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Relative contribution of experimentation and Educational Technology in the science classroom

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Resumen

Hoy en día las TE están muy presentes en la educación y parecen ofrecer grandes promesas, sin embargo, ¿Llegan todas esas promesas realmente a cumplirse? El impacto de estas herramientas dependerá del nivel de integración que tengan en el aula que se puede medir a través de modelos de integración como SAMR o TPCK. Además, en el área de ciencias surgen dudas acerca de si elegir una metodología exclusivamente basada en TE, solo experimentación o una mezcla de ambas.

Mediante el presente estudio empírico se pretende hacer una propuesta de actividades que combinen la experiencia directa y el uso de TIC para abordar las ideas alternativas del alumnado de segundo de Educación Primaria en el área de Ciencias Naturales, y más específicamente el cuerpo humano para comprobar la efectividad y el impacto de esta metodología mixta. Hemos visto que la complementación de experiencia directa y uso de simuladores ayuda al alumnado a comprender no sólo la anatomía humana (lo que vemos) sino que también la fisiología (funcionamiento) de diferentes órganos, aparatos y sistemas. Podemos concluir que se trata de una metodología muy efectiva en la que ambas la experimentación y el uso de TE son necesarias y complementarias.

***Palabras clave*:** TIC; Experimentación; Cuerpo Humano; Ideas Alternativas, Educación Primaria.

Abstract

Nowadays, ET are very present in education and seem to offer great promises, however, do all these promises really come true? The impact of these tools will depend on their level of integration in the classroom, which can be measured through integration models such as SAMR or TPCK. Furthermore, in the area of science, doubts arise about whether to choose an exclusively ET-based methodology, only experimentation, or a mixture of both.

The present empirical study aims to make a didactic proposal that combines direct experience and the use of ICT to address the alternative ideas of students in the second year of Primary Education in the area of Natural Sciences, and more specifically the human body to test the effectiveness and impact of this mixed methodology. We have seen that the complementation of direct experience and the use of simulators helps students to understand not only human anatomy (what we see) but also the physiology (functioning) of different organs, apparatuses and systems. We can conclude that this is a very effective methodology in which both experimentation and the use of ET are necessary and complementary.

Keywords: ICT; Experimentation; Human body; Misconceptions; Primary Education

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Acronyms Index:

CRUE (Conferencia de Rectores de las Universidades Españolas)

DEL: Direct Experience Learning

DigCompOrg: Digital Competent Educational Organizations

ICT: Information and Communication Technologies

MEC: Ministry of Education, Culture and Sports

SAMR: Substitution, Augmentation, Modification and Redefinition

TE: Educational Technology

TEP: Technologies of Empowerment and Participation

TLK: Technology for Learning and Knowledge

TPCK: Technological, Pedagogical, and Content Knowledge

VOL: Vicarious Observational Learning

1. THEORETICAL FRAMEWORK

It is universally acknowledged that nowadays, Information and Communication Technologies (ICTs) are present in all the contexts of life. Considering that Education is one of these contexts, it is natural to think that new technologies have blown in here too (García, 2011, cited in García & Ramírez 2017). In fact, the introduction of ICTs in education has not been an effortless process, but a long and laborious course that has been taking place during the last decades. There are already some other concepts related to new technologies such as TLK (Technology for learning and knowledge) which tries to give a more pedagogical approach to the use of ICTs (Lozano 2011, cited in Napal & Zudaire, 2019) or TEP (Technologies of Empowerment and Participation) inside of a broadened concept of Educational Technology (TE) but these approaches have not penetrated as much as ICT.

1.1. Reasons for introducing ICTs in education

But, why is there great interest in promoting and investing in ICTs? Well, the answer is simple. On the one hand, the educational system has to technologically develop at the same time that society does, in order to meet the necessities and features of new citizens (Napal & Zudaire, 2019). On the other hand, this interest is due to the immense benefits that these tools have the potential to bring to the classroom. As pointed out by Área (2012), the use of ICTs in education has broadened the scope of users, breaking down the distance and timing borders and allowing students from all around the globe, at any time, to get connected to an online lesson. Additionally, this scope has gone even further considering that online education has notably reduced the costs in comparison to “face-to-face” education. Not to mention the increasing autonomy when using ICTs (Sáez López, 2012; cited in Napal & Zudaire, 2019) without leaving aside the group work through a virtual community. Moreover, as Área (2012) states, information (all kinds of it) is more accessible than ever allowing users to easily jump from one piece of information to another one.

Other authors such as Punie et al. (2006), affirm the great impact of these tools on pupil’s engagement and creativity, and how much time they can save. The report *Survey of schools: ICT in education. Benchmarking access, use and attitudes to technology in Europe’s schools* by the European Commission highlights the considerable curiosity for learning and motivation that students show when using new technologies. They state that “el 75% del alumnado coincide en que usar un ordenador es realmente divertido” [75% of the students agree that using a computer is really fun] (European Commission, 2013; cited in Napal & Zudaire, 2019, p.150).

As far as science is concerned, there are several specific advantages implied by the use of new technologies in the classroom. Some examples include being able to see invisible things (e.g. Reality augmentation), see things that exist but we cannot see (the inside of our body covered by the skin or the colorado canyon which is 8000km away), transform abstract ideas into tangible ideas (Animations), visualize abstract concepts that are hard to imagine (animations and simulators), add a third dimension and be able to see something from any angle (3D models) and even add a fourth dimension which involves the variable of time. (Napal & Zudaire, 2019). All these tools defeat the time, distance, cost, complexity, security and scale barriers making the classroom reach many concepts that would have been inconceivable without new technologies. For instance, having a look to the inner parts of our body and its physiology

Indeed, among the eight key competences for Lifelong Learning by the European Union, we can find the Digital Competence (Ferrari, 2013). Digital Competence is defined as “the creative, critical and safe use of information and communication technologies to achieve objectives related to work, employability, learning, use of free time, inclusion and participation in society” (Disposición 738 del BOE núm.25, 2015, p. 6996). Ferrari (2013) also highlights the transversality of this competence since it “enables us to acquire other key competencies (e.g. language, mathematics, learning to learn, cultural awareness)” (p.2). This can be related to the idea of considering new technologies a medium for achieving any educational purpose rather than considering them an aim themselves (Rodríguez de Dios & Igartua, 2015; Zapata-Ros, 2015, cited in García & Ramírez, 2017). Thus, the Digital Competence is a crucial competence which is included in the actual educational law (LOMCE, 2013).

1.2. Critical ideas on the use of ICTs

However, these multiple benefits that new technologies bring cannot be taken for granted. ICT is not an automatic synonym for innovation, and using ICTs does not mean that these promises will come true. As Livingstone (2012) states, the use of ICT does not imply better education or an automatic motivation in students that enhances learning. Many different variables impede establishing these benefits and Livingstone (2012) highlights some of these problems. The first one deals with the broad variety of technologies collected under the term of ICT, which hinders the evaluation of the effectiveness of particular tools. In other words, when the type of technology is not specified it becomes quite difficult to notice any specific improvement so it is necessary to choose a specific tool for a specific task. The second problem is related with the lack of teacher training: as discussed in Napal & Zudaire (2019), providing the classrooms with ICTs is not enough if teachers are not skilled and if there still exists a lack of models of use for teaching. Furthermore, several authors consider that teachers focus on the technical ICT skills instead of integrating those skills within the learning and teaching process (Tonduer et al., 2007, cited in Livingstone 2012). The third problem is related to the lack of coordination between home and school derived from the "digital divide"[1]. In fact, with the sanitary crisis experienced last year, this digital divide has become even more evident since education had to move from face-to-face to virtual or online lessons due to the circumstances and restrictions. Several authors deal with the difficulties that this brought to millions of families around the globe. Lantarón et al. (2021) discuss this increased digital divide that sets aside students without a proper access to digital resources. Furthermore, this study also gave us some highlights of the general disappointment from students on the use of virtual platforms. The results showed that moving education to virtual environments was a failure since institutions did not adopt a virtual model of teaching but instead, they used virtual platforms to replicate the methodologies that work in face-to-face lessons.

Consequently, we can conclude that not having the necessary resources at home could broaden this existing divide making educational opportunities uneven but, even having access is insufficient because it is also necessary to follow a virtual model of teaching (Hernández & Álvarez, 2021).

1.3. Conditions for a proper introduction of ICTs in education

Some authors as García & Ramírez (2017) and Área (2012) suggest that the effective introduction of ICT in instruction activities, and therefore the promotion of the Digital Competence of students and teachers is favoured by the existence of educational policies promoting the use of ICTs, and specific teacher training programs in the use of ICTs.

1.3.1. Educational policies

Many educational Institutions have decided to establish policies in order to effectively introduce ICT in instruction activities (Área, 2012). One example is the agreement of the CRUE (*Conferencia de Rectores de las Universidades Españolas*) to promote virtual campuses (Área, 2012). Besides, there is a reference European Framework for Digital Competent Educational Organizations (DigCompOrg) that serves as a guiding and planification tool for schools and for policy makers (Kampylis, Punie & Devine, 2015 cited in García & Ramírez , 2017).

During the last decades there have been some initiatives promoting the use of new technologies in Spain and more specifically in Navarre. The interest in this integration has been maintained over time and it has taken place in sequence, this means that it has progressively been introduced and the focus has also been changing over time. The first focus was to familiarize teachers with the use of new technologies as didactic tools, then, the

[1] Digital Divide: the problem of some members of society not having the opportunity or knowledge to use computers and the internet that others have (Cambridge Dictionary, 2021).

focus was on the provision of schools with materials and infrastructures, finally, they focus was on the pedagogical integration of new technologies. We can notice this focus change by having a look at the projects that have been implemented.

One significant project was the ATENEA project. This project was launched in 1984 with the aim of introducing ICTs in basic and secondary education levels (only for schools dependent on the Ministry of Education, Culture and Sports [MEC]). This five-year program had the pedagogical aim of using computers as didactic tools (Arango, 1985). Another relevant project is the TRENZA project. This project was launched some decades later in 2009 and it encouraged schools to access the internet by investing for instance on projectors for the schools and plugs on each of the classrooms. Finally an actual project is IkasNOVA, this project started in 2017 on secondary education classrooms facilitating electronic devices (chrome books) for each of the students substituting textbooks and starting to work in online networks. In this way, educational institutions have progressively equipped schools with the necessary technological tools and lately promoted the modernization of the teaching and learning methods. In other words, there has been a shift from infrastructure provision to its final integration.

