ORIGINAL ARTICLE

Biology Teacher Candidates Drawings about Circulatory System

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***Abstract**: The purpose of the drawing method is to reveal the hidden beliefs, attitudes, knowledge and understanding of students without being dependent on words. It is more useful than other techniques in that it is easy to apply and a lot of data can be obtained with a drawing. Some misconceptions can be revealed by asking students to describe or illustrate some objects or phenomena. Biology is mostly concerned with the diagnosis of structures, their interrelationships and their functions. For this reason, it is very important to draw the biological structures correctly. Human circulatory system' comprehension is a major point in biology education. Because understanding this system is a basis for learning the transport and exchange of substances in the human body, the lymphatic system, gas exchange, and other important biological concepts. The aim of this study is to examine the cognitive structures of biology teacher candidates about the "circulatory system" with the drawing technique. In this study, a case study was conducted to reveal the biology teacher candidates' drawings in detail. In order to explore biology teacher candidates' drawing of the circulatory system in detail, their drawings were collected as data through 32 high school students (teacher candidates) in biology education faculty from Turkey. After the drawings were completed, each drawing was effectively scored for the presence or absence of at least one organ/structure in circulatory system. In addition, the drawings were further reclassified, taking into account the pattern of the path of pulmonary and systemic circulations. According to the findings obtained from the drawings of the biology teacher candidates about the circulatory system, it was revealed that the teacher candidates had many misconceptions, mistakes and incomplete information.*

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Introduction

THERE HAS BEEN a long-standing disagreement about the extent to students' understanding that conflicts with what is accepted scientifically, named as misconceptions, naive beliefs, alternative concepts and so forth (Behrendt et al., 2001; Matthews, 1998; Reiss & Tunnicliffe, 2021). Yip (1998) explains misconceptions as thoughts and ideas put forward by students that are inconsistent with scientific knowledge. Misconception can also be defined as students' thinking about a subject differently from the experts on that subject (Driver & Easley, 1978). It is possible to define misconception as the way in which a person understands a concept is used significantly different from its commonly accepted scientific meaning (Marioni, 1989; Riche, 2000; Stepans, 1996).

Misconceptions can be observed in many subject areas (Science, Physics, Chemistry, Biology, Mathematics, Geography) and at age level (preschool, primary education, secondary education, university and later). The claim that misconceptions can be found in all subjects involving people's mental activities seems appropriate or corrects (Baysen et al., 2012). As a result of research conducted in recent years, it has been determined that students in the field of biology, as in other science fields, encounter difficulties in learning many biology subjects and develop misconceptions about these biology subjects. The nature and complexity of biological concepts and the abstract or hidden aspects of natural phenomena make biology a particularly difficult field to teach and learn (Bennett, 2003; Brown & Schwartz, 2009; Rotbain et al., 2008). Students' misconceptions may be caused by their experiences, the language they use in daily communication, the content knowledge of their teachers and textbooks (King, 2009). Students form concepts at an early age as they explore their physical and social worlds. That is, children's misconceptions about natural events usually develop before they start school (Driver, 1988).

One of the most important goals of science education is to enable students to learn and apply science concepts correctly. For this reason, before teaching science subjects, it is necessary to reveal the concepts that students have about the subject. Because students' prior knowledge must be research to remove that students have misconceptions about many science concepts (Yağbasan & Gülçiçek, 2003). These misconceptions are valuable and indispensable for students as they are developed by their individual experiences. Therefore, students are reluctant to correct their misconceptions. In order to make science teaching effective with the developed strategies, first of all, students' misconceptions about science concepts should be identified and eliminated. As a result of this, many researchers have focused on the diagnosis and treatment of misconceptions that students have (Kumandaş et al., 2019; Riche, 2000).

Results from other studies reveal how the strategies listed can help students uncover their misconceptions: concept mapping (Novak & Gowin, 1984), stories and explanations that challenge misconceptions (Novak & Musonda, 1991), predict-observe-explain activities (Liew & Treagust, 1995), and drawing activities (Dempsey & Betz, 2001; Gul & Ozay Kose, 2021; Patrick and Tunnicliffe, 2010; Reis et al., 2002).

The purpose of the drawing method is to reveal the hidden beliefs, attitudes, knowledge and understanding of students without being dependent on words (Pridmore & Bendelow, 1995). Drawings are useful in determining the student's mind and level of understanding for his/her answer. It is more useful than other techniques in that it is easy to apply and a lot of data can be obtained with a drawing. Some misconceptions can be revealed by asking students to illustrate some objects or phenomena.

