concept: "carbon dioxide transforms the colour of hemoglobin into blue". The analysis of related studies reveals that students, in fact, possess various alternative concepts in relation to the colour of blood. However, those studies have not satisfactorily focused on this matter.

It has been found that the number of studies investigating students' knowledge and beliefs specifically regarding the colour of blood were limited (see for example Metty, 2013). The analysis of other studies, in which the alternative concept that "blood is blue" has been identified to be held among participants, indicates that students' opinions have not been evaluated in detail and the reasons for the emergence of such alternative concepts have not been investigated (Koç and Yager, 2016; Özgür, 2013; Schoon and Boone, 1998). Nevertheless, this alternative concept has been observed since as early as 1990s, it continued its existence without any change until 2000s and, in fact, has been more frequently observed in recent years (Schoon and Boone, 1998; Metty, 2013). It is important to recognize that misbeliefs which have not been corrected in a timely manner can result in more people holding such beliefs in time. More specifically, the alternative concepts that prospective teachers possess can cause the students whom they would teach to also possess the same alternative concepts and, consequently, result in an increase in the number of individuals holding such alternative concepts. Posner, Strike, Hewson and Gertzog (1982) explained that human beings -unless they feel uncomfortable with or question a concept that they readily possess- are resistant to make changes to that particular concept. Additionally, Eggen, Kauchak and Garry (2004) stated that once they are formed, it would be really difficult to change alternative concepts. Similarly, Hammer (1996) noted that those alternative concepts, which he described as misconceptions, have strong cognitive formations and affect students' understanding of incidents and scientific explanations. Therefore, Hammer underlined that emergence of alternative concepts should be prevented and existing ones should be corrected.

It is concluded the alternative concepts that students possess are difficult to change and, therefore, it is important to pay serious attention to such concepts in order to prevent their spread. In line with this, the alternative concept "blood has blue colour" should be paid attention to, the reasons for the existence of such an alternative concept should be investigated and actions that can be taken to correct this alternative concept should be discussed.

The aim of the study

The main aim of this study is to identify alternative concepts that students possess on the colour of blood and determine the strength of those concepts as well as the reasons for their existence. A thorough analysis of this matter and the results of such an investigation can contribute to the correction of this alternative concept.

METHODOLOGY

Sampling

The sample of the present study consisted of middle school, high school, and university students. The participants were recruited on a voluntary basis from two middle schools (n= 233), two high schools (n= 207), and a public university (third-year pre-service teachers, n= 181) in Kars province of Turkey.

Pre-service teachers participating had at least taken one of the General Biology, Human Anatomy, and Physiology in their departments. Middle school and high school students, on the other hand, had taken Science or Biology courses. Demographic information about the participants is provided in Table 1.

Table 1
Demographic Characteristics of the Sample

Level	Grade	f*	%*	Female	Male
Middle-School	5th Grade	64	27.467	31	33
	6th Grade	108	46.351	65	43
	7th Grade	61	26.180	34	27
	Total	233	100.00	130	103
High-School	9th Grade	89	42.995	68	21
	10th Grade	57	27.536	43	14
	11th Grade	61	29.468	40	21
	Total	207	100.00	151	56
University	Pre-service Science Teacher	72	39.779	48	24
	Pre-service Primary School Teacher	76	41.988	41	35
	Pre-service Pre-school Teacher	33	18.232	22	11
	Total	181	100.00	111	70

*f= frequency, %= percentage

Procedure

The study utilized the survey method. The data collection tool was administered in classroom environments and the data were collected under the supervision of teachers. Students were informed about the aim of the study and confidentiality of the data they would provide. The collection of the data at each level (i.e. middle school, university) approximately lasted for a lesson.

Instruments

"What colour is our blood?" Questionnaire

"What colour is our blood?" questionnaire was used as the data collection tool in the present study. The questionnaire was prepared by the authors and two biology and biology teaching experts were consulted in the process of developing it. Students were asked two open-ended questions that would allow for an in-depth analysis of the case: "Is our blood red or blue? Explain the reason" and "What is the source of this information?"