1.3.2. Teacher training

On the other hand, as it has been mentioned above, teacher training is indispensable for a meaningful introduction of ICTs. Gutierrez (2008) insists on the fact that teachers need to be digitally literate. The UNESCO (2006) defines digital literacy as “a complex set of critical competencies that allows individuals to express themselves, explore, question, communicate and understand the circulation of ideas between individuals and groups in technological contexts rapidly changing” (p.160). In conclusion, if we want literate students we need competent teachers, which have some further implications. Indeed, “teacher training should not just encompass ICT skills but rather a full understanding and complete mastery of ICTs as pedagogical tools” (Punie et al., 2006, p.13). They also talk about the positive impact of teacher training in their confidence and competence. Other authors as Napal & Zudaire (2019) support Punie’s idea of increased teachers’ confidence when receiving training and relate it with the different technological abilities and capacities highlighting the confidence when exercising operative capacities (digital image editors, films, text editors and processors…) in comparison to their social communication abilities (online chats and forums, use of social media…) or pedagogical decision abilities. Besides, they relate this confidence to the active participation in continuous training.

1.4. Integration models to generate impact: TPCK and SAMR

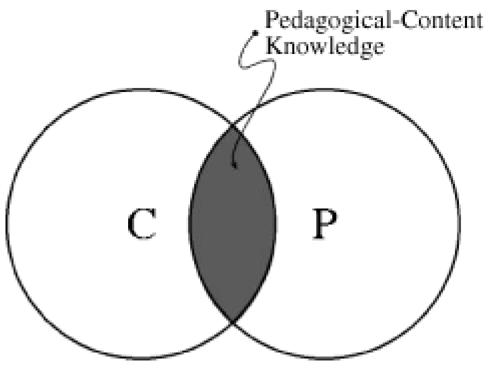
However, the presence of ICT does not ensure a real impact on students. In order to generate this impact and provoke a significant improvement, there exist two integration models known as TPCK (technological, pedagogical, and content knowledge) and SAMR (Substitution, augmentation, modification and redefinition) that can support the process by giving teachers a standard to get compared with, reflect on the impact achieved and if necessary modify their practice in order to improve.

1.4.1. TPCK model

The first model focuses on the different types of knowledge that teachers should have, and is rooted on the concept of (Pedagogical Content knowledge), coined by Shulman in 1986 (Napal & Zudaire, 2019). The PCK model considers the intersection between content and pedagogy (See Figure 1). This relation completely changed the way of teaching and as Mishra and Koehler (2006) explain: “At the heart of PCK is the manner in which subject matter is transformed for teaching. This occurs when the teacher interprets the subject matter and finds different ways to represent it and make it accessible to learners.” (p. 1021). In other words, teachers should focus not only on the content that they want to teach but also in the way they want to do it in order to make it intelligible to others.

Figure 1.

PCK: Pedagogical-Content Knowledge model

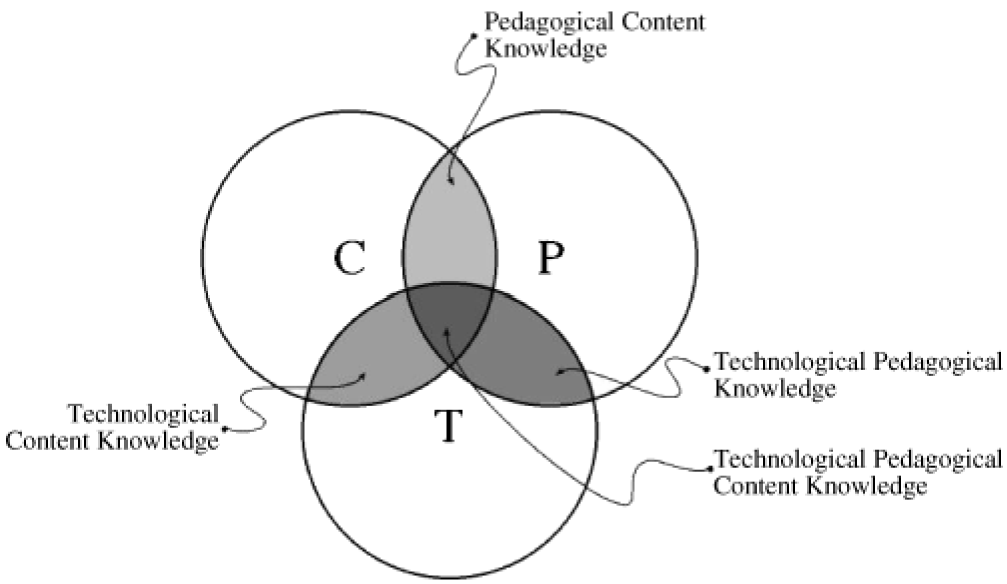


Note: Shulman’s PCK model of 1986 retrieved from: Technological pedagogical content knowledge: A framework for teacher knowledge (p.1022) by Mishra & Koehler (2006). Teachers College Record.

Mishra & Koehler (2006) envisages the introduction of technology as a third sphere that must intersect with the other two, since technologies also can “help make subject matter more accessible to the learner.” (p.1023). Furthermore, they state that new technologies do not remain stable and standardized but in continuous evolution. Hence, teachers need to also focus on the third variable of technology knowledge. They explain that this third variable should not be represented as an isolated domain, but acknowledge the complex relation between the three variables. This last incorporation to the model takes us to the TPCK model (sometimes also named TPACK). As we can observe in Figure 2, this model defines different spaces, characterized by various types of intersection among the three spheres: each domain considered individually: TK, CK, PK, in pairs: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and finally on the intersection of all of them (TPCK). Thus, the TPCK model adds three new concepts to Shulman's model of PCK: two pairs of knowledge (TCK and TPK) and the triad (TPCK). In conclusion, as Napal & Zudaire (2019) express, the intersection of the three dimensions is the key for generating an effective impact when teaching with new technologies.

Figure 2.

TPCK: Technological Pedagogical Content Knowledge model



Note: Scheme of TPCK model retrieved from: Technological pedagogical content knowledge: A framework for teacher knowledge (p.1025) by Mishra & Koehler (2006). Teachers College Record.

1.4.2. SAMR model

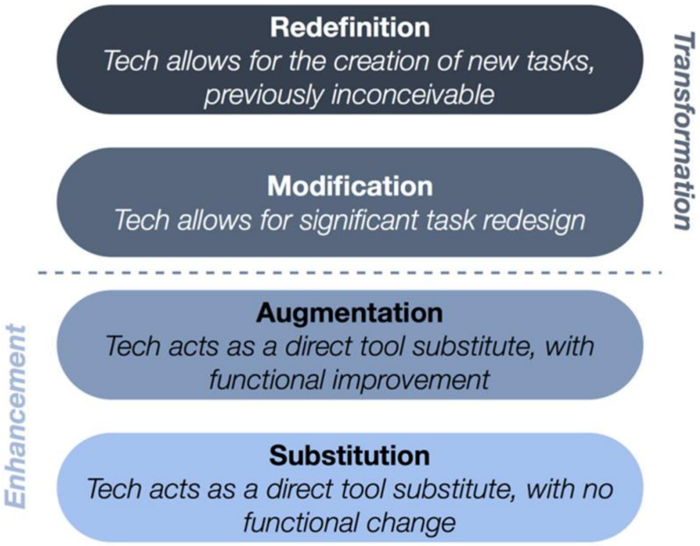
The other model that measures the integration of new technologies in education is the SAMR model (Puentedura, 2006). This model is a taxonomy-based model that has the goal of helping teachers select, implement, and evaluate technology (Hamilton et al., 2016). The acronym SAMR stands for Substitution, Augmentation, Modification and Redefinition, which are the four levels of integration that this model proposes. As previously stated, this model is taxonomy-based, which means that it is represented as a ladder in which Substitution is the lowest level and Redefinition is the highest level and therefore, "leads to higher (i.e., enhanced) levels of teaching and learning" (Hamilton et al., 2016, p.434). *Substitution* is the most basic level in which analog or former technology is substituted for digital or more actual technology, but the substitution results in no functional change.

Secondly, the *Augmentation* level implies the addition of some new functionalities that enhance its function. Thirdly, the *Modification* level implies a significant redefinition of the task and finally, the *Redefinition* level in which new tasks previously inconceivable can take place.

The two lower levels (Substitution and Augmentation) can be expected to provoke a smaller impact on the learning process - *improvement* -, while Modification and Redefinition are associated with a *transformation* (Figure 3).

Figure 3.

SAMR: Substitution, Augmentation, Modification and Redefinition model



Note: Puentedura's (2006) Substitution, Augmentation, Modification and Redefinition (SAMR) model. Retrieved from: http://www.hippasus.com/rrpweblog/

For a better comprehension of the impacts implied by each of the levels of SAMR, a parallelism can be made with the six levels of the Bloom's taxonomy Modification and Redefinition. Although it is not possible to establish an univocal correspondence, activities ranking higher in the SAMR ladder often imply tasks at a higher cognitive level.

1.5. Some drawbacks on the matter

As it has been mentioned above, the use of ICTs in education can contribute to a greater understanding of the matter but it also implies some disadvantages. One example of this is losing connection with reality (at least in science education). When using ICTs in the classroom, students are sometimes missing the opportunity to physically experience what they are learning about, thus wasting the benefits of this practice (Kontra et al. 2015).

A recent study carried out at the University of Chicago discusses the importance of physical experience in science learning. The authors of this study focused on the concept of *embodied cognition* which “explains how physical experience influences understanding” and relates thinking with the sensory and motor systems (Kontra et al., 2015, p.2). The hypothesis of this study was that “interaction with physical quantities should improve students’ understanding of relevant concepts in physics by activating sensorimotor brain systems used to execute similar actions in the past, adding kinetic details and meaning to their thinking” (p.2). The favourable results of their experiments made them conclude that this hypothesis was right and that direct experience does actually enhance learning. In addition, we should also consider that before constructing knowledge by generating ideas, it is necessary to understand some concepts on the matter and this would be impossible without experiencing them. In fact, Freeman et al. (2013) also defended that when active learning and traditional learning are compared, the active learning improves by a half student’s performance while students in traditional learning programs are 1.5 more likely to fail.