An important part of biological studies is to capture the architectural structures of living things. The drawing process is a pictorial record of observation and interpretation. Use the drawing helps to describe the complex relationships of biological structures. Biology deals with the determination of structures, functions and relations with each other. For this reason, it is important to be able to draw biological structures. Biology is mostly concerned with the diagnosis of structures, their interrelationships and their functions. For this reason, it is very important to draw the biological structures correctly. The correct presentation of the biological structures in the drawings is achieved by the correct naming of the structures. The correct relations between the structures and their functions are provided with short explanations written next to the figures.

Drawing is an educational/teaching activity frequently done by students of all levels in schools. Biologists consider the drawing activity useful and use it frequently in the laboratory, anatomical and microscopic studies, and in the field (Dempsey & Betz, 2001). Biology concepts are not represented in print by words alone. They are also visually represented as different diagrams (Cheng & Gilbert, 2014). In the biology lesson, drawing is mostly used to record the things observed and to reveal student understanding of the subject such as organism's cells, tissues, organs and organism specimens. In addition, drawing is an important tool for many educational researchers to help students understand basic biological concepts. However, students can show a wide variety of ideas with drawings. In other words, drawings are different from classical written texts, which students remember what they have learned and understood in the classroom without explanation (Nugraha, 2016).

It is important to learn the human circulatory system in biology. It is important not only because it is a basic human physiological system, but also because it plays a key role in learning the transport and exchange of substances in the human body, gas exchange, lymphatic system and other important biological concepts. In addition, understanding cardiovascular disease and its treatment is related to knowing the concepts related to the circulatory system well (Cheng & Gilbert, 2015).

The understanding of the circulatory system seems to pose a major conceptual difficulty (López-Manjón & Angón, 2009). Learning the human circulatory system is quite difficult. Because at the system level, students should know the main functions of the whole system, namely the transport and exchange of blood. At the organ level, students have to relate the structures and functions of individual organs. Meanwhile, they also need to know how the different functions and structures of individual organs/tissues are arranged to serve system functions (Cheng & Gilbert, 2015).

A number of studies were carried out in which young people were asked to draw on the organ systems of what was inside them:

Conceptual understanding through drawing was investigated in a study conducted with 116 pre-service teachers at a university in Turkey. As a result of the research, it was revealed that 50.9% of the pre-service teachers partially depicted the human digestive system (partial understanding) and only 19.8% understood it fully (Çardak & Dikmenli, 2018). In another study, it was revealed that students had deficiencies in understanding organ systems and most of the students had knowledge about the organ but could not establish a detailed relationship between organ systems, for example, students knew bones but could not draw skeletal systems (Reiss & Tunnicliffe, 2001). In another study, information about the location, shape and function of human internal organs was investigated and it was revealed that more than 50% of the students had problems in drawing the shape of human internal organs and determining their correct location (Prokop & Fančovičová, 2006). In another study, it was revealed that eighth grade students had extensive knowledge about internal organs, but had a poor understanding of how organs work (Özsevgeç, 2007).

Arnaudin and Mintzes (1985, 1986) analyzed issues related to the circulatory system, such as the structure and function of the blood and heart, the circulatory system, the relationships between the circulatory and respiratory systems, and the nature of the closed circulatory system. To determine the type of circulatory pathway, they asked students to choose from a variety of drawings showing the pathways of a drop of blood from the heart to the toe. According to the results obtained, it was observed that the students had difficulties in understanding the blood circulation path. In a study investigating conceptual understanding through circulatory system, students were asked to draw and explain the circulation path of blood on the human body. According to the results obtained, it was seen that 29% of the students did not have a scientific model of the circulatory system following the instruction (Chi, 2005). Reiss, Tunnicliffe et al. (2002), asked students of different ages to draw what is inside their own bodies. According to the analyzes, it was determined that the students showed very little the related structures of the organs within the organ systems and most of them still had very little understanding of the organ systems. Patrick and Tunnicliffe (2010), in their study in which science teachers revealed their understanding of the internal structures of the human body; they found that teachers could draw organs one by one, but they could not draw the relationship between organs and organ systems.

