JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

EXAMINING SECONDARY SCHOOL STUDENTS' MISCONCEPTIONS ABOUT THE HUMAN BODY: CORRELATIONS BETWEEN THE METHODS OF DRAWING AND OPEN-ENDED QUESTIONS

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Abstract. *Students of various age groups manifest numerous explanations that differ from what is known to be scientifically correct. Misconceptions about the human body are one of the best studied areas of students' understanding of scientific phenomena. To explore misconceptions, researchers have at their disposal various methods which can lead to different results. In order to find an effective, cheap and representative diagnostic instrument, correlations between scores obtained by open-ended questions and drawings on the example of the human circulatory system were examined. Open-ended questions provide a more complete understanding of student learning but are harder to evaluate objectively in comparison with drawings, particularly in cross-cultural research. Correlations among scores obtained by these two methods in the present research were moderate, which suggests that drawings reflect students' understanding of the circulatory system, albeit not perfectly. Although drawings probably never provide a complete understanding of children's ideas about science, this cheap and time effective method is recommended particularly in cross-cultural research, where standard, comparable conditions are hard to achieve.*

Keywords: *circulatory system, human heart, human body, students' ideas.*

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Introduction

School students have come to class with concepts about scientific phenomena that they have obtained both from personal experience (Carey, 1985; Driver, Asoko, Leach, Scott, & Mortimer, 1994; Jaakkola & Slaughter, 2002; Prokop, Kubiatko, & Fančovičová, 2008a) and during formal learning (Düsing, Asshoff, & Hammann, 2019; Kramer & Myer, 2012; Ozay & Oztaş, 2003). A number of these concepts differ from conventional scientific views. These incorrect concepts are called naïve ideas (e.g., Pine, Messer, & St. John, 2001), alternative conceptions (e.g., Adadan, Trundle, & Irving, 2010; Prokop, Prokop, & Tunnicliffe, 2008b), misconceptions (e.g., Treagust, 1986; Wandersee, 1986), or both alternative conceptions and misconceptions (Wisch, Farrell, Siegel, & Freyermuth, 2018) (for discussion regarding the use of the term misconception see Leonard, Andrews, & Kalinowski, 2014). They have become one of the possible reasons for student's difficulties in the learning process, because they can interfere with the acquisition of new knowledge (Hadzigeorgiou, 2015; Vosniadou, 2001). Misconceptions are defined as understandings or explanations that differ from what is known to be scientifically correct (National Research Council, 2012, p. 58).

The misconceptions have been identified in all science concepts at various levels of education. With respect to biology education, for example, research has confirmed various misconceptions in the concepts of diffusion and osmosis (Köse, 2008), misconceptions about photosynthesis and plant respiration (Ozay & Oztas, 2003; Svandova, 2014), classification of vertebrates and invertebrates (Kubiatko & Prokop, 2007; Prokop, Kubiatko, & Fančovičová, 2007a, Prokop, Prokop, & Tunnicliffe, 2008b; Tekkaya, 2002; Trowbridge & Mintzes, 1985, 1988), the concept of transport and excretory systems (Yip, 1998), animal breathing (Prokop, Uşak, Özel, & Fančovičová, 2009a), or animal internal organs in a general sense (Prokop Prokop, Tunnicliffe, & Diran, 2007b).

https://doi.org/10.33225/jbse/19.18.549

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Problem of Research

Research on misconception is important because these incorrect understandings are strongly held and often very difficult to change (Mintzes & Wandersee, 1998; Özgür, 2013; Vosniadou, 2001). Thus, it is crucial to establish a valid method(s) to examine misconceptions in order to obtain the best picture about what children really know about biological phenomena. Prior research has used a number of methods to examine misconceptions in biology. For instance, researchers have widely used written closed (e.g., true/false, multiple-choice) (e.g., Treagust, 1986), open-ended questions (Özgür, 2013), both these methods (e.g. Prokop et al., 2007b) or interviews (Gelert, 1962) to examine students' understanding of various biological phenomena. The method of drawing in science education was also commonly used, either in combination with other methods (interviews: Dikmenli, 2010; Strommen, 1995; Teixeira, 2000; Villarroel & Infante, 2014; written responses: Çelikler & Aksan, 2014; Özsevgeç, 2007), or alone (Bartoszeck, Machado, & Amann-Gainotti, 2008; Patrick & Tunnicliffe, 2010; Prokop et al., 2007b; Reiss & Tunnicliffe, 2001; Tunnicliffe & Reiss, 1999, Villarroel, 2016; Villarroel et al., 2018).