Our postulate on this paper is that the use of new technologies should be a complement to the regular lessons but never a substitute. There exists research on this issue in which they compare Vicarious Observational Learning (VOL) and Direct Experience Learning (DEL) in order to see if the application of any of them results in a higher enhancement of students' performance. In other words, they compare eyes-on learning and hands-on learning. The study concluded that both can be useful since the results showed no significant difference (Hoover et al., 2012). Furthermore another study shows that learning the same material from accurate simulators or in the field makes no difference in students’ learning (Winn et al., 2006).

However, we cannot generalize because the methodology to use should be chosen depending on the phenomena we want to study. For instance, Vicarious Observational Learning can be as effective or even more effective than Direct Experience Learning since it does not imply the learning of manual skills to carry out the experiment. DEL students have to deal with many uncomfortable situations in which they have to acquire necessary skills for a specific task and apply them at the same time while VOL learners have free cognitive resources to focus on the specific aspects of the task (Hoover et al., 2012). In fact, DEL or laboratory experimentation usually consumes too much time on technical issues instead of giving metacognitive opportunities to students, in other words, when students go to the lab they consider that they just have to manipulate materials in a scientific way but not ideas (interact and reflect on the main ideas)(Hofstein & Lunetta,2003). Nonetheless, this is not a reason to avoid experimentation since the use of new technologies could also create a cognitive overload on students and it is also fundamental to train manual skills.

What actually shows significant improvement on students’ learning is the combination of both, having first Vicarious observation and then Direct Experience on the subject, which actually reaffirms our postulate (Hoover et al., 2012). Furthermore, Hofstein & Lunetta (2013) also argued that depending on what we want to study we may use one type of methodology or another one. For instance, they discuss that ICT's break economic, danger and time barriers (among others) and bring enriching experimentation moments in a short time that students would never experience without new technologies. An illustrating example of this authors is that when dissecting a frog we could instead use a simulator in order to not "waste life" and save time but it would never be the same as experiencing it by first hand. We can state that hands-on activities or experiments can be really useful for understanding macro concepts while ICT's help with what we cannot see (micro concepts), but both are equally necessary.

1.6. Human body

A science topic that can benefit from this approach is the human body. This topic is recognized in the Educational Curriculum as being one of the main blocks of contents: Human beings and health. Furthermore, it does not only have curricular importance but also personal since it has implications for self-care decision making and also decision making as a citizen, among others.

However, this interesting topic drags down many difficulties in students. Students usually give alternative ideas or explanations to real phenomena that are known as misconceptions. Misconceptions were a popular topic study in the 70ies due to the potential for learning that they have. They should not be considered incorrect ideas but incomplete ideas that should be completed.

Some very common misconceptions are considering digestion as food storage instead of a complete process. Also representing the inner organs of the human body as individual and non related systems or as a central conduct where everything is connected (Arillo, 2013).

Based on the misconceptions of students, we consider that the Human Body topic could benefit from the blended method of experimentation and use of ICTs exposed in our approach. In the first place, we believe that experimentation could definitely amend the difficulties that students show when working on this topic and help them in their learning process. The first of the reasons for believing this is that several authors such as Haefner & Zembal (2007) argue the importance of promoting inquiry skills since they enable students to learn both the processes and contents of science as well as also provide answers to their scientific questions (Couso, 2014). Another reason is the multiple studies that inform about the positive results and the benefits of experimentation such as Kontra et al. (2015). Moreover, the use of ICTs would definitely complement this experimentation by increasing students' engagement on the topic and also allowing students to experiment with phenomena which would be impossible to experiment with without ICTs.

1.7. Objectives

1.7.1. General

To test the effectiveness of a didactic proposal that combines TE with direct experimentation in order to learn about the human body apparatus (both anatomy and functioning).

1.7.2. Specific

- To detect misconceptions about the human body.
- To design a student-centered didactic proposal that integrates purposefully both TE and direct experimentation.
- To detect improvements on learning measuring the comprehension of human apparatus and systems.
- To analyze the relative contribution of TE and direct experimentation in relation to the learning effect that they have.

2. MATERIALS AND METHODS

2.1. Context and participants

The study included a total of 59 students enrolled in three different and homogeneous classes of second grade (7-8 yo.) of Primary Education. There has not been any case of students needing a special adaptation of the project.

If we focus on their previous knowledge, students had basic notions about concepts of the human body, mostly focusing on external parts of the body and not the inner ones. Previous knowledge was assessed at the beginning of the proposal using a questionnaire; results are discussed later on.

Furthermore, these students were supposed to be used to working in groups since the school implements the PBL (Project-based learning) methodology. However, due to the sanitary crisis suffered in 2020, students had little chance to be exposed to this methodology and others that imply getting in groups, such as working by corners. This last issue needed to be considered since most of the lessons of the proposal implied gathering in groups and cooperating.

2.2. Methods

For evaluating the relative contributions of experimental work and ICT tools to learning about the anatomy and physiology of the human body, a 11-sessions didactical unit that combined both approaches was designed.

2.2.1. Diagnostic evaluation

To ensure that the unit was adjusted to the previous knowledge and especially to misconceptions of the students, we conducted an initial diagnostic evaluation. The initial questionnaire (Annex 2) comprised 14 items, including open questions (n=11) to be answered with a drawing or a short text, and dichotomic closed items (n=3) (true-false or yes-not), where students needed to provide a justification for their answers. The topics covered went from general anatomy of the human body to specific questions about the physiology of the respiratory and circulatory apparatus (at a basic level).

The questionnaire was offered in paper and students had unlimited time to complete it (it required two sessions). Additionally, students received a brief explanation of the activities at the beginning of the session but not specific support on the task. It was an individual task so they could not discuss their answers with the peers either, although some of them did it anyway.

The drawings of the human body (Q1) were analysed in reference to the criteria established by Reyero et al. (2013). The rubric is divided in 9 different sections: bones, muscular, nervous, circulatory, respiratory, digestive, urinary, reproductive and other elements. At the same time, these sections are divided into subsections that specify the complexity level achieved on each of the sections (e.g. muscular: muscles in general or specific muscles). The rest of the open questions were categorized following an inductive approach; i.e., the individual productions were analysed and recurrent patterns identified and coded.

This initial evaluation identified a number of misconceptions regarding bones and muscles, which motivated their inclusion as study topics, together with the already decided circulatory and respiratory systems.

2.2.2. Sequence of activities

According to the already mentioned literature, the didactical unit was constructed upon constructivist methods in which students discovered their own learning. Furthermore it followed the scientific method in which learners had to hypothesize, make research on topics and draw up conclusions. Additionally, students had to create their own models and explain them in front of the class.

The language used during these 11 sessions (two double sessions) was English; students are used to having science projects with English as a vehicular language. However, difficult concepts were explained both in English and Spanish and their oral or written productions were in Spanish in order to facilitate their expression. You can find the complete didactic proposal on annexes (annex 1), however, there is a content table in section 3 which shows a first look of the 11 sessions.

As previously mentioned, during the implementation of the didactic proposal there were also occasions to collect data on the students' knowledge of the subject. The production of the children during the sessions, including written and oral productions were observed and recorded, to find evidence of how they conceive the functioning of our body when breathing, or how they imagine bones, muscles and the circulatory apparatus. We were specifically interested in the appearance of misconceptions in order to approach them and reformulate their learning. Data were collected at two different moments of the proposal while the students, in groups, presented some models they had designed on paper about breathing and circulation. Quantitative data were collected through rubrics similar to those of the initial questionnaire but with more specific variables. Furthermore, the information was gathered by triangulating the inductive representation of their drawings and their corresponding explanations.

2.2.3. Final evaluation

Finally, at the end of the unit, students answered another questionnaire (annex 3) slightly different from the initial one. This final questionnaire still included open questions that needed to be answered by drawing and/or writing (n=7), but they specifically dealt with the topics that had been addressed in the didactical unit. Furthermore, it included closed questions (n=5) made up of 4 multiple-choice questions and one dichotomic closed item.

This final questionnaire was also offered in paper and with unlimited time to complete it (it took 1 session). The procedure was the same as with the initial questionnaire, in the beginning they received a brief explanation at the beginning of the session, and it was considered an individual task in which students had no specific help from the teacher and they could not share the answers with the classmates.

All answers have been treated in aggregate form, so as not to compromise the identity of the students. The qualitative questions have been interpreted with the help of a content analysis. That is to say, from the data obtained and analyzing the repeated patterns, we proceed to the induction of categories, in which the observations are then classified.

3. DIDACTIC PROPOSAL

3.1 Learning outcomes

1. To recognize the inner anatomy of our body and its different layers (bones, muscles, circulatory apparatus, respiratory system, digestive system, nervous system…).
2. To identify and locate at least 3 bones in our body.
3. To understand the main functions of bones and muscles (movement, protection, stability).
4. To recognize the anatomy of a muscle
5. To understand the agonist-antagonist movement of the muscles.
6. To identify and describe respiration as a vital function and know and perform exercises for its correct execution.
7. To identify the main organs of the respiratory system.
8. To design a drawing and formulate an explanation for the breathing process.
9. To notice the relation between lungs and heart.
10. To design a drawing and formulate an explanation for the circulation and gas exchange processes.
11. To identify the main organs of the circulatory apparatus (heart and veins) and their function. (impulse blood and transport blood leaving the "good things" and bringing back the "bad things")
12. To discuss the importance of oxygen in the air and why we need it.

3.2 Activities

For this study, we designed a 11-session proposal divided in four different main blocks of contents referring to bones, muscles, the respiratory system and the circulatory apparatus in which experimentation and the use of simulators are combined (table 1).

Table 1.

Content summary of the didactic proposal

Session	Phase	LO	Objective (teacher)	Description of the activity	Grouping	Experimental/ simulador
1 A look inside our body	INTRO	1	Rekindle previous knowledge Detect misconceptions	Draw together a human body.	BG	Locate organs in the body
2 Our skeleton	BONES	1, 2	Transform misconceptions Mobilize and expand previous knowledge about bones	Compare human body drawing with a simulator Make labels of bones for the class skeleton	BG	Locate bones in the body, investigate names and locations, relationship with organs
3 Where is the bone?	BONES	2	Synthesis: Recall and reinforce newly acquired contents about bones	Place the labels on the skeleton Colour and complete an individual skeleton	BG I	Locate bones in the body, investigate names and locations, relationship with organs
4 My muscles	BONES AND MUSCLES	3,4,5	Mobilize and expand previous knowledge about muscles Proof and apply newly acquired content about muscles	Discuss and experiment with the muscles and their functions Analyze the anatomy and physiology of a muscle	SG BG	Locate muscles in the body. Investigate their anatomy and their physiology (agonist and antagonist) Proof the function of muscles
5 Corners	BONES AND MUSCLES	3,4,5	Recall, apply and reinforce knowledge about bones and muscles.	Corners: Classify bones depending on their shape Experiment the anatomy of a large bone	SG	Analyse the inner anatomy of bones and muscles. Distinguish the different types of bones.

