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Abstract: *Teachers' subject matter knowledge is a substantive component of the teaching-learning process. For a teacher to be able to transform and integrate into the classroom all the knowledge and experience they have acquired in the course of the professional activity, it is first necessary to acquire a deep and solid knowledge of the matter. The aim of the research was to analyse the understanding that pre-service teachers have about the physiology and anatomy of the human body. The alternative conceptions that pre-service teachers held about the nutritional function in living beings were also explored. The research was conducted on a biology course of the Primary Education Bachelor's Degree during the 2018/2019 academic year. Drawings and open-ended questions were collected from 96 pre-service teachers. The results reveal that the students surveyed have limited knowledge of the subject before entering university. The use of drawing proved to be an excellent tool for detecting previous conceptions and evaluating the progression made by the students in their learning. Numerous alternative conceptions were identified among the students, thus demonstrating the need to think about the scientific methodology used to teach these contents.*

Keywords: *alternative conceptions, human body, human nutrition, pre-service teacher's drawings, subject matter knowledge*

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UNDERSTANDING PRE-SERVICE TEACHER CONCEPTUAL KNOWLEDGE OF HUMAN NUTRITION PROCESSES THROUGH DRAWINGS

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Introduction

One of the main components in the teaching-learning process is the teacher, and therefore the improvement of teaching is partly based on the performance of teachers in the classroom. Although it is true that other factors that can affect this process, such as those directly related to the student (intelligence, motivation, learning speed, previous knowledge, etc.) or socio-environmental factors (classroom characteristics, socio-economic situation, family context, cultural and religious variables), it is especially necessary to determine the knowledge that the teachers should have to teach efficiently (Gipps, 1999; Wragg et al., 1998).

Numerous research studies have indicated that subject matter knowledge (SMK) is closely linked to the teacher's didactic knowledge of content, and therefore positively influences teachers to develop more effective teaching and have a wider repertoire of instructional resources (Ball et al., 2008; Kaya, 2009; Krauss et al., 2008; Özden, 2008; Rollnick et al. 2008). SMK includes possessing the factual knowledge contained in the course material and organising the material in a curriculum (Ball & McDiarmid, 1989), as well as knowing the correct answer to problems (Ball, 1991; Rizvi, 2004; Schmidt et al., 2009), the methods of enquiry (Kennedy, 1990), and the social history roots of the subject (Baturó & Nason, 1996; McDiarmid, 1988). Several researchers have even shown that low subject knowledge leads to greater reliance on the textbook (Hashweh, 1987; Lee & Porter, 1993), a greater number of less cognitively demanding activities (Carlsen, 1993), more difficulties in setting learning goals and teaching strategies (Abell & Roth, 1992; Glasson & Lalik, 1993; Sanders et al., 1993; Smith & Neale, 1991) and a higher incidence of misconceptions among students (Valanides, 2000).

It is therefore not surprising that it is of particular interest to know whether teachers, practicing or in training, possess this kind of knowledge, which is absolutely necessary for their professional development as teachers.

The present research was focused on this second group of teachers, and more specifically, on the knowledge of the subject (physiology and human anatomy) possessed by a group of pre-service teachers before taking the first subject of natural sciences in the teaching degree.

Human Body Knowledge Using Drawings as a Method of Conceptual Analysis

The study of human life functions should begin during the first years of schooling due, among other reasons, to the predisposition of children of these ages to explore their own bodies. Nutrition fulfils an essential life-maintaining function allowing living beings to exchange matter and energy with the environment. However, students have serious difficulties in understanding it because it requires knowledge of the different biological or physiological processes involved in the nutrition function, such as breathing, blood circulation, etc. In the Spanish primary school curriculum, the respiratory and digestive processes are taught in the early years of education (ages six to eight); the rest of the functions, and the organs responsible for carrying out these functions, are taught later (ages eight to ten), and the organ systems involved in the function of nutrition and their interrelations are taught in the last stage of primary education (ages ten to twelve). Different studies carried out with children of these ages all indicate that this type of teaching is too focused on the anatomical aspects of each of the systems that make up the human body (Cañal, 2008; Carvalho et al., 2004; García-Barros et al., 2011). In this methodology, learning the names of many of the structures of our body is usually encouraged, however, understanding the functioning and biological meaning of these structures is rarely promoted, and it is common for students to develop little significant and highly fragmented knowledge about the human organism (Enochson & Redfors, 2012; Nuñez & Banet, 1996).