Recent meta-analysis of diagnostic tools in science education research has revealed that 58% of studies used a combination of two or more diagnostic methods (Gurel, Eryılmaz, & McDermott, 2015). These researchers have confirmed the most common diagnostic tool were interviews, then questionnaires with open-ended and multiple-choice questions. Along with a few similar instruments such as concept maps or essays, drawings were the least frequently used diagnostic instruments (only 9% of research papers). Interviews (used in 53% of research papers, see Gurel, Eryılmaz, & McDermott, 2015) can be better in revealing children's concepts about science compared with drawings, but this method is also very time consuming, particularly if the researcher(s) needs representative samples of participants (Frankel & Wallen, 2000). Open-ended questions are used more frequently than drawings (34% of research papers, see Gurel et al., 2015), but the results obtained by this method are relatively difficult to evaluate.

Research Focus

The accuracy of the results obtained by drawings, reflecting students' concepts about natural phenomena, has not yet been examined in deeper detail. Khwaja and Saxton (2001), for instance, have demonstrated that if the general teaching instruction (*Draw what you think is inside your body)* widely used in similar research (e.g., Reiss & Tunnicliffe 2001; Reiss et al., 2002) changed to more specific teaching instruction (*Draw the bones that are inside your body),* then children's drawings of the human skeletal system would be significantly improved. Similar results have been obtained for children's drawings of the endocrine and urinary system (Prokop, Fančovičová, & Tunnicliffe, 2009b). Prokop and Fančovičová (2006) have showed that there are no correlations between scores obtained with open-ended questions and drawings of the human body in a sample of preservice teachers. This has suggested that drawings could not express children's knowledge about the human body in detail.

This research examined students' misconceptions about the human circulatory system. It was chosen as an example of the human organ system, because the heart is most frequently found in children's drawings of human bodies across cultures (Prokop & Fančovičová, 2006; Reiss & Tunnicliffe, 2001; Reiss et al., 2002). This can imply that the concept of circulatory system is well developed. Research using various methodologies has showed, however, that there are numerous misconceptions regarding the human circulatory system in both children (Gellert 1962,), high school and university students (Arnaudin & Mintzes, 1985; Bahar, Özel, Prokop, & Uşak, 2008; Bartoszeck et al., 2008; Özsevgeç, 2007) as well as among teachers (Patrick & Tunnicliffe, 2010; Yip, 1998). For instance, students do not understand the delivery of oxygen into the body and lungs and the exchange of breathing gases (Pelaez, Boyd, Rojas, & Hoover, 2005). According to students of various age groups, the heart pumps the food we eat and/or cleans the blood (Arnaudin & Mintzes, 1985; Özsevgeç, 2007) and is drawn in anatomically incorrect shape (Bartoszeck et al., 2008). Moreover, many students think that the heart is the centre of feelings (Özgür, 2013).

In the present research, correlations between specific teaching instruction focused on drawings of the human circulatory system and open-ended questions were primarily examined, which offers an incomplete understanding of student learning (Treagust, 1988), in order to better understand students' misconceptions about the human body with using effective, and not time-consuming research methods. More specifically, correlations between scores from drawings obtained after specific teaching instructions (cf. Khwaja & Saxton, 2001) and open-ended questions both focused on the human circulatory system were explored. Because it is unclear 1) whether there are significant associations between drawings and open questions, and 2) what is the prevalence of various misconceptions about the human circulatory system in Slovak secondary school students, our research goal was 1)

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to examine correlations between drawings and open questions and 2) the prevalence of various misconceptions about the human circulatory system both by drawings and open-ended questions.

Research Methodology

General Background

The research was conducted in June 2016. This research surveyed a cross-sectional sample of students about their misconceptions about the human body using quantitative research methods. Selection of participants was not intentional but was based on teachers' willingness to participate on the research in the accessible school in which researchers had personal contacts with the director. The questionnaire was administered to all participants in selected classes irrespective of the participants' knowledge about the human body. Data analysis focused on interpreting students' responses considering their understanding of the human circulatory system.

Sample

Data were collected throughout three consecutive weeks on gymnasium at Varšavská street 1 in Žilina. All students (N = 220) of lower-secondary and upper-secondary education (123 girls and 97 boys) from grades 5–9 (age 10–15 years) comprised the sample.

Ethical Approval

All procedures performed in studies involving humanparticipants were in accordance with the ethical standards of the institutional research committee at Trnava University and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Instrument and Procedures

The preliminary developed questionnaire with open-ended questions and the drawing method was used to determine students' misconceptions of the circulatory system. A panel of 3 scientists and 3 science educators determined the content validity. These experts were asked to evaluate whether open-ended questions and teaching instruction clearly indicated intentions of researchers. All experts agreed that the research toll is well designed. The complete time for the answers and drawings was 45 minutes. The questionnaire was anonymous and comprised three parts: the first part contained demographics such as gender and the grade of students, the second part contained two open questions identifying the importance of breathing and the importance of blood ("Why we breathe" and "What is the significance of blood in our body?").