				Experiment with boiled meat to see the muscle fibers Research on human body books and anatomy sets		Locate the organs inside of the human body.
6 How do we breath?	RESPIRATORY SYSTEM	6,7,8	Introducing the respiratory system. Recall and mobilize previous knowledge . Unveil students' misconceptions.	Reflect on breathing Design a model (drawing) that explains breathing	Think-pair-share SG	Feel the chest inflating when breathing and other changes that breathing implies
7 How do we breathe? (2) (double session, 90')		6,7,8	Unveil students' misconceptions Reconstruct and expand students' knowledge Experiment and apply the new concepts of the respiratory system	Present breathing models Corners: Experiment with breathing models Experiment with real lungs	SG SG	Explore the anatomy of real lungs Experiment with two breathing models
8 Move and breathe		9,11	Expand knowledge about the respiratory system to understand the relation between the respiratory and the circulatory systems Apply newly acquired concepts about breathing	Compare their breathing models with simulators Experiment with breathing when we move (measure breathing per minute)	BG I or Pairs	Compare their breathing models with the simulators Notice the relation between respiratory and circulatory system by observing the capillaries in the alveoli Measure the breathing per minute in calm and in movement to discuss the function of breathing

9 What does the air have?		9,10, 11,12	Recall and expand previous knowledge about air composition Understand the relation between respiratory and circulatory systems.	Reflect on the importance of breathing Measure the oxygen and carbon dioxide in air with a sensor before and after breathing out on it. Reflect on the gas exchange taking place inside of our body	BG BG (one volunteer) BG	Measure the oxygen and carbon dioxide with the sensors to see introduce the gas exchange phenomena Use a simulator to show the relation between lungs and heart
10 Tell me how	CIRCULATORY APPARATUS	9,10, 11,12	Recall, mobilize and expand previous knowledge about the circulatory system Unveil students' misconceptions	Discussion on the function of veins and blood. Create circulation models (drawings) to explain the gas exchange.	BG SG	Create analogic models
11 The beating heart (double session 90')		9,10, 11,12	Unveil students' misconceptions Apply newly acquired knowledge about both respiratory and circulatory systems	Present circulatory models Analyze the heart anatomy and physiology with a simulator and an animation Corners: Experiment with circulatory models Experiment with real hearts	SG BG SG	Recognize the anatomy of the heart and its physiology when beating Notice the route of the blood when circulating Notice the gas exchange in our body Explore the anatomy of a real heart Experiment with two circulatory models

Unless otherwise specified, all the sessions last for 1 class hour (45'). Groupings; BG . big group, SG . small group, I . individual.

4. RESULTS

En este apartado se analizarán los resultados obtenidos en nuestra propuesta, tratando tanto la medición previa del alumnado a través del cuestionario inicial, como las diferentes mediciones a lo largo de las sesiones y la medición final a través de otro cuestionario. Cabe destacar que salvo en preguntas con resultados muy dispares, los resultados de los tres grupos serán analizados de modo conjunto.

4.1. Organización general del cuerpo humano. Órganos y sistemas.

Como hemos mencionado previamente, los estudiantes pasaron un cuestionario inicial para medir sus conocimientos previos y detectar posibles ideas alternativas en los temas propuestos (Annex 2).

En primer lugar, el alumnado recibió una silueta humana que debían completar dibujando y escribiendo todo lo que piensan que tenemos por dentro (debajo de la piel)(Q1). Los sistemas más conocidos por el alumnado en segundo de primaria son: el óseo (78% de los alumnos lo dibujan), el nervioso (el 89% de los alumnos dibuja el cerebro), el circulatorio (el 66% de los alumnos dibuja el corazón acompañado de venas y/o sangre y un 25% dibuja al menos el corazón) y el respiratorio (el 57% de los alumnos dibuja los pulmones) (Tabla 2).

Por otro lado, sólo un 28% del alumnado dibujó el órgano representativo del sistema digestivo (estómago), y un 33% más hizo además referencia a otros órganos específicos (esófago, boca, ano…). El muscular aparece representado con una frecuencia baja: un 8% dibujó “carne” y un 5% músculos específicos. Esto datos son comparables a los datos obtenidos en los otros dos aparatos menos reconocidos por el alumnado, que son el reproductor - con un 6% del alumnado dibujando los órganos representativos (pene y vulva) y tan solo un 2% representando órganos específicos (útero) - y por otro lado, el urinario, del cual tan solo un 5% del alumnado ha dibujado su órgano representativo (riñón) y un 10% ha dibujado órganos específicos (vejiga).

Tabla 2.

Resultados de ¿Qué tenemos por dentro?

Aparatos / sistemas	Elementos	%
Óseo	Huesos en general	78%
	Huesos específicos (Costillas, mandíbula, cráneo, fémur, cadera)	25%
	Articulaciones: rodilla, muñeca, ligamentos,tobillo	31%
Muscular	Músculos en general (carne)	10%
	Músculos específicos (gemelos)	7%
Nervioso	Órgano representativo (Cerebro)	89%
	Órganos específicos (bulbo raquídeo, cerebelo, nervios, médula, cuerpo calloso)	2%
Cardiovascular	Órgano representativo (corazón)	25%
	Órgano representativo y Elementos específicos (sangre, venas)	66%
Respiratorio	Órgano representativo (pulmones)	57%
	Anatomía gruesa (nariz, tráquea, laringe)	31%
	Anatomía fina (bronquios, bronquiolos, alvéolos)	0%
Digestivo	Órgano representativo (estómago) , tubería, comida flotante	28%
	Órganos específicos (esófago, boca, intestinos, faringe, ano)	31%
Urinario	Órgano representativo (riñón)	5%
	Órganos específicos (uréter, vejiga, uretra)	10%
Reproductor	Órgano representativo (pene, vulva)	6%
	Órganos específicos (útero)	2%
Otros elementos	Elementos internos (tímpano, apéndice, cuerdas vocales)	8%
	Elementos externos (pelo, oreja, ojos, culo)	20%

Porcentaje de alumnos que dibujan los órganos señalados. Las categorías no son exclusivas, por lo que los porcentajes no deben sumar 100%. Creación propia a partir de Reyero et al. (2013).

4.2. Huesos y músculos

4.2.1. Cuestionario inicial

Al principio, cuando los alumnos pasaron el cuestionario inicial (Q1), la mayoría del alumnado representó el sistema óseo (78%) pero tan solo el 25% demostró un nivel superior de conocimiento mencionando huesos específicos o articulaciones (31%). Además, los alumnos que mencionaron algún hueso específico o articulación generalmente supieron localizarlos en el lugar correcto.

Sin embargo, el sistema muscular fue uno de los menos representados por los alumnos. Tan solo el 10% representó este sistema y el 7% demostró conocer músculos específicos como los gemelos.

Dada la importancia de estos dos sistemas y la baja representación del segundo de ellos, se decidió incorporar estos contenidos a la propuesta con el objetivo de familiarizar al alumnado con estos sistemas tan importantes.

4.2.2. Antes y durante la propuesta

Al principio de la tercera sesión cada uno de los alumnos sabía por lo menos el nombre y la localización de tres huesos del cuerpo humano ya que tuvieron que realizar una investigación en casa para traer información a clase.

Con la ayuda de un póster de esqueleto a tamaño real y el simulador zygotebody (annex 5), los alumnos pudieron colocar en el esqueleto los nombres de los 5 huesos que más se mencionaron, que fueron: fémur, costillas, cráneo, tibia y radio. Además, en la sesión 5 de la propuesta, en la que trabajaron por rincones, pudieron experimentar con huesos reales (de pollo y de ternera) los diferentes tipos de huesos que existen, su textura y su dureza. Las conclusiones fueron que el alumnado pudo reconocer que existen diferentes tipos de huesos además del huesos alargado típico (fémur) y que al contrario de lo que pensaban (al menos los huesos largos) son rígidos por fuera pero contienen una médula blanda en su interior. Esto se vió reflejado en los resultados finales que comentaremos a continuación.

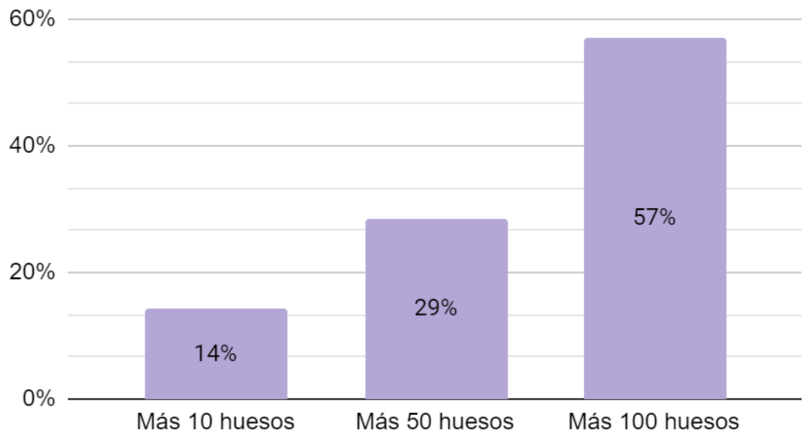
Por otro lado, los músculos eran reconocidos como carne y como fuente de fuerza para el cuerpo. Estos fueron trabajados de forma experimental para su localización y función: se nombraron músculos como el bíceps y el tríceps. Además, se descubrió su papel en la función de movimiento y de estabilidad a través de pequeños juegos experimentales por parejas (sesión 4). Por otro lado, también se trabajó su textura tocando los músculos de nuestro propio cuerpo o diseccionando un trozo de carne cocida para ver las fibras musculares (sesiones 4 y 5), para ver que los músculos están formados por fibras musculares que tienen una estructura alargada. Además para ver de una manera más precisa la anatomía interna de los músculos y su fisiología se utilizó un modelo digital de la vista transversal de un músculo y un simulador de los movimientos agonistas y antagonistas; es decir, pudimos ver de cerca las fibras musculares de las que estábamos hablando y además el movimiento de nuestros músculos del brazo (bíceps y tríceps), descubriendo que cuando uno de los músculos se contrae, su antagonista se estira.