Numerous studies have been undertaken to determine the conceptual understanding that students have of the human body's functions and structure (Bahar et al. 2008; Carvalho et al., 2004; Cuthbert, 2000; Fančovičová & Prokop, 2019; García-Barros et al., 2011; Manokore & Reiss 2003; Prokop et al. 2009; Reiss & Tunnicliffe, 2001; Reiss et al., 2002; Rowlands, 2004; Tunnicliffe & Reiss, 1999). Although different techniques have been used (surveys, questionnaires, two-tier diagnostic tests, interviews, etc.), drawings seem to be the ideal methodology, because they allow us to detect a student's mental model (Buckley et al., 1997; Guichard, 1995; Rennie & Jarvis, 1995) and to compare the knowledge of students from different countries (Reiss et al., 2002). It is widely recognised that drawings demonstrate a student's true understanding and conceptualisation of basic concepts unlike written texts, where it is not possible to identify students' misconceptions (Scherz & Oren, 2006). Various reports have revealed that students of different ages were not able to draw connections between organ systems or between organs within the same system (Cuthbert, 2000; Dempster & Stears, 2014; Ozseveg, 2007; Óskarsdóttir, 2006; Óskarsdóttir et al., 2011; Reiss & Tunnicliffe, 2001). Other authors reported that children first learn that there are different organs in our body, then they realise that organs have a specific location in the body and discover that some organs are related to each other and that this allows them to carry out a specific function. In some cases, students come to learn that different organs constitute a system, but most present misconceptions or difficulties in appreciating the interrelations between different organs and systems (Carvalho et al., 2007; Reiss et al., 2002). It is therefore essential that primary school teachers, and more specifically, pre-service teachers, possess a global knowledge of human anatomy and physiology, and understand that the human body is an open system that is continuously exchanging matter, energy and information with the environment that surrounds it, and that is formed by many interconnected elements whose set is much more than the sum of its components.

The aim of this research was thus to understand the knowledge that pre-service teachers have of anatomical and/or functional aspects related to human nutrition before the experimental sciences course.

The research focused on the following research questions:

1. Do pre-service teachers have adequate knowledge of human anatomy and physiology when they reach the university stage?
2. What is the prevalence of misconceptions and alternative conceptions about the human nutrition in Spanish pre-service teachers?



Research Methodology

General Background

The research was carried out during the 2018/2019 academic year by collecting both quantitative and qualitative data that were used to examine pre-service teachers' knowledge and misconceptions about the nutrition process. This work was part of a larger research to know previous knowledge that pre-service teachers have regarding human anatomy and physiology before taking the first subject of natural sciences. The sample was selected using non-probabilistic convenience sampling.

Participants

The participants ($n = 96$) were second-year students studying 'The Curriculum Development of Experimental Sciences' in the Bachelor's Degree in Primary Education at the University of Valladolid (Spain). The genders and ages of the students surveyed, as well as the pre-university schedule leading up to the Degree in Primary Education, are shown in Table 1.

Table 1
Gender, Age and Pre-university Schedule of the Pre-service Teachers (N (%))

	Gender		Age			Pre-university schedule		
	Men	Women	19-24	25-30	>30	Science baccalaureate	Non-science baccalaureate	Non-baccalaureate
Students (n=96)	29 (30.2%)	67 (69.8%)	85 (88.6%)	8 (8.3%)	3 (3.1%)	31 (32.3%)	54 (56.2%)	11 (11.5%)

Data Sources

The data were collected during the first lectures on the subject from two primary sources: 1) student drawings, and 2) a knowledge questionnaire. The drawing method used in this research was based on previous studies (Reiss & Tunnicliffe, 1999; 2001; Reiss et al. 2002). Students were asked to draw the different organ systems of the human body involved in the nutrition process on a blank paper. They were told to write their age, gender and their pre-university schedule at the top of the paper. Pre-service teachers were given 35 to 40 minutes to complete the drawing.