Learning the circulatory system also requires understanding the various diagrams involved, as well as reading and understanding the relevant text. It has been reported that some students only use their verbal memory while learning some scientific concepts. While their verbal recall was scientifically correct, when asked to transcribe their verbal descriptions, their drawings were unscientific translations of verbal recall. That is, students memorized scientifically acceptable verbal information. Since learning many biological processes and functions requires the correct spatiality of structures, it will be useful to have students draw the structure and function of biological components (Cheng & Gilbert, 2015).

Existing research has reported pre-service biology teachers' concepts of human binary circulation. This study explored pre-service biology teachers' knowledge of circulatory system structures and organs and how they could visualize the blood flow between them and some of their drawings that show the blood flow path through the circulatory system. The aim of this study is to examine the cognitive structures of biology teacher candidates about the "circulatory system" with the drawing technique. For this purpose, biology teacher candidates were asked to make the following drawings.

1. Draw the structures and organs of the circulatory system and write their parts on the drawing. It doesn't matter if the drawing is artistic. If you wish, you can write the details of the organs and structures you have drawn next to them.
2. Draw the blood flow in the pulmonary and systemic circulations in the circulatory system. Write their parts on the drawing. It doesn't matter if the drawing is artistic. If you want, you can write down the steps of the path you have drawn.

Method

In order to reveal a more detailed understanding of biology teacher candidates' drawings, a case study was used in this study.

Participants

In order to reveal a more detailed understanding of biology teacher candidates' drawing of the circulatory system, their drawings were collected as data through 32 biology teacher candidates in education faculty from Turkey. Their ages were between 20 and 21. They were taught the topic human circulatory system during the previous year.

Procedure

In order to draw the circulatory systems, pre-service biology teachers were given 20 minutes to complete their drawings. Before of drawing session, it was expressed that "*You won't get any points from this work, so please don't copy each other's drawings. We are only interested in your knowledge of the human circulatory system. Also, it doesn't matter if the drawing is artistic*". After the drawings were completed, each drawing was effectively scored for the presence or absence of at least one organ/structure in circulatory system. In addition, the drawings were classified, taking into account the pattern of the path of pulmonary and systemic circulations.

Analysis Criteria

Each drawing was effectively scored for the presence or absence of at least one organ/structure in circulatory system. Each drawing was scored independently by two biology teacher. The structures in the drawings have been digitized and given as a list. Each organ/structure in the list is presented in **Table 1**. In addition, the codes and categories of each structure were created by examining the drawings one by one, and the findings were presented with numerical values. In the display of numerical values, the number of biology teacher candidates (f) and the biology teacher candidates' ratio (%) indicating the organ/structure/section in the research are given in separate columns in the table (**Table 2**).

In addition, the drawings were classified, taking into account the path of pulmonary and systemic circulations. Drawings were classified using the same stages Biology of Campbell et al. (2016) (**Figure 1**). In this figure, there are 11 stages that 4 of them are pulmonary circulate stages and 7 of them are systemic circulate stages. Biology teacher candidates received points for each stage drawn (**Table 3**).

Pulmonary Circulate

1. It begins with contraction of the right ventricle of the heart.
2. The blood is pumped into the pulmonary arteries, which are the arteries that bring oxygen-poor blood to the left and right lungs.
3. This oxygen-poor blood then enters into a dense network of capillaries that blankets the entire respiratory surface of the lung. It is

Table 1. Descriptive Statistics of Biology Teacher Candidates' Drawings.

Organ/Structure	f	%
Heart	30	94
Lungs	14	44
Arteries	26	81
Venules	26	81
Capillaries	8	25
Blood	12	38

Table 2. Findings of Drawings for The Circulatory System.

Structure	Section	f	%
Heart	Atriums	24	75
	Ventricules	24	75
	Semilunar Valve	8	25
	Atrioventricular Valve	8	25
	Heart walls	4	13
	S.A. Node	2	6
	A.V Node	2	6
	Purkinje Fibers	2	6
	Bundle Branches	2	6
Lungs	Bronchus	8	25
	Bronchiole	8	25
	Alveoli	4	13
Blood	O2-Rich Blood	18	56
	CO2- Rich Blood	18	56
	Leukocytes	2	6
	Erithrocytes	2	6
Venules	Pulmonary Vein	24	75
	Superior Vena Cava	12	38
	Inferior Vena Cava	10	31
Arteries	Aorta	28	88
	Pulmonary Artery	20	63
Capillaries	Endothelium	4	13