Considering the alternative concepts regarding blood in the literature, rather than the question: "What colour is our blood?", students were asked "Is our blood red or blue? Explain the reason". The reason for this was to enable students to think in a Socratic and critical manner. Moreover, the question "Is our blood red or blue?" was found to reveal students' alternative concepts during a focus group conducted with prospective teachers who did not participate in the present study. Therefore, the decision was made to ask the question in this way rather than "What colour is our blood?".

The collected data were content analysed and the qualitative data were transformed into quantitative

data. As such, statements that resembled each other were collected under the same themes in an effort to reduce the data and represent it in frequencies as well as percentages.

The authors completed the content analysis in which themes and categories were developed independently. The authors then met and named the themes that they created and participant statements were collated under related themes. Content analysis process did not yield any disagreements. Student responses were clear and understandable. Furthermore, direct quotations were used in order to increase the reliability of the study.

FINDINGS

The analysed data were grouped in line with students' study levels (i.e. middle school, university) and were tabulated separately. The following tables include information gathered from students who possessed alternative concepts (i.e. blood has blue colour). Additionally, the reasons students provided regarding their conceptions indicate where they received that information. The most striking responses and the ones with the highest frequency were highlighted in bold. Findings from middle school students' responses are provided in Table 2.

Table 2
Summary of Responses Collected from Middle School Students

Grade	Colour of blood	f (%)*	Reason	Source of the information
5th Grade (n=64)	Blue	3 (4.6)	• The Contact of blood with oxygen (f=2) • It appears blue in our vessels (f=1) • Sometimes blue sometimes red (f=1)	• Seeing (f=2) • Book (f=1) • Science lesson (f=1) • YouTube (f=1) • Hospital (f=1)
	Red-Blue	3 (4.6)	• Red when it is warm blue when it is cold (f=1) • Blue when it is warm red when it is cold (f=1)	
6th Grade (n=108)	Red-Blue	14 (12.9)	• Clean blood is red, venous blood is blue (f=10) • When it mixes with hemoglobin it becomes red, otherwise it is blue (f=2) • It appears as red because of the light, otherwise it is blue (f=2)The contact of blood with oxygen (f=3) • It appears blue in our vessels (f=3)	• Teacher (f=8) • Science lesson (f=3) • By doing research (f=3) • Family (f=2) • Internet (f=2) • Seeing (f=1)
	Blue	6 (5.5)	•	• Surrounding (f=1)
7th Grade (n=61)	Red-Blue	5 (8.1)	• Clean blood is red, venous blood is blue (f=3) • When blood is venous it becomes red (f=2)	• Images in science fairs (f=2) • Experience (f=1)
	Blue	2 (3.2)	• The merging of blood with oxygen (f=2) •	• Internet (f=1) • Teacher (f=1) • Science lesson (f=1) • Family (f=1)

*f= frequency, %= percentage

The data collected from 234 middle school students indicated that 33 of them (about 15 %) reported that they considered blood to have blue colour (see Table 2). Detailed analysis of student responses suggested that while some students believed blood to have blue colour, others expressed that blood

has both blue and red colour. The reason for this conception was generally reported as; "blood is blue, but it turns red when it gets in contact with oxygen" or "clean blood is red, but venous blood is blue". Furthermore, a number of students reported they perceived blood to be blue since our veins appear to be blue on the outside. A number of direct quotations from student responses are given below. Details such as participants' year of study, participation number, and gender are provided at the end of each quote.

"Our blood is blue because our blood vessels are also blue." (5th Grade 28M)

"Red blood is clean blood, but blue blood is venous blood." (7th Grade 33F)

"Our blood is both red and blue, it changes colour because of oxygen." (6th Grade 18F)

The analysis of student responses indicated that they developed their conceptions mainly through their interactions with their teachers and in science classes. Additionally, a striking finding was that students who considered clean blood to be red and venous blood to be blue expressed that their sources for that information were various visual elements. Few students responded: "If our blood is red then why do our veins appear to be blue?".