Subsequently, and to supplement the information provided by the drawings, a questionnaire consisting of four open questions was included (one question per organ system). Questions were related to the functions of the systems involved in human nutrition (respiratory, circulatory, digestive and urinary) (e.g., Please, could you explain the process of physiological respiration or respiratory system?). The questionnaire was chosen as an information-gathering tool, taking into account that, although it depends on the verbal and written skills of students, it also promotes reflection, creativity and even problem solving, as students must constantly make decisions about what to write and how to write it (Kellogg, 2008).

Data Analysis

Drawings were classified using a seven-point scale initially developed by Reiss and Tunnicliffe, (2001), and later modified by Prokop and Fančovičová (2006), reflecting different levels of biological and/or scientific understanding. Students were asked to make four independent drawings, one for each organ system involved in the nutrition



process (respiratory, circulatory, digestive and urinary), and these organ systems were assigned a level from one to five. A total score which ranged from one to a maximum of seven was also assigned for the whole drawing. Level 1 meant that no organs of any system were present in the drawing and Level 7 that pre-service teachers were able to draw the four organ systems. The criteria for coding each organ system were based on the criteria used by Reiss and Tunnicliffe, (2001). The drawings were coded three times (organs/organ systems/biological quality of the drawing). The artistic quality of the drawings was not taken into consideration. The drawings were scored independently by two professors of the department, who decided whether they met the criteria for each of the organ systems. The coding agreement rate was >95%.

As with the drawing evaluation, the questionnaire answers were evaluated autonomously by the same two professors of the department. To facilitate the analysis of the information, student responses were categorised on three levels (incorrect, correct and excellent), according to different parameters (scientific/biological knowledge, clarity of response, capacity of synthesis, diversity, quantity or type of terms used, etc.). All the statistical analysis was performed using the statistical package R (version 3.5.0) (R Core Team, 2019). A descriptive analysis was applied for each item, using the percentages of each category as descriptive statistics. Parametric (Student's *t*-test, one-way ANOVA) and non-parametric tests (Mann-Whitney *U* test, Kruskal-Wallis ANOVA) were used to evaluate the differences between the different groups analysed.

Research Results

The Drawings

The drawings made by the pre-service teachers were analysed and categorized according to the above criteria. The average overall level achieved by pre-service teachers in their drawings was 5.6 (range from 1 to 7; Table 3), corresponding to between one and three organ systems drawn (e.g. respiratory or digestive systems). As Figure 1 shows, half the pre-service teachers ($n=48$) drew two or three major organ systems (Level 6). Approximately, 30% of the students scored at Level 5, drawing two or more connected organs in appropriate positions (e.g. oesophagus connected to stomach or arteries connected to heart) and 14% reached Level 7, drawing the four organ systems involved in the nutrition process (Figure 2). Less than 10% of the pre-service teachers scored at Levels 1, 2, 3 and 4. No significant differences were found in the average level achieved by students regarding the pre-university schedule.

Figure 1

Percentages of Students ($n=96$) Scoring on Seven-point Scale (Reiss & Tunnicliffe, 2001)