In the third part, two open-ended questions were dealt with to determine students' concepts about the heart and its function, as well as the path of blood using the drawing method ("Draw the heart, describe its parts and function in the human body" and "Draw the circulatory system into the shape of the body and the path of blood coming from the heart, where does it go?"). For both questions, students were asked to describe their drawings.

The drawing of a heart was divided into four main categories: heart shape, division of a heart, heart description and physiological mechanisms of the heart such as blood circulation for the heart. Each category was classified separately by assigning the drawing to the created subcategories. The scores were then assigned to the subcategories according to drawing level. By adding the points from all four main categories, summed score for each respondent was created and used them in further analyses.

Scoring pictures of the circulatory system in the second drawing were like those of the heart except for the three main categories: we scored the drawing of the circulatory system, the positioning of the heart and the size of the heart. Correlational analysis was performed on the summarized scores of the drawings and open-ended questions.

Data Analysis

Data were analyzed with Pearson correlation coefficients (r). When a confounding variable appeared in analyses, it was controlled for this potentially confouding effect by computing the partial correlation coefficient.

https://doi.org/10.33225/jbse/19.18.549

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

All statistical tests were two-tailed. Statistical tests were performed with StatisticaÒ (Version 8, StatSoft 2007, Tulsa, OK, USA, Weiß, 2007).

Research Results

Correlations between Open-Ended Questions and Drawings

The mean scores obtained from open-ended questions and drawings are shown in Table 1. Students were most successful in drawings of the circulatory system (mean success = 63%) and heart (mean success = 56%), followed by open-ended questions regarding the significance of blood (mean success = 37%) and significance of breathing (mean success = 23%).

Table 1. Descriptive statistics for open-ended questions and drawings.

Instrument	Task	Min	Max	*M*	*SD*
Open-ended question	Breathing	0	3	0.70	0.63
	Blood	0	5	1.88	1.61
Drawing	Heart	0	14	7.90	3.78
	Circulatory system	0	11	6.90	2.75

Drawings of the heart ($r = .47$, $p < .001$) and scores from the significance of blood ($r = .14$, $p < .05$) positively correlated with the grade. After controlling for effect of the grade, moderate relations between scores from drawings of the heart and open-ended questions were confirmed (Table 2).

Table 2. Partial correlations ($r_{ab.c}$) controlled for effect of grade.

	The significance of blood (open question)	Drawing of heart (drawing)	Drawing of the circulatory system (drawing)
The significance of breathing (open-ended question)	.27	.35	.23
The significance of blood (open-ended question)		.30	.21
Drawing of heart (drawing)			.30

Open-ended Questions

The most common idea concerning the significance of breathing was the reasoning "To get oxygen into the body and to have blood oxygenated" (54.5%). Only 5% of students reported that breathing is associated with degradation of nutrients.

Students' misconceptions concerning the significance of blood included: spreading oxygen (15.4%) or nutrients (22.4%) to the body. Only 16.8% reported spreading *both* oxygen and nutrients and 13.6% reported distribution of breathing gases to the cells. Other functions of blood (e.g., thermoregulatory or immune) were not reported.

Drawings of the Heart

Students' images of the heart were clustered into four categories: heart shape, heart division, heart description and heart function.

Students' drawings of the heart were in three shapes. 30% of the students drew it as Valentine heart (Figure 1a), 16% drew it as a circle (Figure 1b) and 54% drew heart in its real shape (Figure 1c).