Findings from high school students' responses are provided in Table 3.

Table 3
Summary of Responses Collected from High School Student

Grade	Blood colour	f (%)*	Reason	Source
9th Grade (N=89)	Blue	14 (15.7)	• The contact of blood with oxygen (f=9) • It appears blue in our vessels (f=5) • Clean blood is red, venous blood is blue (f=5) • It appears red as a result of different refraction of sun rays (f=2) • Blue in males, red in females (f=2)	• Internet (f=7) • Teacher (f=4) • Friend (f=3) • School (f=2) • Own idea (f=2) • Hospital (f=1) • Science lesson (f=1) • Surrounding (f=1) • Doctor (f=1) • Social media (f=1)
	Red-Blue	9 (10.1)		
10th Grade (N=57)	Blue	6 (10.5)	• The contact of blood with oxygen (f=6) • Certain types of blood are blue due to erythrocytes (f=1) • Erythrocytes don't give the red colour (f=1)	• Friend (f=4) • Surrounding (f=1) • Internet (f=1) • Social Media (f=1) • Family (f=1)
	Red-Blue	2 (3.5)		
11th Grade (N=61)	Blue	10 (16.3)	• The contact of blood with oxygen (f=10) (Blue) • Clean blood is red, venous blood is blue (f=2) • The contact of blood with oxygen (f=1) (Green)	• Internet (f=5) • Social Media (f=3) • Biology lesson (f=2) • Teacher (f=1) • Family (f=1) • Documentary (f=1)
	Red-Blue	2 (3.2)		
	Green	1(1.6)		

*f= frequency, %= percentage

The analysis of data collected from 207 high school students suggested that 43 (about 21 %) students considered blood to be blue (see Table 3). The main reasons for why students perceived blood to be blue included; "blood is, in fact, blue, but it turns red when it gets in contact with oxygen" and "blood

appears to be blue in veins and, therefore, it is blue". Students who considered blood to be blue and red stated "clean blood is red and venous blood is blue". Direct quotations from student responses are provided below.

"Clean blood is red. Blue blood is venous." (9th Grade 12F)

"Our blood is blue because our blood vessels are blue." (9th Grade 18F)

"Our blood is blue. It turns red when it gets in contact with oxygen." (10th Grade 34F)

"When our blood is in our vessels, it is blue. When we bleed, our blood gets in contact with oxygen and this changes its colour into red" (11th Grade 20M)

The analysis of student responses suggested that the internet and social media were the main sources of information. Moreover, there were a number of students who reported that they learned this information from their teachers or friends. Even though the number of participants holding this alternative concept is not high, this situation should be taken seriously. This is because misinformation can spread via the internet and social media and the number of students a teacher possessing this alternative concept can teach and, therefore, transfer this misinformation should not be underestimated. One of the students who thought that blood was blue and turned into red when it got in contact with oxygen expressed that they learned this information through social media. The student noted that they saw and read a statement on Facebook which was circulating around.

Findings from pre-service teachers' responses are provided in Table 4.

Table 4
Summary of Responses Collected from Pre-service Teachers

Departments	Blood colour	f (%)	Reason	Source
Pre-service science teachers (N=72)	Blue	12 (16.6)	• The contact of blood with oxygen (f=12) • Clean blood is red, venous blood is blue (f=1) • It is actually blue, I don't know why it appears as red (f=1)	• Internet (f=5) • Friend (f=3) • Lesson (f=3) • Magazine (f=1) • While preparing for university exams (f=1) • Seeing (f=1)
	Red-Blue	2 (2.7)		
Pre-service primary school teachers (N=76)	Blue	30 (39.4)	• The contact of blood with oxygen (f=17) • It appears blue in our vessels (f=10) • It appears red due to light (f=1) • The pigment in the erythrocyte gives the red colour (f=1) • Any reason not stated (f=1)	• Internet (f=7) • Friend (f=5) • Seeing (f=4) • Lesson (f=3) • Hearing from people around (f=3) • Teacher (f=2) • Book (f=1) • Pre-service teachers (f=1) • Newspaper (f=1) • Doctor (f=1) • From sick people (f=1)
	White	1 (1.3)	• Red blood also is composed of white blood (f=1)	
	Red-Blue	1 (1.3)	• Clean blood is red, venous blood is blue (f=1) •	