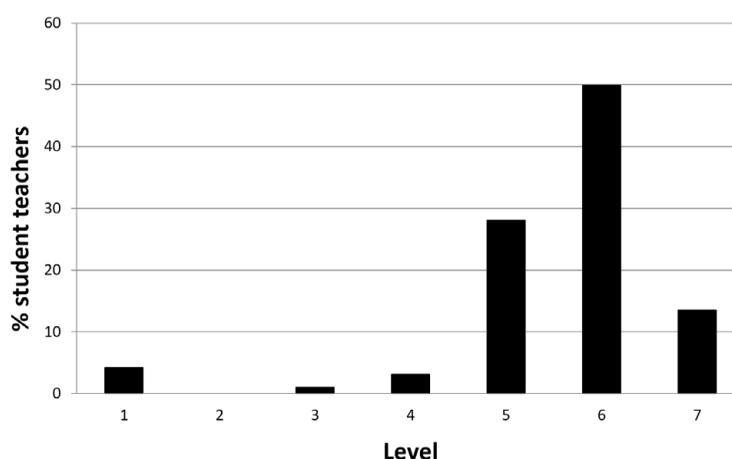
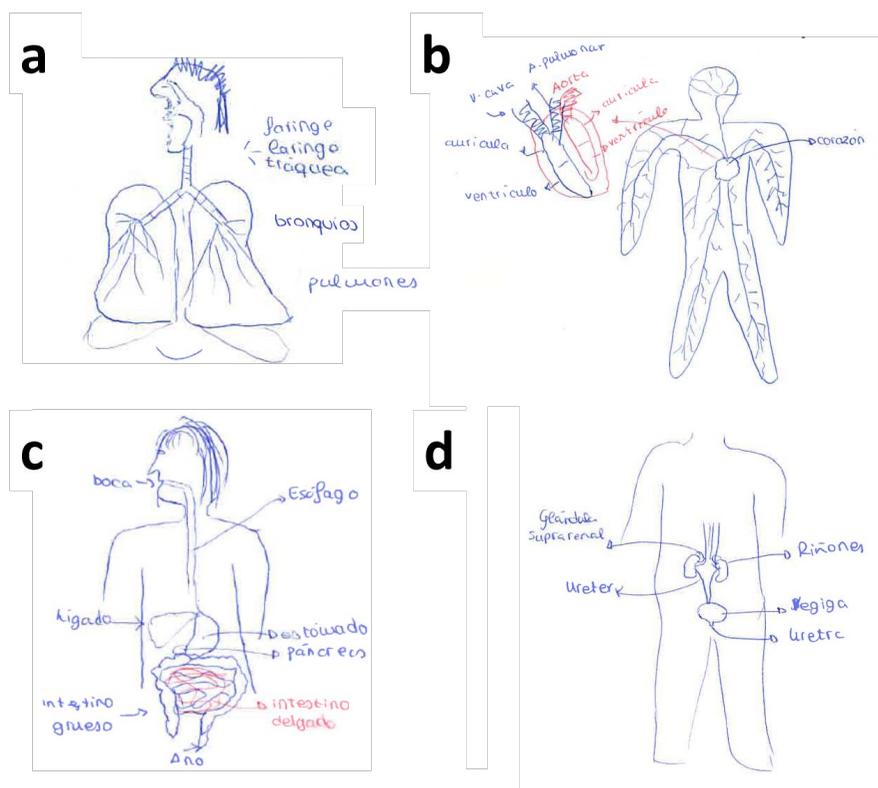


Figure 2

Examples of Pre-service Teacher Drawings of (a) Respiratory, (b) Circulatory, (c) Digestive and (d) Urinary Systems



Note: Each drawing was individually scored as Level 5, and globally as Level 7. (Captions read: faringe=pharynx, laringe=larynx, traquea=trachea, bronquios=bronchi, pulmones=lungs, corazón=heart, arterias=arteries, venas=veins, aurícula=atrium, ventrículo=ventricle, boca=mouth, esófago=oesophagus, estómago=stomach, hígado=liver, intestino delgado=small intestine, pancreas=pancreas, intestino grueso=large intestine, ano=anus, riñones=kidneys, ureter=ureter, vejiga=bladder, uretra=urethra, glándula suprarrenal=adrenal gland)

When the drawings of the organ systems were scored separately (respiratory, circulatory, digestive and urinary systems), the average levels achieved by pre-service teachers were 3.9, 3.7, 3.5 and 3.0 (range from 1 to 5, Table 3), respectively, corresponding to between one and two organs in suitable positions but no relations between them (e.g. the trachea was not connected to the lungs, or the kidneys were not connected to the bladder). The statistical analysis revealed that the science baccalaureate group achieved higher scores in the urinary system's drawing than the unscientific baccalaureate group ($p < 0.01$). Figure 3 provides an overview of the levels scored by pre-service teachers for each organ system involved in the nutrition process. Most of the pre-service teachers included connections between the organs and correctly drew an organ system (Level 5), and the circulatory system (61.46%) was the best drawn organ system, followed by the respiratory (56.25%), digestive (44.79%) and urinary (38.54%) systems. Many students (20-30%) did not draw any type of internal structure or organ on their drawings, however (Level 1). The urinary system registered even more students at this level (nearly 50%) than in the rest. The third most frequent type of drawing made by pre-service teachers (<20%) showed organs in the appropriate positions in each system but without marked relations (Levels 3 and 4) (e.g. the larynx was not connected to the lungs, or the intestines were not connected to the anus).