4.2.3. Tras la propuesta

En el cuestionario final demostraron que habían comprendido la gran cantidad de huesos que tenemos en el cuerpo puesto que al preguntarles por el número de huesos que tenemos (Q2), más de la mitad del alumnado (57%) reconoció que tenemos más de 100 huesos. Aún así, el resto de las opciones no dejaron de tener representación en los resultados puesto que un 29% optó por la segunda de las opciones (más de 50 huesos) y un 14% por la primera de ellas (más de 10 huesos)(figura 4).

Figura 4.

Respuestas a la cantidad de huesos que tenemos por dentro



Además, los alumnos supieron reconocer que existen diferentes tipos de huesos. El 100% del alumnado reconoció que tenemos diferentes tipos de huesos (Q3), y el 95% respondió que no todos los huesos son iguales. Para justificarlo dibujaron diferentes huesos que hemos clasificado en cuatro grupos diferentes (Q1) (Figura 5 y 6). La gran mayoría recurrió a huesos estructurales como el cráneo (30%) o las vértebras (14%), otro 18% optó por las articulaciones como los huesos de la mano (16%). Un 4% mencionó huesos “finos” como el estribo (2%) y el martillo (2%) y por último, un 18% del alumnado dibujó un hueso típico similar al que se les adjuntó en el cuestionario (hueso largo tipo fémur, con dos cabezas y una caña larga).

Figura 5.

Huesos representados en la primera pregunta del cuestionario final

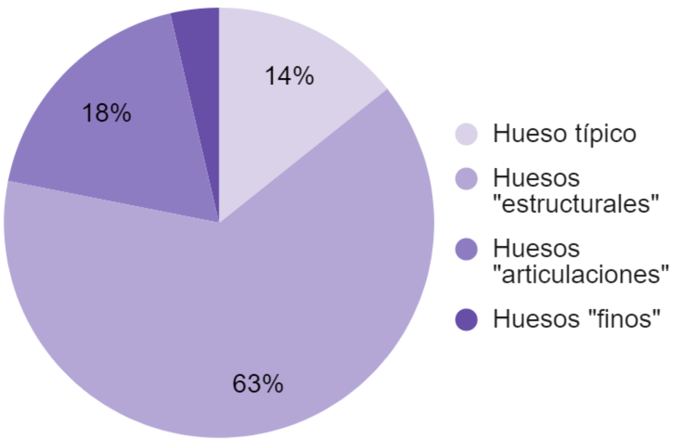
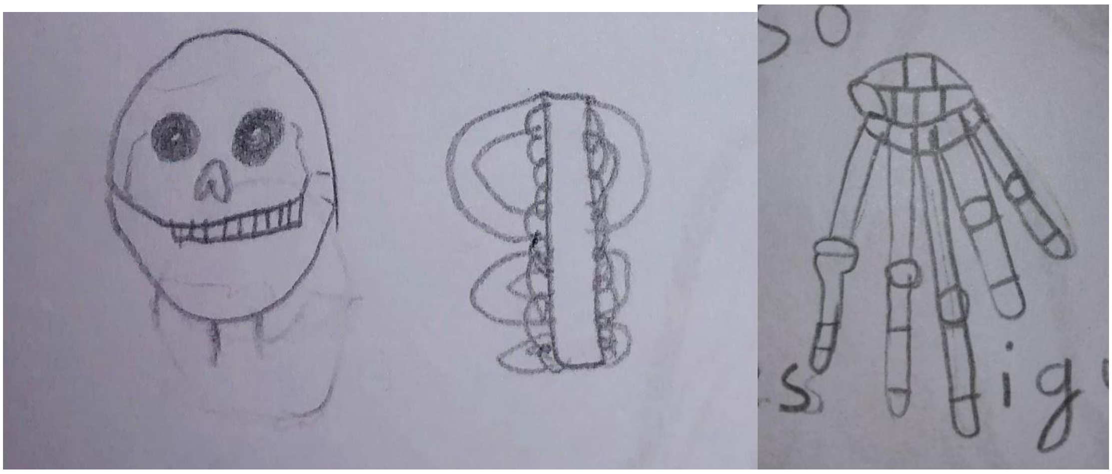


Figura 6.

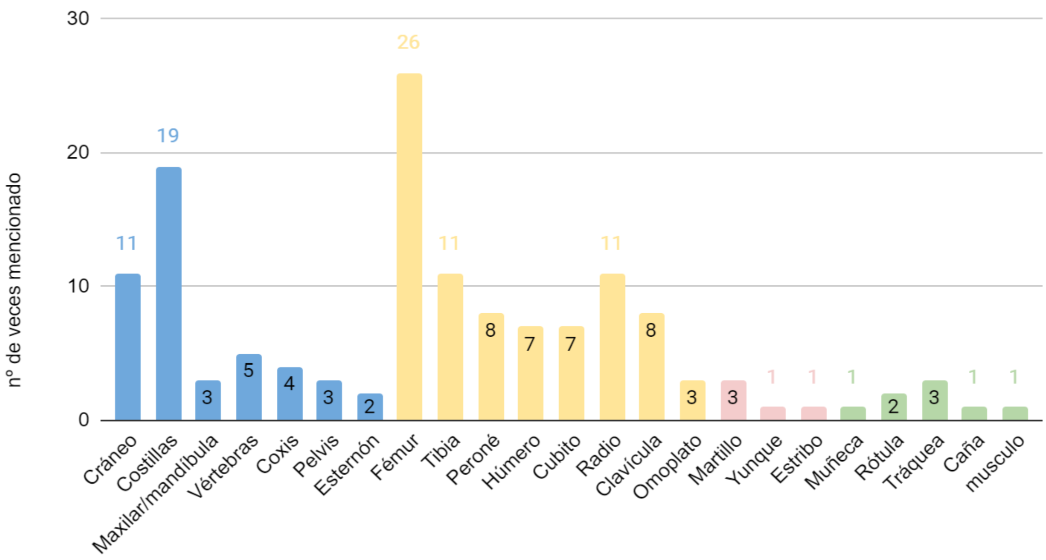
Ejemplificación de representaciones del alumnado en la Q1 del cuestionario final. Cráneo, columna vertebral, costillas y mano.



Además, el alumnado tuvo que mencionar el nombre de tres huesos del cuerpo humano (Q5). Se recogieron un total de 141 respuestas citando 23 huesos diferentes, la mayor parte de ellos pertenecientes a las extremidades (57%) o estructurales (33%). Un 4% señaló huesos de pequeño tamaño, en órganos específicos, y un 6% nombró estructuras que no eran huesos. Además los huesos más mencionados coinciden con los huesos que aparecieron durante la discusión en el aula (Figura 7).

Figura 7.

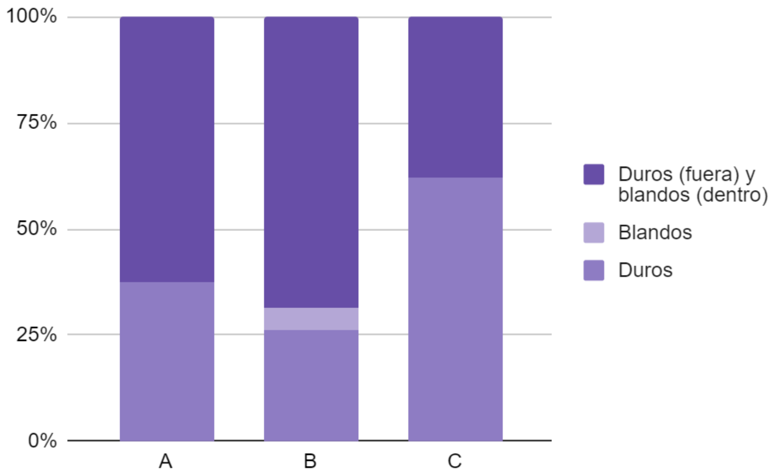
Huesos mencionados en la quinta pregunta del cuestionario final.



Por último, tras haber explorado la textura y dureza de los huesos en la quinta sesión de la propuesta a través de la experimentación, se incluyó una pregunta sobre la dureza de los huesos (Q4) en el cuestionario final en la que más de la mitad de los alumnos (55%) reconoció que a pesar de que los huesos sean duros por fuera, tienen una cavidad blanda en su interior. El 43% respondió que eran completamente duros y el 2% restante que eran blandos. La distribución de respuestas varió entre grupos dado que durante el desarrollo experimental, el grupo C fue el último en experimentar con el hueso alargado por lo que para entonces la médula ya se había endurecido y les pareció seca y dura en vez de blanda (Figura 8).

Figura 8.

Gráfico con los resultados a la pregunta relativa a la textura de los huesos.

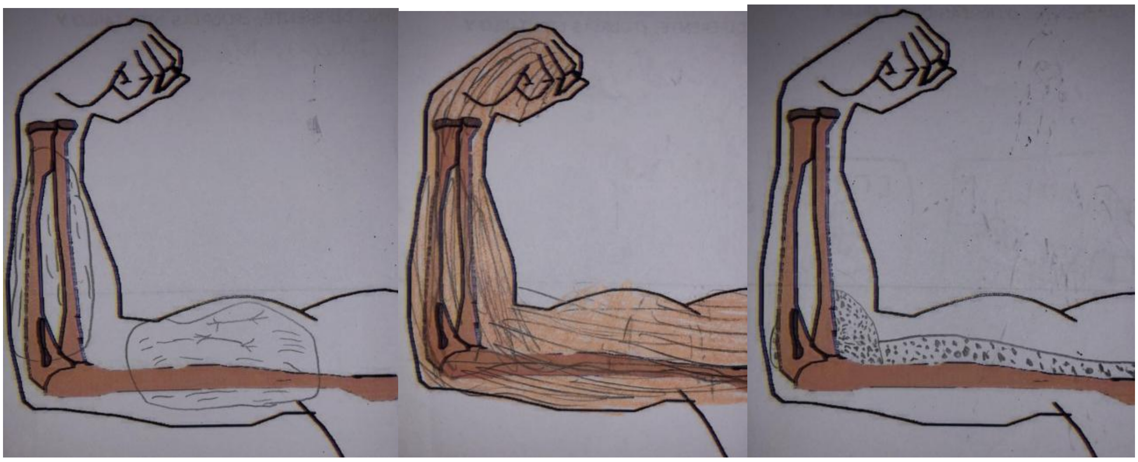


En cuanto a los músculos, se incluyeron dos preguntas en el cuestionario final relacionadas con lo que vieron en clase con ayuda del simulador de una sección transversal del músculo, el experimento con carne cocida para ver las fibras musculares y los experimentos en parejas para evidenciar las funciones de los músculos. La primera pregunta pedía dibujar un músculo (Q6) y la segunda preguntaba por la función de estos (Q7).