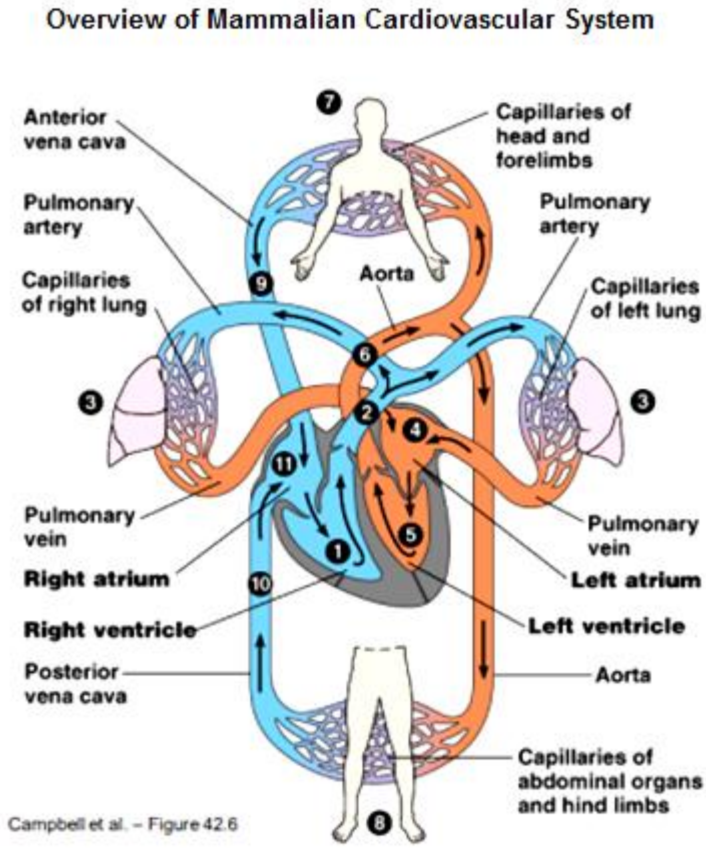

Figure 1. The Pulmonary and Systemic Circulations in the Circulatory System.

Table 3. Percentage of Biology Teacher Candidates' Drawing for Blood Circulation.

Stages	f	%
1	20	62
2	24	75
3	0	0
4	24	75
5	20	62
6	24	75
7	6	18
8	20	62
9	6	18
10	20	62
11	20	62

here where the blood releases carbon dioxide into the lungs and absorbs oxygen.

4. The oxygen-rich blood enters the pulmonary veins, which are the veins that bring oxygenated blood from the lungs back to the heart.

Systemic Circulate

1. From the pulmonary veins, blood enters the left side of the heart and is pumped into the aorta, which is the main artery that leads directly out of the left side of the heart.
2. The aorta is the largest blood vessel in the human body, and branches off into many smaller arteries that bring oxygenated blood to the various tissues of the body.
3. The blood then enters capillaries that distribute the blood to every cell in upper parts of the body, oxygen is released into the tissues and carbon dioxide is picked up by the blood.
4. The blood then enters capillaries that distribute the blood to every cell in lower parts of the body, oxygen is released into the tissues and carbon dioxide is picked up by the blood of the body
5. The blood is then collected back into veins (superior vena cava),
6. The blood is then collected back into veins (inferior vena cava),
7. Oxygen-poor blood returns to the right atrium of the heart and the cycle is ready to repeat itself (Campbell et al., 2016).

Findings and Discussion

In the process of analyzing the data obtained from the biology teacher candidates drawings in the research, the extent to which the organs/structures that make up the circulatory system are included for the first research problem were examined in detail. Each organ/structure is presented in Table 1. In the display of numerical values, the number of biology teacher candidates indicating the organ/structure in the research (f) and the ratio of biology teacher candidates indicating the organ/structure (%) are given in separate columns in the tables.

According to **Table 1**, the most frequently drawn organs/structures are the heart (94%), arteries (81%) and venules (81%), while the less frequently drawn organs/structures are lungs (41%), Blood (38%) and Capillaries (25%). Learning the human circulatory system, like learning many other biological concepts, is challenging. (Arnaudin & Mintzes, 1985; Sungur & Tekkaya, 2003).

As seen in **Appendix 1-2**, while most of the biology teacher candidates who were asked to draw the organs and structures of the circulatory system included the heart, arteries and veins in their drawings, they gave very little space to the lungs, capillaries and blood. Also, the shape of the heart is mostly drawn in the form of love.