Figure 3
Percentages of Students (n=96) Scoring on a Five-point Scale for Each Organ System Involved in the Nutrition Process

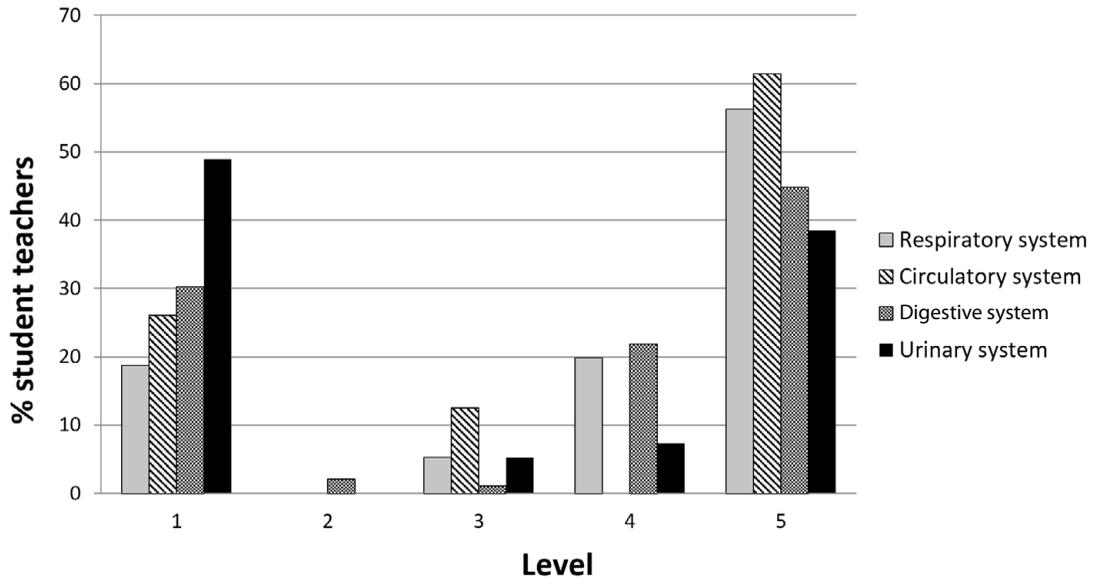
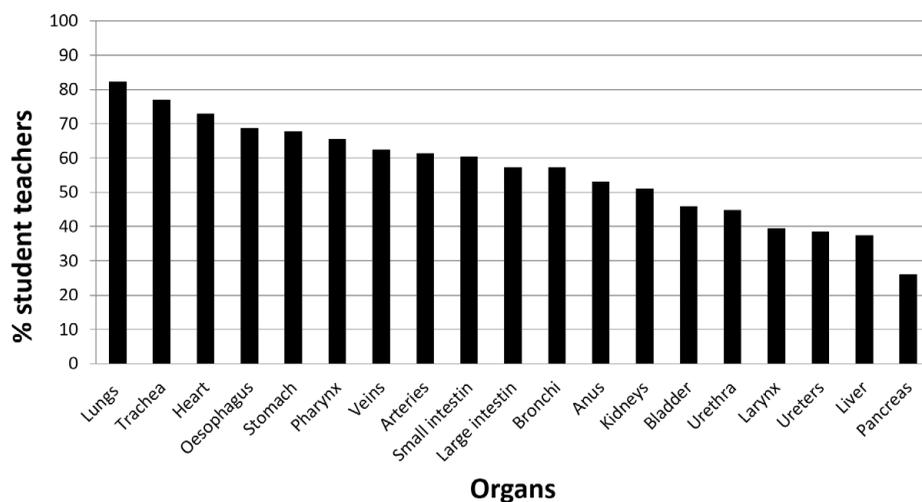


Figure 4 shows the most common organs drawn by pre-service teachers. The lungs were present in more than 80% of all drawings, trachea in more than 75%, and the heart, oesophagus and stomach were present in more than two-thirds of all drawings. In contrast, organs of the urinary system, such as the kidneys (51.1%), bladder (45.8%), urethra (44.8%) and ureters (38.5%) were least commonly shown. The larynx (39.6%), liver (37.5%) and the pancreas (26.1%) were the organs least drawn by pre-service teachers. No significant differences were found in the distribution of the main organs drawn regarding the pre-university schedule of the pre-service teachers.