				• Any source not stated
Pre-service pre-school teachers (N=33)	Blue	10 (30.3)	• The contact of blood with oxygen (f=7) • It appears blue in our vessels (f=3) •	• Lesson (f=6) • Friend (f=2) • Teacher (f=1) • Any source not stated

*f= frequency, %= percentage

The analysis of the data collected from 181 pre-service teachers showed that 55 of them (about 30 %) thought that blood was blue (see Table 4). The analysis of responses for each group of pre-service teachers showed that alternative concepts were most frequently held by pre-service primary school teachers (about 41 %; n= 31 out of 76), pre-service pre-school teachers (about 30 %; n= 10 out of 33) and pre-service science teachers (about 19 %; n= 14 out of 72). Considering those results overall, it is quite worrying to find out that 30-40 % of prospective teachers, who would teach science to future generations, hold alternative concepts.

Around one out of five science teachers participating in the present study considered blood to be blue. Taking into account that those prospective teachers were in their third year of study at university and they had previously taken general biology courses, it is clear that they were not able to correct the alternative concepts that they possessed up to that time.

Participant explanations for why they considered blood to be blue indicated that pre-service teachers - similar to middle and high school students- thought that blue blood turns into red when it gets in contact with oxygen (see Table 4). There were also a number of prospective teachers who thought that blood was blue since it appeared as blue in our veins. Furthermore, in spite of them being pre-service teachers, it was disappointing to find out that there were participants who thought that clean blood was red and venous blood was blue. A number of samples from participant responses are given below.

"It is blue. It becomes red following contact with oxygen." (Pre-service Science Teacher, 27M)

"Our blood's colour is blue. When it interacts with oxygen, it becomes red. When we look at our veins, we can see that they are also blue" (Pre-service Primary School *Teacher, 15M)*

"Blood is blue because it appears to be blue when observed from blood vessels on the outside." (Pre-service Pre-school Teacher, 19F)

The analysis of responses showed that the main sources of information regarding the alternative concepts held by pre-service teachers were the internet and friends. A striking finding was that few prospective teachers (especially those in pre-school education department) reported that the source of information for their alternative concepts were the courses that they had taken during their university education.

Based on the results of the study, the most important alternative concepts identified to be held by students were as following:

Alternative concept one: *Blood is blue; it turns red when it gets into contact with oxyge.*

Participants considered blood to be blue whilst circulating in our bodies and it turns into red following exposure to air and getting in contact with oxygen. This alternative concept was more frequently observed among high school students and pre-service teachers. It was found that 7 out of the 33 (about 21 %) middle school students, 25 out of the 42 (about 59 %) high school students, and 36 out of the 55 (about 65 %) pre-service teachers possessed this alternative concept.

Alternative concept two: Blood is blue because when we look at our blood vessels it appears to be blue

Participants thought blood was blue since they perceived blood to appear as blue when observed from blood vessels on the outside. This alternative concept was also frequently held by students. 4 out of 33 (about 12 %) middle school students, 6 out of 42 (about 14 %) high school students, and 12 out of 55 (about 22 %) pre-service teachers were found to possess this alternative concept. It can be seen that this alternative concept was more common among university students. A detailed analysis of student responses showed that those participants did not provide any scientific explanations for why they considered blood to be blue. In addition, among those who correctly answered the question, one 5th grade student and nine 6th grade students stated that blood vessels appear blue since sun rays are reflected.