El 53% del alumnado dibujó músculos en una zona concreta, el 42% por todo y un 5% no completó el dibujo (figura 9). Además el 36% los representó a través de fibras musculares, el 22% a través de líneas que no hacía referencia a fibras musculares, el 29% con círculos y un 13% no completó el dibujo (figura 9 y 10).

Figura 9.

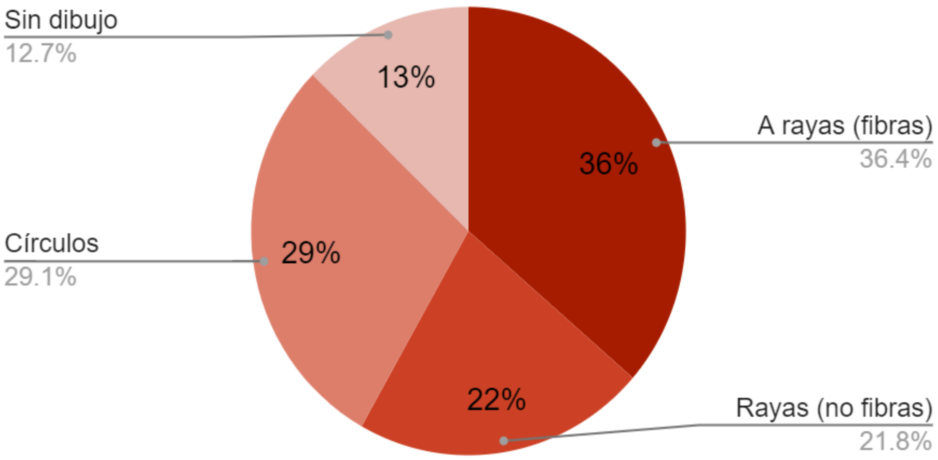
Ejemplificación de las representaciones de los estudiantes en la Q6 del cuestionario final



1. Focalizado con fibras , 2. por todo con líneas (no fibras), 3. focalizado con puntos o círculos.

Figura 10.

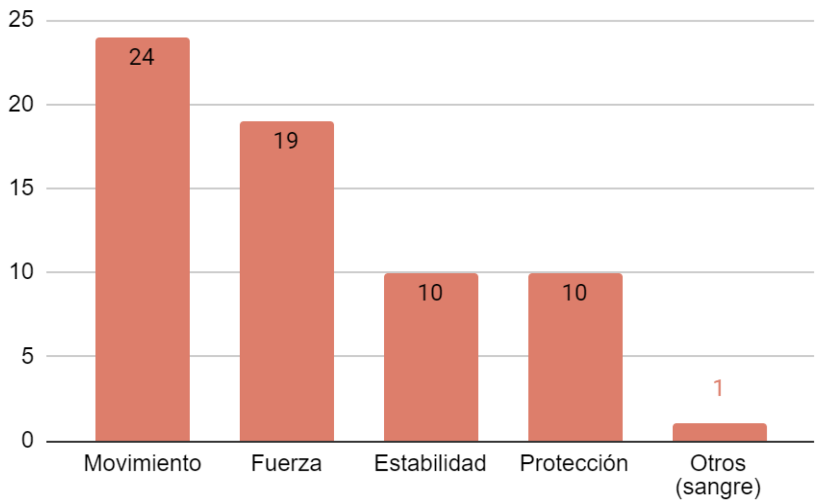
Gráfico con los resultados de las representaciones gráficas de los músculos en el cuestionario final.



Por otro lado, tras ver las diferentes funciones de los músculos durante la cuarta sesión de la propuesta, 24 alumnos relacionaron los músculos con el movimiento, 19 alumnos siguieron relacionándolos con la fuerza frente a 10 mencionando la estabilidad, otros 10 la protección y tan solo uno mencionando la sangre (función no relevante) (Figura 11).

Figura 11.

Gráfico con los resultados de las funciones asociadas a los músculos en el cuestionario final.



4.3. Respiración

4.3.1. Cuestionario inicial

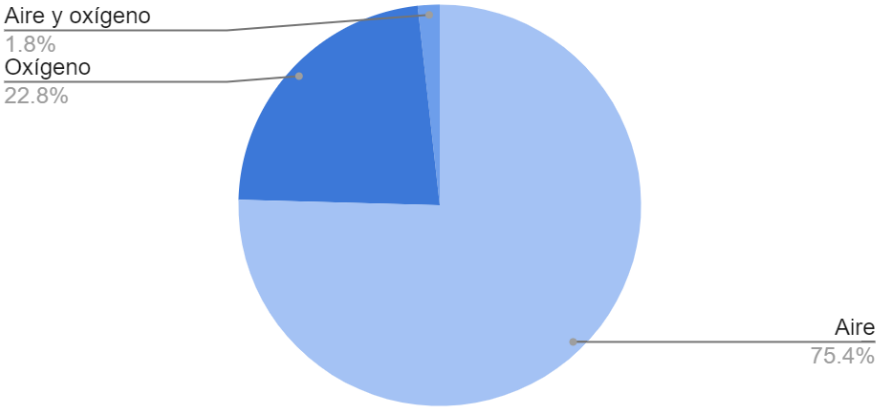
Como se ha mencionado previamente, el 57% del alumnado representó los pulmones en la primera pregunta del cuestionario inicial (Q1), además, un 31% representó algún elemento correspondiente a la anatomía gruesa del aparato respiratorio (tráquea, boca, nariz...) (Tabla 1).

Aparte de este diagnóstico general también se incluyó una sección del sistema respiratorio en este cuestionario inicial que consistió en primeramente reconocer qué es la respiración, cómo respiramos y hacer una pequeña representación en papel. Posteriormente los estudiantes responderían una pregunta corta sobre las funciones de la respiración (Annex 2).

El 100% de los estudiantes reconocieron la respiración como la acción de coger y soltar aire (Q10). Además a la pregunta de ¿Qué entra por nuestra nariz cuando respiramos? (Q11), el 75% de las respuestas fue “aire” mientras que un 23% mencionó el oxígeno y un 2% mencionó ambas sin reconocer que el oxígeno es un componente del aire (ver figura 12).

Figura 12.

Predicciones sobre la composición del aire inspirado



Por otro lado, el alumnado tuvo que dibujar y tratar de explicar el recorrido del aire desde que entra por la nariz hasta que vuelve a salir (Q12). A pesar de que un gran porcentaje del alumnado representó la nariz (91%) y los pulmones (84%) y la asoció con la función de respirar, tan solo un 37% del alumnado representó la unión entre ambos, la tráquea. Además pocos alumnos identifican la boca (16%) como elemento que interviene en la respiración. Por otro lado, en los dibujos, se pudo analizar si relacionaban la respiración con el aparato circulatorio o proponían un sistema alternativo por el que circula el aire por nuestro cuerpo. La gran mayoría (72%) optó por la segunda de las opciones, siendo el 18% del alumnado el que asocia la circulación del aire al aparato circulatorio sanguíneo (Figura 13 y Tabla 3).

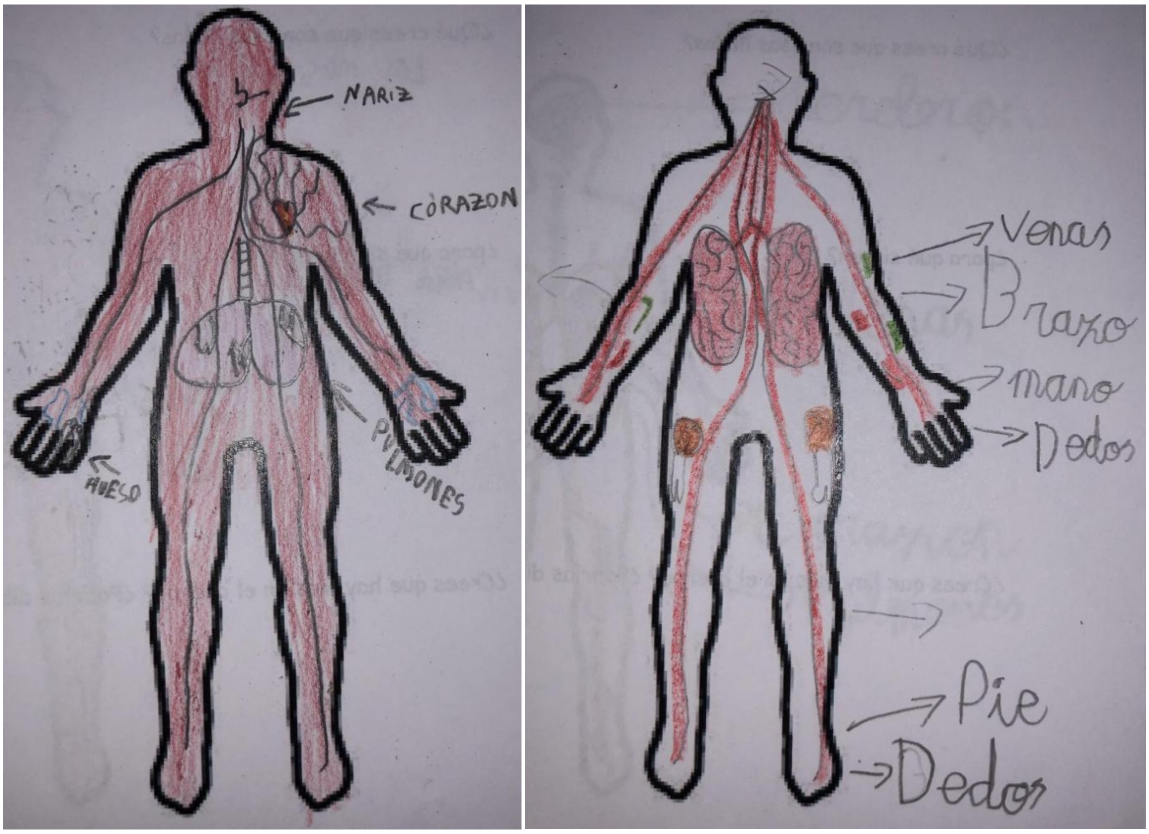
Tabla 3.