Figure 4
The Most Common Organs Drawn by Pre-service Teachers (n=96)



Open-ended Questions

Figure 5 shows the students' knowledge of concepts related to nutrition processes through the questionnaire. Approximately two-thirds of pre-service teachers correctly defined the respiratory, circulatory and digestive processes that take place in humans. These percentages were significantly higher ($p < 0.05$) in the science baccalaureate group than in the other groups. Among these answers, it is necessary to point out that some 5% were categorised as excellent, giving not only a general response but also citing other important aspects of each process (e.g. in the respiratory system, including concepts or terms such as pulmonary ventilation, external and internal respiration, homeostasis, diffusion, alveolar and atmospheric pressure, cellular respiration, etc.). There was an important percentage of students (>30%), however, who were not able to define them adequately, demonstrating that these biological or physiological processes are not always well-known by many of the students. This percentage was even above 50% for the urinary system (Figure 5), demonstrating the limited knowledge pre-service teachers have about this system.

Figure 5

Percentage of Categorised Answers Mentioned by Pre-service Teachers in the Questionnaire

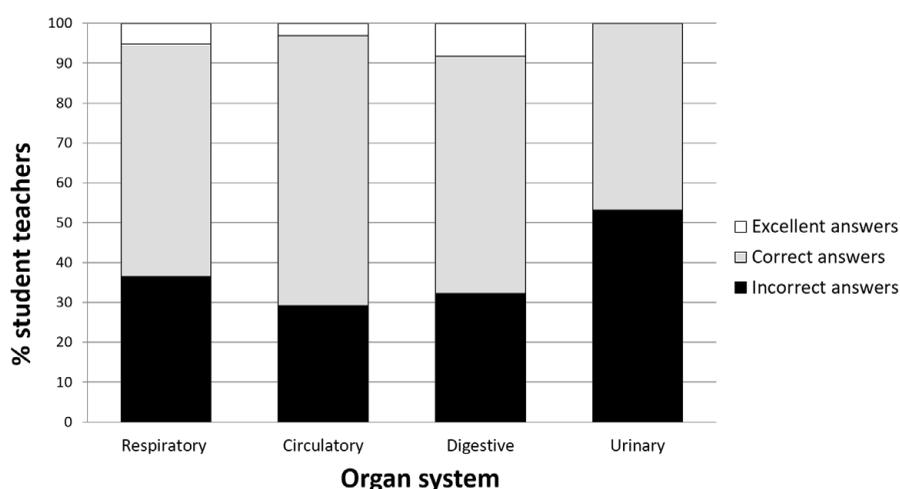


Table 2 shows the main misconceptions and alternative conceptions mentioned by pre-service teachers.

Table 2

Frequency of Misconceptions and Alternative Conceptions Mentioned by Pre-service Teachers (n=96)

System	Alternative conceptions/Misconception	Frequency
Respiratory	Human respiration consists solely and exclusively of introducing oxygen into the lungs and expelling carbon dioxide into the environment	13
	Oxygen is the only gaseous molecule involved in the respiratory process	11
	Students confuse external respiration with artificial respiration	3
Circulatory	The heart oxygenates and cleanses the blood	12
	Blood is produced in the heart	10
	All veins contain deoxygenated blood, and all arteries contain oxygenated blood	9
	Oxygenated and deoxygenated blood and dirty blood circulate on the left and right sides of the body, respectively	3



System	Alternative conceptions/Misconception	Frequency
Digestive	Digestion starts in the stomach	11
	Food moves to the stomach by gravity alone	8
	Students think that there is only chemical digestion	4
	Absorption of nutrients into the bloodstream occurs throughout the digestive system	3
	Students often confuse the oesophagus (part of digestive system) with the trachea (part of respiratory system).	2
Urinary	Students confuse the urinary system with the digestive system	24
	Urinary system is composed only of the kidneys, bladder and urethra	12
	Urinary and circulatory systems are not connected	8

Discussion

The results obtained in this research show that pre-service teachers have limited knowledge of human anatomy and physiology before entering university. Analysis of the questionnaires and drawings completed by the students demonstrates that many are partially or totally unaware of the processes and/or structures involved in the function of nutrition. Others present conceptual errors (misconceptions or alternative conceptions) that probably remain from their previous educational stages and prevent them from advancing towards more precise knowledge, demonstrating the need to reflect on the school model that is currently being used for science teaching. It should be noted that most of the students who access the Grade in Primary Education, have previously studied a non-scientific baccalaureate where there are no subjects related to biology or physiology, which can burden them when learning scientific content in the degree. This hypothesis is confirmed by this research, as the students coming from the science baccalaureate were noted to have greater knowledge and therefore a stronger scientific base than the others.