Alternative concept three: Clean blood is red and venous blood is blue

Participants who held this alternative concept thought that clean blood was red and venous blood was blue. This alternative concept was also one of the frequently mentioned ones by students. 13 out of 33 (about 39 %) middle school students, 7 out of 42 (about 17 %) high school students, and 2 out of 55 (about 4 %) pre-service teachers were found to hold this alternative concept. It can be clearly seen that this alternative concept was much more frequently held among middle school students. Detailed analysis of student responses on this alternative concept showed that students did not specify what they meant with "venous blood".

DISCUSSION

Evaluation of the results in the present study indicated that a number of participants held opinions that were not scientific on the colour of blood. Students who considered blood to be blue provided logical explanations for their beliefs and they explained that their source of information was their physical and social environment. Similarly, Gilbert and Swift (1985) and Abimbola (1988) underlined students held such alternative concepts.

The present study which was conducted with the participation of three cohorts of students studying at different levels of the education system indicated that 14 % of middle school students, 20 % of high school students, and 30 % of pre-service teachers participating in the study considered blood to be blue. On the contrary of expectations, those percentages indicate that the number of individuals possessing alternative concepts increases as the grade and level of education increases. More specifically, the fact that a high proportion of prospective teachers, who would teach future generations, held this alternative concept is an issue that should not be taken lightly. Similarly, Schoon and Boone (1988) noted that 45 % of pre-service primary school teachers they conducted their study with thought that venous blood was blue. Likewise, Metty (2013) asked two cohorts of prospective teachers what colour blood was and 39 out of the 42 prospective teachers in the first cohort, and 33 out of the 35 prospective teachers in the second cohort reported that they thought blood was blue. Those results, overall, indicate that this alternative concept is held by a considerable amount of students and the number of people possessing this alternative concept increases day by day. Furthermore, it can be seen that middle school, high school, and university students possessed similar alternative concepts. This indicates that the alternative concepts individuals develop in their youth do not change as time passes and they even continue to exist increasingly.

The analysis of student responses suggested that they tried to provide scientific explanations so as to why they considered blood to be blue and there were similarities between their responses. Therefore, it can be argued that students considered the statement "blood is blue and it turns into red when it comes out of blood vessels and gets in contact with oxygen" to be a scientific one and they internalized it. Driver and Easley (1978) explained that students' alternative concepts were products of their imagination which they developed whilst trying to explain incidents in the physical world.

There were many sources of information that students reported with regards to their conceptions of the colour of blood such as lessons, books, teachers, school, friends, family, and so on. The analysis of student responses indicated that there were few students who reported that the sources of their conceptions were doctors and university lecturers. These suggest that students either misinterpreted visual elements or the idea -that blood has blue colour- spread around from one person to another. Metty (2013) underlined that misconceptions can occur as a result of daily life experiences and observations, images and texts in course books, and communications between individuals. Kwen (2005), on the other hand, noted that in-service and pre-service teachers' and students' perceptions of scientific events can cause misconceptions. Moreover, Gomez-Zwiep (2008) stated that misconceptions can have internal and/or external sources, specifically highlighting the following external sources; family, television, friends, the internet, computer games, and books.

Investigation of the alternative concepts that students have and the reasons for their existence suggested that the most frequently encountered alternative concept among students was "blood is blue; it turns red when it gets into contact with oxygen". Students' explanations regarding this alternative concept indicated that they either read about it from a source or heard about it from their teachers, parents, or friends. Therefore, it is understood that students learn about such alternative concepts through their interactions with their physical and social environments. Furthermore, such alternative concepts were also identified by other research studies in the literature (Metty, 2013; Koç and Yager, 2016; Pelaez, Boyd, Rojas, and Hoover, 2005).