Presencia en los dibujos de los escolares de elementos del sistema respiratorio

Categoría	Elementos representados	Frecuencia
Anatomía externa	Nariz	91%
	Boca	16%
	Tráquea (garganta)	37%
Anatomía interna	Pulmones	84%
Función	Relación con aparato circulatorio	18%
	Circulación del aire alternativa al aparato circulatorio	72%

Figura 13.

Representaciones del alumnado del sistema respiratorio en el cuestionario inicial



1. Relación con sistema circulatorio 2. Circulación del aire alternativa al sistema circulatorio

Finalmente, el alumnado tuvo que argumentar el por qué de la respiración, en otras palabras, su función (Q13). Solo un 11% del alumnado relaciona la respiración con una función específica frente al 83% que dan razones específicas y el 6% que da otro tipo de funciones a la respiración (tabla 4).

Tabla 4

Funciones que asocia el alumnado a la respiración

Funciones	Razonamientos	Porcentaje
Proporcionar oxígeno	Para tener oxígeno/ aire	4%
	Para no ahogarnos	7%
Vivir	Para no morir / para vivir	81%
	Para que funcione el corazón	2%
Otras funciones	Para que pase por nuestro cuerpo	1.75%
	Para hablar	1.75%
	Para tranquilizarnos	1.75%

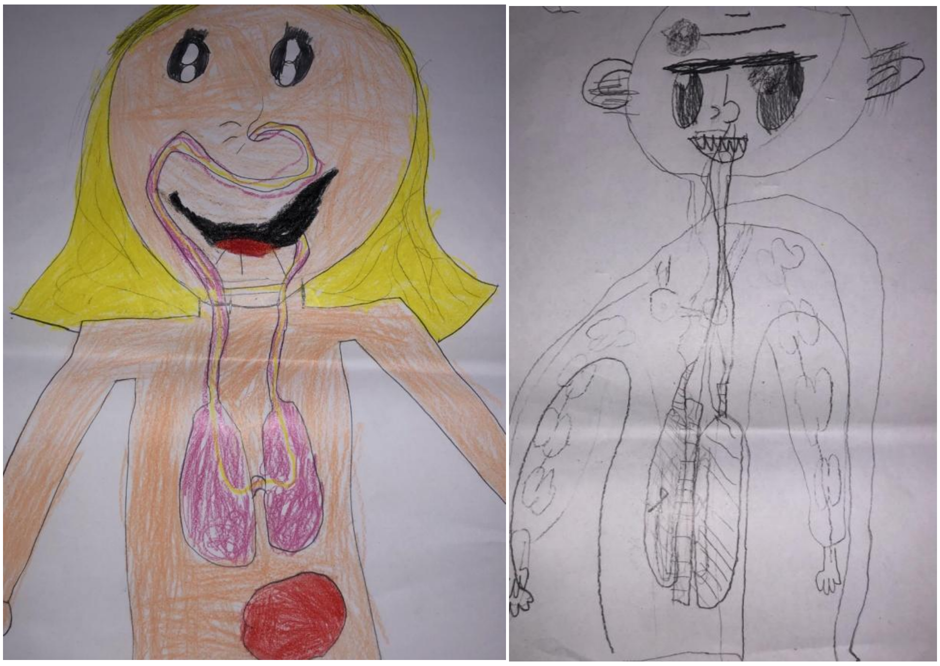
4.3.2. Antes y durante la propuesta

Antes de empezar con el tercer bloque de contenidos de la propuesta dedicado a la respiración, los estudiantes tuvieron que diseñar sus propios modelos (dibujos) respiratorios en papel con el objetivo de construir el aprendizaje a partir de sus ideas previas. Estos modelos se crearon en grupos de 4 o 5 alumnos y para guiarlos se llevó a cabo previamente una breve actividad de experimentación para hacer el proceso de respiración evidente y ayudarles a crear una posible explicación para este fenómeno (sesión 6). Esta actividad previa a la creación de los modelos consistió en la discusión de varias preguntas relacionadas con el aparato respiratorio utilizando el método "think-pair-share[2]". Algunas de las cuestiones discutidas fueron fijarse en los movimientos de nuestro cuerpo al respirar, reflexionar sobre los órganos involucrados en el proceso, sentir como el aire entra por nuestra nariz o pensar si hacemos algún esfuerzo para respirar. A través de esta actividad de reflexión los alumnos se dieron cuenta, entre otras cosas, de que no solo respiramos por la nariz sino que también lo podemos hacer por la boca y el aire que entra en nuestro cuerpo nos hincha el pecho (los pulmones). Además entendieron que la respiración es una acción involuntaria del cuerpo, es decir, que respiramos sin darnos cuenta.

A partir de los patrones de los dibujos y sus correspondientes explicaciones, se detectaron distintos perfiles considerando tanto la anatomía como el funcionamiento del sistema respiratorio (Figura 14 y tabla 5).

Figura 14.

Representaciones grupales del sistema respiratorio



1. Ruta circular del aire y tubo adicional uniendo los pulmones, 2. Ruta de ida y vuelta del aire y representación de la tráquea.

[2] Una técnica pedagógica en la que el alumnado reflexiona sobre algo individualmente, luego lo comparte con una pareja y finalmente se discute en grupo.

Tabla 5.

Elementos del sistema respiratorio representados en los modelos de los escolares.

VARIABLES	Especificaciones	Porcentajes
Boca y nariz	Representan boca y nariz	100%
	Relación boca-nariz (no independientes)	73%
Faringe y tráquea	1 tubo	33%
	2 tubos	67%
Tráquea	Representa la tráquea con anillos	13%
Ruta del aire	Solo ida	7%
	Ida y vuelta por el mismo sitio	67%
	Ruta circular	27%
Componentes del aire	Aire	67%
	Oxígeno/Dióxido de carbono (intercambio gaseoso)	27%
Lugar al que va el aire	Aire de nariz y boca va a pulmones	93%
	Aire de nariz y boca va a sitios diferentes	7%
Tubos adicionales	Entre pulmones	27%

Además, una de las actividades más atractivas de este bloque fue la experimentación con pulmones reales. En la disección de los pulmones, se les mostró la estructura esponjosa que estos tienen y la presencia de la tráquea y sus rígidos aros. Además vieron como los pulmones duplican su tamaño cuando se hinchan y como esa textura esponjosa se vuelve aún más blanda. Se discutió la anatomía tanto de los pulmones como de la tráquea y se les hizo ver que la rigidez de la tráquea se debe a la función de que pase el aire por ella sin obstruirse. Además el uso del simulador permitió llegar a la idea de que cuando los pulmones se hinchan todo nuestro tronco superior se mueve y que internamente los bronquiolos también se hinchan y el oxígeno pasa a la sangre por las venas que les rodean.

4.3.3. Tras la propuesta

En el cuestionario final, los alumnos demostraron haber mejorado sus representaciones del sistema respiratorio respecto de la primera medición del cuestionario inicial. Para recoger resultados sobre este bloque, se repitió el ejercicio propuesto en el cuestionario inicial en el que a través de una silueta humana vacía, el alumnado debía representar y explicar la respiración (cómo entra el aire al cuerpo, por qué sitios pasa y cómo sale)(Q8).

Los órganos y elementos más representados fueron la nariz (91%), la tráquea (84%), los pulmones (96%) y el corazón (70%) mientras que los menos representados fueron la boca (41%) y los bronquios y bronquiolos (20%). Por otro lado, el 64% de los alumnos relaciona la respiración con el aparato circulatorio, el 14% representa una circulación del aire alternativa al aparato circulatorio y por último, un 18% menciona o representa el intercambio gaseoso que tiene lugar durante la respiración (tabla 6). Es decir, se aprecia una mejora a la hora de representar ideas más complejas como la relación entre el sistema respiratorio y el circulatorio y una mejora en la complejidad de sus dibujos viendo en un 20% de los casos presencia de anatomía fina como bronquios y bronquiolos.

Tabla 6.

Elementos del sistema respiratorio representados en el cuestionario final.

	Órganos	**Porcentaje de representación**
Órganos y elementos	Nariz	91%
	Boca	41%
	Tráquea (garganta)	84%
	Pulmones	96%
	Bronquios o bronquiolos	20%
	Corazón	70%
Funciones	Relación con aparato circulatorio	64%
	Circulación del aire alternativa al aparato circulatorio	14%
	Intercambio gaseoso	18%

4.4. Circulación

4.4.1. Cuestionario inicial

Un 66% del alumnado demostró conocer el aparato circulatorio durante el cuestionario inicial representando el corazón y otros elementos específicos como sangre y venas, además del 34% de alumnos restante, un 25% representó al menos el corazón (Q1) (tabla 1). A parte de este diagnóstico inicial, el alumnado tuvo que responder a una sección dedicada exclusivamente a hablar sobre el aparato circulatorio.

Para comenzar con la sección, se reprodujo el sonido del latido de un corazón con el objetivo de ver si los alumnos reconocían el sonido y el órgano que lo producía (Q2). El 100% del alumnado supo reconocer el sonido y anotar que se trataba del corazón. Una vez reconocido el órgano se les pidió representar y explicar su funcionamiento una vez más en una silueta humana.

Los resultados nos muestran que el 100% del alumnado representó el corazón en diferentes niveles de complejidad (Figura 15). El primero de los niveles, siendo el más básico, engloba a los alumnos que representaron exclusivamente el corazón (44%). El segundo de los niveles corresponde al alumnado que representó venas además del corazón (37%). El tercer nivel representa a los alumnos que dibujaron el corazón y el pulmón pero no venas (3%). Finalmente el nivel más complejo, alcanzado por el 15% de los alumnos en el que representaron el corazón, venas y los pulmones (Q3)(figura 16).

Figura 15.