While it is true that this topic has been widely addressed in primary school classrooms, it should be noted that most of the work published to date has focused almost exclusively on the ideas of students (Andersson et al., 2019; Carvalho et al., 2004; Dempster & Stears, 2014; García-Barros et al., 2011; Óskarsdóttir et al., 2011; Prokop et al. 2009; Reiss & Tunnicliffe, 2001; Reiss et al., 2002; Rowlands, 2004; Teixeira, 2000). Although common sense suggests that a teacher's knowledge and beliefs influence their teaching decisions, and that the results of educational research reinforce the idea that teachers play a key role in the design of their students' learning environments and experiences (Bahamonde & Gómez-Galindo, 2016), there are few studies referring to the assessment of the teachers' SMK, and even less so if the target in question is pre-service teachers. This scarcity of studies, together with the low scientific knowledge of primary school teachers that many authors dare to suggest (Ball et al., 2008; De Jong et al., 1998, Özden, 2008), is what has motivated us to carry out this research, since it is clear that for children to obtain good learning results, it is needed for teachers to have the best possible knowledge of the content they are going to teach.

According to the drawings scored in the present research, the average level achieved by the pre-service teachers (5.6) was slightly higher than levels shown in previous studies with similar characteristics. For example, Prokop and Fančovičová (2006), in a work conducted with 133 first-year student teachers, indicated that the mean level acquired from drawings averaged at 3.34. These authors reported that the organ systems were included in <13% of drawings (\geq Level 5). This does not mean that drawings were empty, however, but that most organs were drawn without remarkable relations (e.g. windpipe was not connected with the bronchi). Ozsevgec (2007) assumed that the students may be learning the functions and names of the organs and not their systemic relations. Patrick and Tunnicliffe (2010), in another study conducted with more than 70 science teachers, reported that the mean level for all teachers was 5.04, demonstrating that the teachers were able to draw a wide variety of organs but that they had much more difficulty knowing how the organs were connected and therefore, drawing the organs in relation to the organ systems. These researchers also indicated that approximately 30% of the teachers were not able to draw a complete organ system and that only 7% of the teachers scored at Level 7 (four or more organ systems drawn). The data obtained in our research were slightly better and indicated that less than 10% of the teachers in train-



ing scored below Level 5. However, it is necessary to point out that unlike previous studies, where students were asked to draw all the organ systems that there are inside the human body on the same paper, in this research only the students were asked to draw the four organ systems involved in the function of nutrition (respiratory, circulatory, digestive and urinary) and furthermore, on different space or paper, which could have improved the results. Another aspect to be highlighted, despite the improvement observed with respect to previous studies, is that the pre-service teachers reached slightly higher levels than those shown in previous studies conducted with students from primary and secondary school, who showed a notable lack of connections between organs (Dempster & Stears, 2014; Óskarsdóttir et al., 2011; Reiss & Tunnicliffe, 2001; Reiss et al, 2002). It is therefore logical to suppose that if the understanding of teachers and students is not so different, the SMK of science teachers should be assessed to make decisions in order to increase the volume of knowledge of these teachers with respect to their students.

The organs most commonly drawn by the pre-service teachers were the lungs, trachea, heart, oesophagus and stomach, corresponding to respiratory, circulatory and digestive systems, which were also the best drawn organ systems because they included connections between the organs. These results are consistent with those showed in previous studies (Patrick & Tunnicliffe, 2010; Prokop et al. 2009; Prokop & Fančovičová, 2006; Reiss & Tunnicliffe, 2001), with some variation in frequency order. The common inclusion of these organ systems in pre-service teacher drawings can be explained because they are most familiar with the organs of these systems, and because these organs or the functions they perform can be felt and perceived. Everyone is able to feel the air coming in and out of their lungs, hear the heartbeat and the same applies to the digestive system (eating, food, hunger, etc.). The urinary system was the worst drawn, probably because it is the least familiar to learners and there is a lack of awareness of the ureters, which connect the kidneys to the bladder. Other organs, such as liver and pancreas, were rarely drawn by pre-service teachers, as they believed these organs were not part of the digestive system. Several authors have also indicated that the organs shown in student drawings are possibly influenced by social, economic and cultural factors (Dempster & Stears, 2014; García-Barros et al., 2011 Óskarsdóttir et al., 2011; Reiss et al., 2002).