Borazan (2008), Çobanoğlu and Bektaş (2012), analyzed students' drawings on subjects such as the shape of the heart, the location of the veins in our body, the location of the heart in our body, the function of the heart, the meaning of clean and dirty blood, the purpose and place of large and small blood circulation, blood circulation. It has been determined that there are misconceptions about the subject. It has been stated that the majority of these misconceptions in students are due to the fact that the subject of the circulatory system includes abstract concepts, while some misconceptions arise from their teachers, textbooks and education programs. Again, since the names and functions of the organs of other systems were not learned scientifically correctly, it was stated that there may have been misconceptions about the organs in the circulatory system and their functions. Bahar et al. (2008), revealed the level of understanding of science teacher candidates about the internal structure of the heart by having them draw. When the drawings of the science teacher candidates were analyzed, it was revealed that most of them had misconceptions in terms of the internal structure of the heart and they also had insufficient knowledge.

In addition to the above, each drawing made by the biology teacher candidates was examined in detail in terms of structural features and the findings are presented below (**Table 2).**

Looking at **Table 2**, it is seen that the most frequent atrium and ventricle structures of the heart are drawn (75%), the pulmonary veins (75%) are the most drawn in the veins, and the aorta (88%) is the most drawn in the arteries, and the O2-rich blood and CO2- rich blood (56%) is drawn in the blood. It is seen that bronchi and bronchioles (25%) are drawn in the lungs. S.A. Node, A.V. Node, Purkinje Fibers and Bundle Branches (6%) are drawn in the heart.

As seen in **Appendices 3, 4,** and **5**, while most of the biology teacher candidates who were asked to draw in detail in terms of the organs and structures of the circulatory system included the atriums, ventricules, aorta, pulmonary vein and pulmonary artery in their drawings, they gave very little space to the capillaries, lungs, blood cells and impulse generation structures. They drew the circulatory system, but they did not consider the role of the lungs, but only the heart. Also, there are incorrect drawings in the places of organs and structures of the circulatory system. Another teacher candidate confused the left and right parts of the heart (**Appendix 4**).

Gül (2011) asked the following question to her students in her study "What are the structures that produce impulses in the heart?" In response to the question asked, students; "neurotransmitter substances (12.82%)", "sensory nerves, somatic nerves, parasympathetic nerves (2.56%)", "brain (3.85%)", "caffeine, nicotine, etc. substances (3.85%)" and "neuron, synapse gap etc. (2.56%)" and they reflected the misconceptions that had settled in their minds. Michael et al. (2002) and Sungur et al. (2001) also stated in their study that the majority of students gave the answer "brain" to this question. These answers reveal students' misconceptions by relating the subject to the subject with their knowledge about the nervous system, rather than stating that the impulse in the heart is produced by the SA node (sinoatrial node). Gül (2011), Michael et al. (2002) and Sungur et al. (2001) concluded in their studies that students do not have enough knowledge about the circulatory system. In their study on the circulatory system, Arnaudin and Mintzes (1985) determined that students have misconceptions about blood circulation at all levels of the education system. In addition, they found that they did not understand concepts such as the structure of the blood and the circulatory system, the direction of blood flow, and they did not have enough information about how the lungs supply oxygen to the blood.

For the second research problem, the blood flow order presented, drawings were classified by using the same stages Biolgy of Campbell et al. (2016). It was determined how well the biology teacher candidates comply according to this stage, their percentages were taken in terms of each stages (**Table 3**).

Teacher candidates are responsible to drawing how blood circulated in the pulmonary and systemic circulations and how blood flows from artery through the arteriole, to the capillaries, return to venule to vein, and then back to the heart. Prospective biology teachers have demonstrated that the function of the heart pumps blood in two separate ways, and some participants have drawings of a correct relationship between the heart and lungs. We can conclude that the participants who drew the circulatory system in this way truly understood the heart as a pump. Many people know that the heart's function is to pump blood; however, some did not perceive that the heart was pumping blood in two separate ways. In fact, pre-service teachers tried to make sense of the circulation of blood throughout the body by drawing a circular path. However, most participants also have a drawing that includes an incorrect relationship between the heart and lungs. This drawing is inconsistent with a real understanding of the heart's role as a pump. Since the lungs cannot pump blood, blood cannot go from the lungs to the toe; only the heart has this capacity (López-Manjón & Postigo, 2005). However, the participants in this study were not aware of this error. The study by Chi et al. (1989) revealed that students had difficulty in stating the purpose of the lung and the number of circulation cycles. Pelaez et al. (2005) found that pre-service teachers had difficulties in perceiving some concepts. 70% of primary school teacher candidates could not understand large and small blood circulation, 30% were confused about blood vessels, 55% had misconceptions about gas exchange, and 19% had difficulty understanding gas conduction and 20% lung functions. Arnaudin and Mintzes (1985, 1986) asked students, “What path does blood follow when leaving the heart?” Only 7-15% of students chose the scientific model: heart-foot-heart-lung-heart. These students largely incorporated the lungs into the circulatory system as their age and teaching level increased, but they got it wrong.