Related literature marks that there are many sources that can trigger the development of alternative concepts. To begin with, not all experiences that students gain in schools result in correct information. Secondly, when their children ask questions, parents or other family members may provide children with wrong answers rather than admitting that they do not know the correct answer (Simpson and Marek, 1988; Soeharto, 2016; Thompson and Logue, 2006). Additionally, various source materials, media, and teachers can also cause the emergence of alternative concepts (Thompson and Logue, 2006). In fact, students trust those sources of information. Therefore, they accept the information they receive from such sources to be correct and, thus, they develop alternative concepts. In line with the above, the results of the present study indicate all of those sources reinforce the alternative concept that blood is blue. Moreover, the analysis of reasons for why this alternative concept was more frequently encountered among high school and university students showed that -different from middle school students- the sources of those students' alternative concepts were the internet and friends. This indicates that as they get older, students start to use the internet more frequently and they pay more attention to their social environment. Thus, it is believed that students should be better informed about the fact that not all information available on the internet is true and they should also be advised on where they can find correct information.

In relation to the second most frequently observed alternative concept ("blood is blue because when we observe our blood vessels it appears to be blue"), students marked that they thought blood was blue specifically when they checked the blood vessels on their wrists. Similarly, Metty (2013) noted that when asked why they considered blood to be blue, pre-service teachers showed the inner sides of their wrists. Therefore, students might have developed an alternative concept based on the experiences they gained through their physical environment. Additionally, it has been observed that this alternative concept was more common among university students. The fact that primary school and pre-school teachers more frequently held this alternative concepts indicate that they lack in terms of scientific knowledge and they reached their conclusions based on their observations. The reason for why blood vessels and blood appear to be blue is associated with wave length of the light or its reflection, and this was only mentioned by a small proportion of middle school students.

The third most frequently observed alternative concept ("clean blood is red and venous blood is blue") indicated that there were two types of circulation in our body; clean blood and venous blood. Participants explained that veins transport blue and venous blood and arteries transport clean and red blood. The source of this conception was identified as the diagrams present in course books and various visual

elements. Following this notable observation, the analysis of students' course books and visual elements available to them showed that the depiction of systemic circulation and pulmonary circulation in those materials was made in the following way; veins were coloured blue and arteries red (Biology and Science course books used in schools in Turkey: Acarlı and Acarlı, 2018; Çiğdem, Minoğlu-Balçık and Karaca, 2018; Demirbilek, Kolotoğlu and Akan, 2018; Gökçe and Işık, 2017; Tokgöz, Yılmaz, Bagatır, Yüceler, and Atalay, 2018). This situation is a good example of how the visuals and texts within course books can cause the development of alternative concepts (Kwen, 2005; Metty, 2013). Likewise, Metty (2013) marked that veins were depicted in blue and arteries red in biology course books and added that some teachers taught students that deoxygenated blood was blue and oxygenated blood was red. In addition, in their study conducted with primary school students, Özgür (2013) noted that 85 % of students perceived that clean blood circulated in the left part of our bodies and venous blood on the right part. Similar to other studies, Özgür (2013) also related this result to the visuals present in students' course books. In their study conducted with pre-service teachers, Koç and Yager (2016) reported that 75,6 % of prospective teachers perceived the blood circulation in our veins to be blue. Likewise, Allen (2014) underline that it is a common belief that blood in veins which is poor in oxygen is blue and blood in arteries which is rich in oxygen is red. Furthermore, this alternative concept was more frequently observed among middle school students in the present study. The analysis of student responses indicated that the source of this alternative concept was reported as science course books and teachers. In line with this, it is assumed that teachers who held such alternative concepts transferred those ideas to their students via teaching.

The statements "blood is blue because when we observe our blood vessels it appears to be blue" and "clean blood is red and venous blood is blue" qualify as alternative concepts since they carry the characteristics of this term. However, detailed analysis of student responses indicates that students have insufficient knowledge on this topic. When we look at our wrists on the outside what we see are veins that transport the deoxygenated blood which we refer to as venous blood. Deoxygenated blood absorbs more red light and, therefore, reflects blue light. Additionally, arteries are generally not visible since they are smaller than veins and have thicker blood vessel walls (Kienle et al., 1996). Participants holding alternative concepts in the present study did not provide any scientific information in their responses. Therefore, it is concluded that students did not have sufficient knowledge on this topic.