Another objective of the research was to identify whether the alternative conceptions about functional aspects related to human nutrition, which have been relatively well documented in children (Carvalho et al., 2004; Dempster & Stears, 2014; García-Barros et al, 2011; López-Manjón & Postigo, 2009; Teixeira, 2000), are also present among the students. The results of the present research showed that the most common mistakes were related to the urinary system, demonstrating the close relation between the drawings and the written answers, in contrast to previous reports (Fančovičová & Prokop, 2019; Prokop & Fančovičová, 2006). The pre-service teachers confused the urinary system with the digestive system and believed that some organs of the digestive system such as the intestines or pancreas were part of the urinary system. Moreover, many students thought that the substances following digestion were urinary substances and that they are harmful for the body (Genç, 2013). Another alternative conception noted in this research was related to the exchange of gases that takes place in the respiratory process. Many students thought that the process ended when the oxygen was introduced into the lungs and the carbon dioxide was expelled into the environment, and they did not consider that oxygen must be delivered to the bloodstream and then the tissues to produce energy. A possible explanation could be that some students are not able to apply their knowledge to organs that cannot be seen or to structures at the micro level. This same misconception was reported by Badenhorst et al. (2016) in a study concerning the naïve beliefs of first-year medical students regarding respiratory physiology.

The findings of this research also indicated several alternative conceptions related to the function of the heart and blood circulatory pattern. As in previous studies (Bahar et al., 2008; Pelaez et al., 2005; Tekkaya, 2002), one of the most common misconceptions in this topic was that the heart has the function to clean or produce the blood. Özgür (2013) suggests that one of the main sources of such alternative conceptions are the diagrams and figures that appear in textbooks, because many student interpretations of these diagrams contradict scientific knowledge. The two most frequent alternative conceptions in the present research regarding the digestive system were that gravity is solely responsible for moving food to the stomach and that digestion starts in the stomach. Prokop and Fančovičová (2006) reported that students have an inadequate understanding of where digestion takes place and some thought that digestion was the function of the liver, colon or pancreas.

Conclusions and Implications

According to educational standards, teachers need a deep SMK to efficiently resolve all the doubts of their students and solve the difficulties that may arise in their learning. The results obtained in this research show that pre-service teachers have limited knowledge of human anatomy and physiology before entering university. Com-



parative analysis among the different groups of students intuitively suggests that one of the possible reasons for this could be the degree of scientific disconnection that a good part of these students have experienced since their pre-university stages. This lack probably weighs heavily on these students throughout the science subjects of the grade, preventing them from achieving the expected learning results. It is thus vitally important to identify the previous ideas of students so that the educational system can adjust and adapt to the students' true knowledge.

Another conclusion reached is that drawing, together with a brief explanation by means of open questions, is an excellent tool for detecting previous concepts and evaluating the progress made by students in their learning. Drawing improves the acquisition of information by promoting the modification of mental representations, the construction of knowledge and significant learning. The results highlight the need to include drawings and descriptions in teacher training, so that they can be used later in the modelling of processes and concepts by students.

Finally, the main misconceptions and alternative conceptions that the students have on this subject and that demonstrate the need to reflect on the model used for their teaching have also been detected. The use of specific teaching methodologies for the teaching of science could be an ideal way to drastically reduce these conceptual errors. This is especially relevant in the Primary Education Bachelor's Degree, as teachers are professionals who act as transmitters of knowledge and could provide feedback on the persistence of these conceptual errors among their future students. In this sense, it would be important to advance a similar line of work that encompasses all the systems of the human body which would be a crucial research tool when designing activities for the training and professional development of teachers, and the planning of their teaching in the classroom. Another line of work could be focused on the scientific correction of the illustrations present in the textbooks, since as some authors suggest, one of the main sources of misconceptions are the figures that appear in these textbooks. The aim is to reduce or eliminate alternative or misconceptions from an early age and to avoid their persistence in pre-service teachers as they could negatively interfere with didactic transposition.

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