The four-chambered human heart, containing all blood vessels, works according to a ‘double circulatory system’. The pulmonary circulation separates clean blood from polluted blood through the lungs. Systemic circulation is the blood circulating throughout the body, taking the clean blood and returning the dirty blood to the heart (Cheng & Gilbert, 2015). However, it can be seen that the all of participants who drew lungs had a representation in which the capillaries covering the entire respiratory surface of the lung were not included (**Appendices 6** and **7**). This is where the blood delivers carbon dioxide to the lungs and takes up oxygen. At the system level, pre-service teachers are aware of the main function of the circulatory system, namely the transport and exchange of blood. However, at the organ level, pre-service teachers’ associations with the structures of the lungs are lacking. Previous studies have revealed that students’ understanding of the human circulatory system can be problematic. For example, by looking at students’ drawings, it has been found that some believe the blood contains a drop of blood that circulates throughout the body before returning to the heart. They failed to grasp the importance of the pulmonary circulation (Arnaudin & Mintzes, 1985; Pelaez et al., 2005).

Moreover, it can be seen that the most of participants had a representation in which blood goes from the heart to the body lower parts and then returns to the heart. However, the very few of participants had a representation in which blood goes from the heart to the body upper parts and then returns to the heart. As if the candidates thought that the heart only pumps blood to the lower part of the body and did not draw the path of blood flow to the upper part of the body. In addition, it has been drawn that the blood does not follow a direct path from the heart to the target organ; on the contrary, it follows a circular path to other parts of the body before returning to the heart when leaving the heart (Appendix 8-9). An incorrect association has been established between the heart and lungs. This means a misconception about the heart’s role as a pump. Borazan (2008) had students make drawings about the circulatory system and the following situations were observed: Systemic circulation was drawn below the heart and pulmonary circulation was above the heart. Systemic circulation was only drawn on the body. Systemic circulation and pulmonary circulation are drawn everywhere except arms, legs and head. The veins are drawn without being distributed all over the body.

In the drawings obtained from Özgür (2013)’ study; the systemic and pulmonary circulation are independent of each other and occur in different parts of the body. Pulmonary circulation takes place in the upper part of the body and systemic circulation takes place in the lower part of the body. All structures of the human circulatory system should show very clearly the spatial position and gross appearance of the heart, lungs, and some blood vessels leading to the upper and lower parts of the body (Cheng & Gilbert, 2015). The scientific path where an artery leaves the heart and divides into secondary pathways, reaches the capillaries of the target organ and returns to the heart via the veins can be called the central model. However, some participants drew a different route, where blood did not follow a direct route from the heart to the target organ and returned to the heart.

Given the differences in ways the teacher candidates drew the blood flow diagram, perhaps not surprisingly, participants connected the pulmonary artery carrying dirty blood only to the right lung, and they connected the pulmonary vein carrying clean blood only to the left lung. It's as if the right lung is getting dirty blood and the left lung is sending clean blood to the heart (**Appendices 10** and **11**). In this case, a parallel running of an artery and a vein was drawn in the blood flow chart, and arteries and veins were connected to the heart and extended to other parts of the body. In fact, contraction of the right ventricle pumps blood to the lungs through the pulmonary arteries. The blood comes from the capillary beds in the left and right lungs to the left atrium of the heart through the pulmonary veins to the left atrium. Özgür (2013) observed in student drawings that while clean blood circulates on the right side of the body, clean blood circulates on the left side of the body. Clean blood circulates on the left side of the body, and unclean blood circulates on the right side of the body. In reality, clean and unclean blood is everywhere in the body. For this reason, it is wrong to show dirty blood only on the right side and clean blood only on the left side (Güngör & Özgür, 2009). Gençbay (2016) examined and compared the pre- and post-education misconceptions of 6th grade students about the concept of blood circulation and found that the students could not adequately comprehend the content of clean and dirty blood, could not visualize where and how the dirty blood was cleaned in their minds, experienced various imbalances and reported some phenomena showed that they were misconfigured.