CONCLUSION

The results obtained in this survey study indicated that some students have alternative concepts about the color of blood and this alternative concept increases day by day. Furthermore also the alternative concepts students hold regarding blood being blue increases with age and education level. School, teachers, family, friends, media, and various visual elements play a role in the development of those alternative concepts. An interesting finding is that students who possessed alternative concepts on the colour of blood have provided similar explanations to those that other students provided in research carried out in other countries. This suggests students considered their explanations to be scientific and such explanations spread around like a myth. As such, Newquist (2012) stated that the idea "our blood is blue" is a myth and Richards (1991) highlighted one of the most significant myths taught in schools was: "deoxygenated blood is blue". Thus, finding out that this misconception is spread to such an extent among students is an indicator that those results should not be taken lightly and precautions should be taken in an effort to correct such alternative concepts.

The following suggestions can be made based on the results achieved in this study:

The first course of action should be to correct in-service and pre-service teachers' alternative concepts.

The visuals representing blood circulation in books and other media should be amended. Arteries should be depicted in light red colour and veins should be depicted in dark red (burgundy) rather than blue.

Considering that some students developed their alternative concepts based on information which

resembled scientific information and was available on social media accounts, it, then, becomes important to increase students' awareness on this topic.

One solution to eliminate those alternative concepts can be the preparation of concept changing texts by teachers in an effort to replace students' alternative concepts with the correct ones.

REFERENCES

Abimbola, I.O. (1988). The problem of terminology in the study of student conceptions in science. *Science Education,* 72*,* 175-184.

Acarlı, D. S. & Acarlı, H. A. (2018). *Ortaöğretim biyoloji 11 ders kitabı [Secondary biology 11 textbook]*. Kök Yayıncılık

Allen, M. (2014). *Misconceptions in primary science*. McGraw-Hill Education.

Çiğdem, C., Minoğlu Balçık, G. & Karaca, Ö. (2018). *Ortaokul ve imam hatip ortaokulu fen bilimleri 6. sınıf ders kitabı [Middle school and ımam hatip middle school science textbook 6]*. Sevgi Yayınları

De Leeuw, N. (1993). Students' beliefs about the circulatory system: Are misconceptions universal. In *Proceedings of the Fifteenth Annual Conference of the Cognitive Science Society* (pp. 389-393). Lawrence Erlbaum Associates, Publishers.

Demirbilek, E., Kolotoğlu, S. & Akan, Ş. (2018). *Ortaöğretim fen lisesi biyoloji 11 ders kitabı [Secondary science high school biology 11 course book]*. MEB Devlet Kitapları.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, *5*, 61–84.

Eggen, P. D., Kauchak, D. P., & Garry, S. (2004). *Educational psychology: Windows on classrooms*. Pearson/Merrill Prentice Hall.

Gilbert, J. & Swift, D. (1985). Towards a lakatosian analysis of the piagetian and alternative conceptions research programs. *Science Education*, *69*, 681-696.

Gomez-Zwiep, S. (2008) Elementary teachers' understanding of students' science misconceptions: Implications for practice and teacher education, *Journal of Science Teacher Education*, *19* (5), 437-454.

Gökçe, N. & Işık, N. (2017). *Ortaokul fen bilimleri ders kitabı 6 [Middle school science textbook 6]*. Tuna Matbaacılık.

Güneş, M. H. & Güneş, T. (2005). İlköğretim öğrencilerinin biyoloji konularını anlama zorlukları ve nedenleri [Difficulties and their reasons in learning biology concepts in primary school students. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi*, *6*(2), 169-175.

Gratzer, W. B. & Kollias, N. (1998). Tabulated molar extinction coefficient for hemoglobin in water. Retrieved from https://omlc.org/spectra/hemoglobin/summary.html

Hammer, D. (1996). More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research. *American Journal of Physics, 64*, 1316–1325.

Helm, H. (1980). Misconceptions in physics amongst South African students. *Physics Education*, *15*(2), 92.