https://doi.org/10.33225/jbse/19.18.549

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

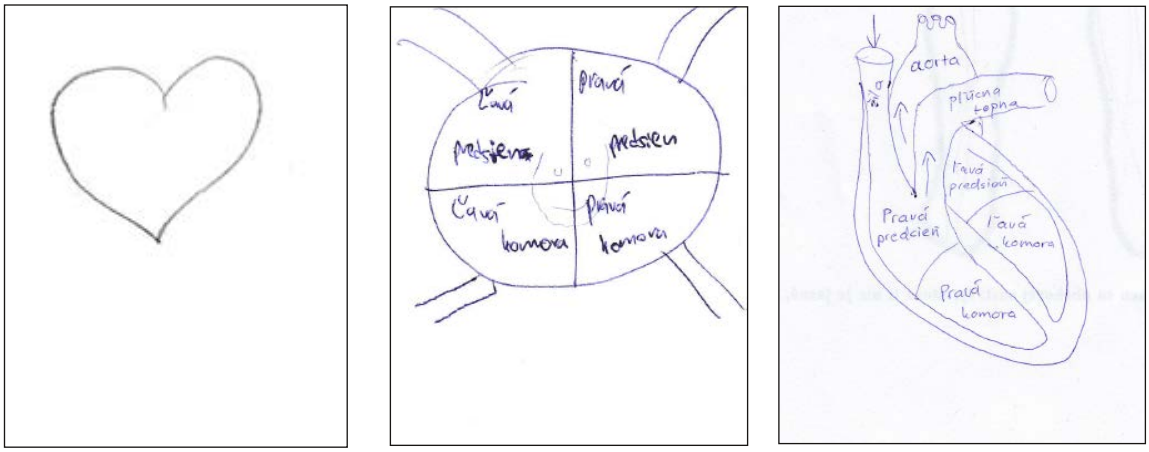

Figure 1. Three shapes of heart in students' drawings; (a) Valentine heart, (b) circle, and (c) a real-looking heart.

The drawings were divided according to the division of the heart, into four groups. First, a substantial number of students (27.3%) did not split the heart and did not display any specific parts of the heart. Second, the heart was not schematically divided, however, there were signs of veins and arteries, like outlets from and to the heart (9.1%). Third, the heart was schematically divided into upper left and right atria and lower left and right ventricles (49.5%). Fourth, the heart was schematically divided as above, and other parts such as the aorta, the pulmonary valve, the valves and the sign of a connection with the respiratory system were indicated by 14.1% of students (Figure 1c).

Heart Description

Five groups of heart description were identified in the students' drawings. First, the heart was correctly marked with veins and arteries (5.5% of students). An incorrect description of the inner division was found in 11.8% of students. A correct description of the inner division of the heart (but without connections with aorta and veins) appeared in 41.8% of students.

Concepts such as artery, upper and lower hollow veins, tipped flaps, etc. were found in 13.2% of students. A total of 27.7% of students did not provide any description of the heart.

Heart Function

The images of the heart function were categorized as follows: blood purification (55.9%), blood pumping / blood circulation (41.4%) and blood oxygenation (0.27%).

Drawings of the Circulatory System

The images of students concerning the circulatory system (Figure 2) were evaluated in two categories: 1) drawing of the circulatory system, 2) placement of the heart.

The drawings of the circulatory system were divided into seven groups.

1) Only the heart without connection to other organs was shown by 5% of children.
2) The heart was connected with blood vessels (3.6% of students). Vessels were present in the entire body except the head.
3) The heart and the vessels connecting all parts of the body including the head were shown by 37.3% of students.
4) The heart and the vessels were shown. Vessels are branched into the capillaries and lead to the entire body except the head (5.5%).
5) The heart and the vessels are shown. Vessels are branched into the capillaries and lead throughout the body and into the head (9.1%).

https://doi.org/10.33225/jbse/19.18.549

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

6) Both large and small blood circulation are indicated, but without lungs (3.6%).
7) It is indicated that the lungs also belong to the bloodstream (30%). A total of 5.9 drawings lacked any description.

On the left, up to 68% and 10% of students placed the heart on the left and the right part of the body, respectively. These data must be interpreted with caution, however, because the template body contour does not clearly indicate whether the person faces us or stands back to us. So students could place the heart to any side and would be right. About 22% of students placed the heart in the centre of the body contour.