One reason for difficulty is the necessity of an integrated understanding of the different representations of the system when learning about the circulatory system. These include diagrams representing, for example, the four-chambered heart, the blood vessel system in the human body, the blood flow in the pulmonary and systemic circulation, the differences of arteries, veins, and capillaries. Arnaudin and Mintzes (1985, 1986) concluded that of all the different concepts of the circulatory system analyzed, the circulatory model is one of the most difficult to change. In this study, a diagram in science course textbooks was used and it was seen that many students' interpretations of this diagram contradicted scientific knowledge. Although the sample of the research consists of biology teacher candidates, it is seen that all misconceptions of the students are reinforced with the help of such materials in the science textbooks.

The teacher candidates could show with arrows that the blood coming from the lungs and aorta artery first passes from the atria to the ventricles and then disperses to the whole body but the drawings showed that the pulmonary artery of the candidates carried clean blood, and the pulmonary veins carried dirty blood (Appendix 12). Some of the misconceptions identified on this subject are “clean blood is carried in the pulmonary artery”. Here, it is seen that the teacher candidates confuse the vessels that bring blood to and from the heart, and generally think that the arteries carry clean blood and the veins carry dirty blood. These misconceptions were also revealed in the studies of Kete (2006), Sezen and Çimer (2009), which showed that very few teacher candidates have knowledge about the functions of pulmonary arteries and veins, which are exceptional cases in arteries and veins. It was emphasized by Canpolat et al. (2004) that this might be due to the over-generalization of concepts by students.

Conclusion and Recommendations

Understanding the human circulatory system is more difficult than teachers and education researchers think. Given the difficulty of learning, it is not surprising that students and even pre-service teachers advocate structures and blood flow that do not support the functions of the circulatory system.

This research is a study that reveals how pre-service teachers might have drawn the structures and organs related to the circulatory system and the blood flow between them. In the light of the findings obtained from this research, it is seen that pre-service teachers have some deficiencies and misconceptions about the blood circulation system. Although this result is not different from those found in previous studies, it supports what has been reported in the literature about students’ understanding of the human circulatory system.

This study reported teacher candidates’ conceptions of the human double circulation. While teacher candidates are learning new information and concepts, they have difficulties in combining them with their mental structures. Sometimes erroneous combinations were seen; because of sometimes learning by rote occurs. This leads to misconceptions. One of the important reasons why meaningful learning does not occur is the learning and teaching methods used.

In order to understand scientific ideas such as how the circulatory system facilitates the exchange of substances in organs such as the lungs, pre-service teachers should be encouraged to use pictures when appropriate. Drawing can form the basis for teachers and trainee teachers to assess their understanding. More research should be done to inform science teachers about how to have better practice in drawing. Specifically, teachers may want to help trainees understand that parallel work of arteries and veins does not exactly replicate the location of veins in the human body in teaching blood flow charts. In addition, pre-service teachers should learn how the ideas represented in the diagram relate to blood flow in the human body or body organs.

While textbooks are specifically pointed out as the cause of misconceptions in students, teachers, who are the source of information transfer, are also cited as the most important reason for misconceptions in students. In particular, identifying the current misconceptions in teachers will perhaps ensure that these misconceptions are minimized during their training, and therefore, when they become teachers, they will be able to educate their students in a way that will have the least misconceptions. At this point, more comprehensive studies are needed to identify and eliminate teachers' misconceptions. In addition, identifying misconceptions in the textbooks and correcting the textbooks after this detection will prevent book-related misconceptions.

Contemporary teaching techniques to be developed to eliminate misconceptions about the circulatory system are of great importance here. Considering that the circulatory system contains many abstract concepts, it is extremely important to present the subjects to students using all kinds of visual and audio materials during the teaching process and thus provide concrete learning. Many studies supporting this result show that concept maps, conceptual change texts, concept networks, meaning analysis tables, audio-visual tools, etc. can be used in eliminating students' misconceptions showing that its use positively affects learning. Therefore, if biology teachers prioritize the use of such materials in their lesson plans, they can minimize students' misconceptions.

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