Kienle, A., Lilge, L., Vitkin, I. A., Patterson, M. S., Wilson, B. C., Hibst, R., & Steiner, R. (1996). Why do veins appear blue? A new look at an old question. *Applied Optics*, *35*(7), 1151-1160.

Koç, I., & Yager, R. E. (2016). Preservice teachers' alternative conceptions in elementary science concepts. *Cypriot Journal of Educational Sciences*, *11*(3), 144-159.

Kwen, B. H. (2005). Teachers' misconceptions of biological science concepts as revealed in science examination papers. Australian Association for Research in Education Conference, Parramatta, Australia

Metty, J. (2013). The color of blood. *Journal of College Science Teaching*, *42*(5), 8-10.

Newquist, H. P. (2012). *The book of blood: From legends and leeches to vampires and veins*. Houghton Mifflin Books for Children.

Novick, S. & Menis, J. (1976). A study of student perceptions of the mole concept. *Journal of Chemical Education*, *53*, 720-722

Özgür, S. (2013). The persistence of misconceptions about the human blood circulatory system among students in different grade levels. *International Journal of Environmental and Science Education*, *8*(2), 255-268.

Pelaez, N. J., Boyd, D. D., Rojas, J. B., & Hoover, M. A. (2005). Prevalence of blood circulation misconceptions among prospective elementary teachers. *Advances in Physiology Education*, *29*(3), 172-181.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211-227.

Reiss, M. J., & Tunnicliffe, S. D. (2001). Students' understandings of human organs and organ systems. *Research in Science Education*, *31*(3), 383-399.

Richards, R. S. (1991). *Myths the world taught me*, Thomas Nelson Publishers.

Rozenblit, L. & Keil, F. (2002). The misunderstood limits of folk science: An ıllusion of explanatory depth. *Cogn. Sci*. *26* (5), 521–562

Sanders, M. (1993). Erroneous ıdeas about respiration: The teacher factor. *Journal of Research in Science Teaching*, *30,* 919-934.

Sauter, C. (1988). Letter to the editor: Why human blood must be red. *American journal of hematology*, *29*(3), 181-181.

Schoon, K. J., & Boone, W. J. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education*, *82*(5), 553-568.

Simon, E. J., Dickey, J.L., Hogan, K. A, & Reece, J. B. (2017). Dolaşım ve solunum (E. Cansunar, trans.). E. Gündüz, A. Demirsoy ve İ. Türkan (Ed.), *Campbell temel biyoloji* [*Campbell biology*] (494-515). Palme Yayıncılık. (2016).

Simpson, W. D., & Marek, E. A. (1988). Understandings and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. *Journal of Research in Science Teaching*, *25*(5), 361-374.

Soeharto, S. (2016). Implementation of text transformation in physics education to reduce students'misconception. *Journal Of Education, Teaching and Learning*, *1*(2), 56-60.

Taber, K. S. (2015). Alternative conceptions/frameworks/misconceptions. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 37-41). Springer-Verlag.

Thompson, F., & Logue, S. (2006). An exploration of common student misconceptions in science. *International Education Journal*, *7*(4), 553-559.

Tokgöz, H., Yılmaz, U. G., Bagatır, A., Yüceler, B. & Atalay, N. (2018). *Ortaöğretim biyoloji 11 ders kitabı [Secondary biology 11 textbook]*. MEB Devlet Kitapları.

Wong-Staal, F. (2006). Dolaşım ve gaz alışverişi (E. Cansunar, trans.). E. Gündüz, A. Demirsoy ve İ. Türkan (Ed.), *Biyoloji* [*Biology*] (871-899). Ankara: Palme Yayıncılık. (2001).

Yeşilyurt, S., & Gül, Ş. (2012). Secondary school students' misconceptions about the "transportation and circulatory systems" unit. *Journal of Theoretical Educational Science, 5*(1), 17-48.

Yip, D. Y. (1998). Teachers' misconceptions of the circulatory system. *Journal of Biological Education*, *32*(3), 207-215.