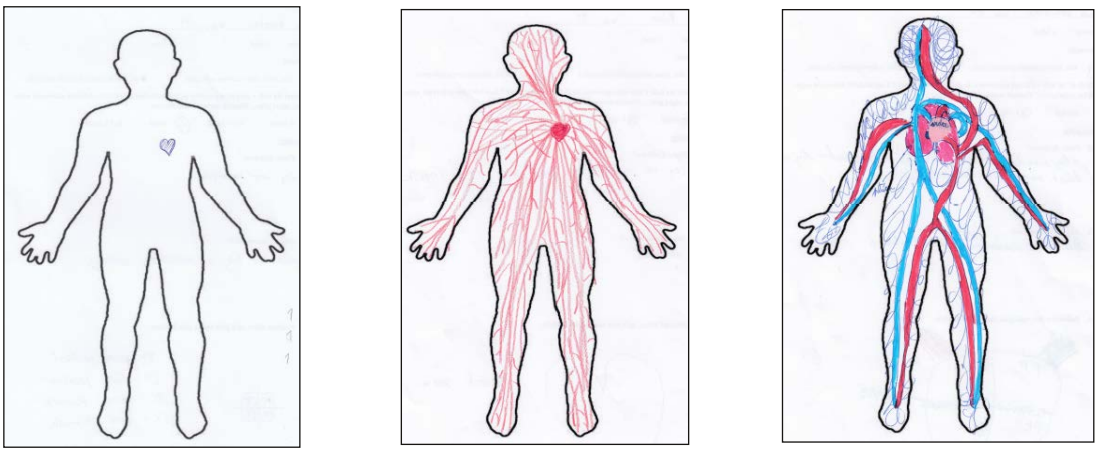

Figure 2. Examples of drawings of the circulatory system.

Discussion

Moderate correlations between scores obtained by the two independent research instruments (drawings and open-ended questions) were found. Similarly as with other researchers, numerous misconceptions about the human circulatory system were identified.

Scores from open-ended questions (significance of breathing and blood) and two drawings (heart and circulatory system) significantly, albeit moderately, correlated ($r_{ab.c}$ between .21 and .35). This suggests that drawings reflect students' ideas about the circulatory system, albeit this accuracy is not high. Cross-cultural as well as inter-individual comparisons of students' ideas about the human body measured with the drawing method can therefore be recommended. Previous failures to find any associations between open-ended questions and drawings (Prokop & Fančovičová, 2006) could stem from the use of "general instruction" (*Draw what you think is inside your body*). This is because, as was shown in the case of the urinary system (Prokop et al., 2009b) as well as for the circulatory system (the present research), moderate, but significant correlations between open-ended questions and drawings exist at least for these two organ systems.

Students have misconceptions about breathing, because about half of the students reported some association with oxygenation of the body (single accurate response), but very few (5%) reported that oxygenation is necessary for degradation of nutrients. Similarly, as reported by Arnaudin and Mintzes (1985), the frequency of more accurate functions of blood changed as the age of children progressed in all probability due to the positive influence of formal education. A minority of students understood the connection between the circulatory and respiratory system which suggests that students generally take into account the role of the heart, but not the role of the lungs (Arnaudin & Mintzes, 1985; López-Manjón & Angón, 2009).

Curiously, the heart is one of most frequently drawn organ by students of various age groups (Bartoszek et al., 2008; Özsevgeç, 2007; Prokop & Fančovičová, 2006) including teachers (Patrick & Tunnicliffe, 2010), but drawings with the connection of the heart with other organs of the circulatory system are rare (Patrick & Tunnicliffe, 2010). The students, who participated in this research by revealing their mental models through drawings, demonstrated similar patterns to that shown by other studies (Bartoszeck et al., 2008; Özsevgeç, 2007; Reiss et al., 2002). The

https://doi.org/10.33225/jbse/19.18.549

analysis of the students' drawings revealed that the typical Valentine heart drawn by 30% of students is a typical, frequently reported, misconception about the shape of the heart (Arnaudin & Mintzes, 1985; Bartoszeck et al., 2008). More than one third of children did not seem to have any idea about how the heart is divided. Arnaudin and Mintzes (1985) similarly reported that about 40% of primary school children thought that the human heart is three-chambered (amphibian-type). A majority of children (55.9%) thought that the function of the heart is blood purification which is in agreement with other researchers (Arnaudin & Mintzes, 1985; Özgür, 2013; Özsevgeç, 2007).

Limitation

The results of the present research are based on a specific homogeneous sample of Slovak students from one school. Thus, some caution must be made when interpreting these data. Future research should further investigate misconceptions about the human body with data from larger, more diverse samples.

Conclusions

These results suggest that the use of "general instruction" in association with the method of drawing should be avoided due to its limited scientific value. It has been found that data obtained from drawings will probably never provide an insightful understanding of students' ideas in comparison with interviews, but the drawing method still has scientific value. Careful instruction along with additional questions provides valid image about students' misconceptions. Researchers should be very careful in instructing children what to draw in order to obtain accurate responses. Drawings are cheap, time efficient and easy to conduct. It has been confirmed that features of the drawing instruction are particularly valuable in cross-cultural research, where standard, comparable conditions are hard to achieve.

Acknowledgment

The authors thank David Livingstone for improving the English. This research was supported by the university grant no. 8/TU/2018 and by the Slovak Research and Development Agency under the contract No.APVV-14-0070 [grant number APVV-14-0070]. PP was partly funded by grant VEGA no. 1/0104/16.

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ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

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Received: *March 02, 2019* Accepted: *July 21, 2019*

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https://doi.org/10.33225/jbse/19.18.549