Valoración inicial de la representación del aparato circulatorio, dividida en 4 niveles

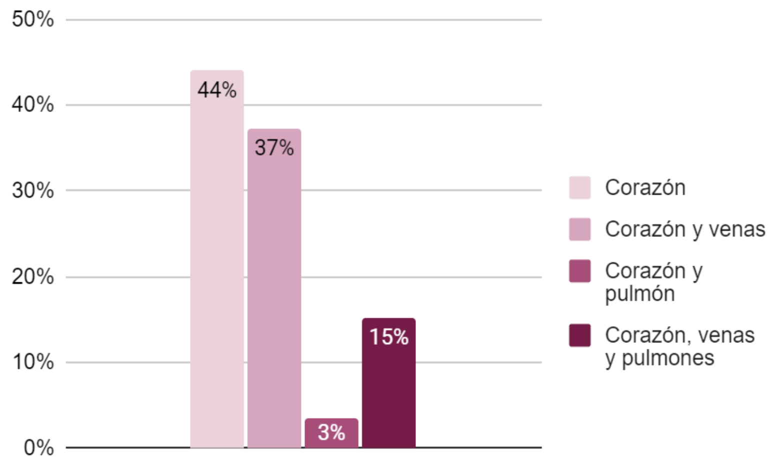
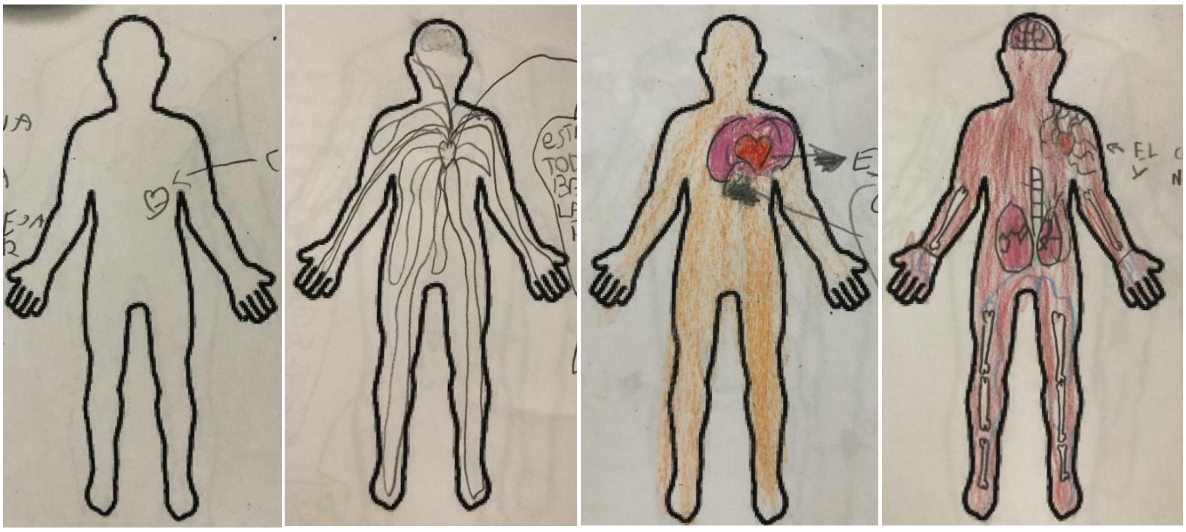


Figura 16.

Representaciones del sistema circulatorio en el cuestionario inicial por rango.

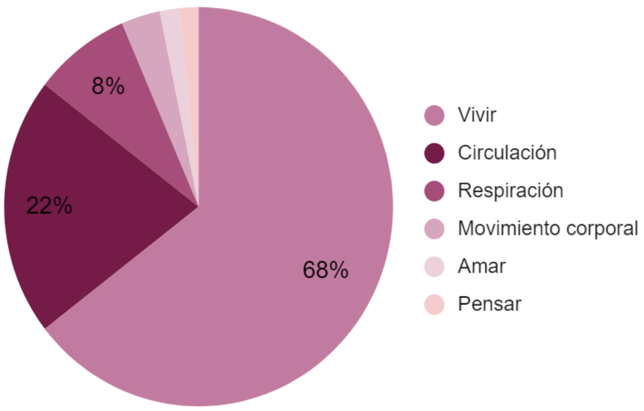


1.Corazón, 2.Corazón y venas, 3. Corazón y pulmones, 4. Corazón, venas y pulmones.

La mayor parte del alumnado (68%) asocia el corazón a una función vital: "para vivir", "para no morir". La segunda función más mencionada es la de hacer circular a la sangre (22%): "para que funcione la sangre" "para llevar la sangre". Además algunos alumnos asocian el corazón a la respiración o a la circulación del aire (8%). Otro pequeño grupo de alumnos asocia la función del corazón al movimiento corporal (3%): "para movernos". Por último el 2% del alumnado relaciona el corazón al concepto del amor: "para amar" y un último 2% "para pensar" (Figura 17) (Q4).

Figura 17.

Representación de las diferentes funciones del corazón por alumnos de segundo de primaria.



Los escolares debían responder sobre la veracidad de dos afirmaciones, justificando su respuesta. El 64% del alumnado respondió que la frase "El corazón limpia la sangre" (Q5) era falsa, y un 32% verdadera. Sólo un 60% del alumnado justificó su elección; la tabla 7 contiene un resumen de las diferentes justificaciones que los alumnos dieron a sus respuestas.

Tabla 7.

Justificaciones de la afirmación "el corazón limpia la sangre", por categoría de respuesta. Se presentan los porcentajes unitarios y agregados.

Justificación	Verdadero/Falso	Porcentaje V o F	Porcentaje justificación
Relacionado con el aparato circulatorio	F, su función es solo hacerla circular	24%	36%
	V, su función se relaciona con la circulación	12%	
Relacionado con la limpieza de la sangre	F, la sangre no se ensucia o no se limpia	3.5%	7%
	V, la sangre necesita limpiarse	3.5%	
Otras razones (sin razonamiento, moral…)	F, Porque es raro, porque no se mueve, porque es cuando te haces una herida	10%	17%
	V, para vivir, por Dios, porque así está limpio	7%	

V: verdadero, F:falso

La segunda afirmación es: "El corazón produce la sangre del cuerpo" (Q6). El 90% del alumnado respondió esta cuestión: las respuestas fueron mayoritariamente "Verdadero" (68%), frente a un 22% de "Falso" (22%). Solo el 27% del alumnado justificó su elección, aportando razones variadas (Tabla 8).

Tabla 8

Justificaciones de la afirmación "el corazón produce la sangre del cuerpo"

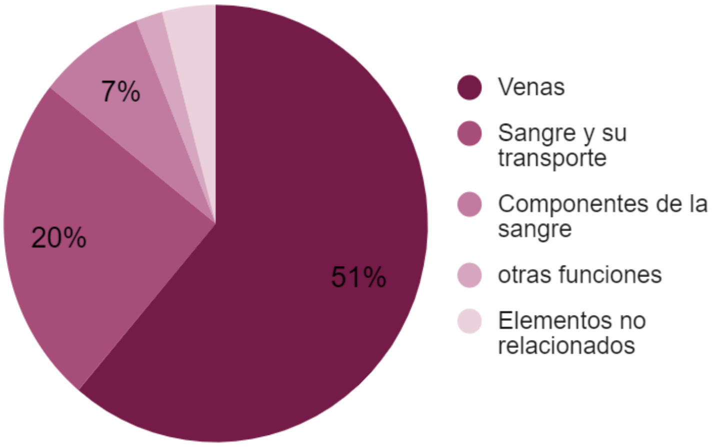
Justificación	Verdadero o Falso	Porcentaje
F, su función es solo hacerla circular	No, Porque solo la suelta	7%
	No, solo la transporta	
	No, porque solo está conectado	
	No, lo hacen los pulmones	
V, su función se relaciona con la circulación	Porque es el único órgano por el que pasa	15%
	Porque late	
	Porque la sangre la produce el cuerpo humano	
	Porque está conectado a las venas	
Otras razones (sin razonamiento, moral...)	Sí, porque así vivimos / porque nos da la vida	5%
	Sí, porque tengo un esqueleto de plástico	

V: verdadero, F: falso. Resultados presentados por categoría de respuesta. Se presentan los porcentajes agregados.

Finalmente, los alumnos se enfrentaron a diferentes preguntas relacionadas con las venas. La primera de ellas fue una pregunta de reconocimiento en la que a partir de un dibujo debían reconocer qué eran las líneas (Q7). El 51% del alumnado reconoció que se trataba de las venas mientras que el 21% hizo referencia a la sangre y su transporte (conductos de sangre), un 7% hizo referencia a componentes que transporta la sangre (agua, conductos de oxígeno), un 2% hizo referencia a otras funciones (limpian la sangre) y finalmente un 3% respondió con elementos no relacionados (huesos, músculos)(Figura 18).

Figura 18.

Gráfico con los resultados del reconocimiento de las venas en un dibujo.

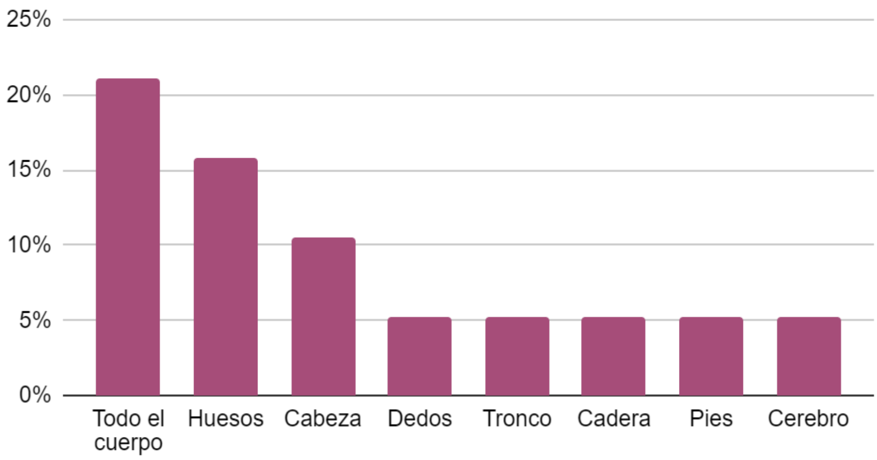


Al preguntar al alumnado sobre la función de estas líneas (venas) (Q8), tan solo el 72% de los estudiantes supo responder. Entre estos, el 37% asoció su función a la de la circulación o transporte, ya sea de sangre (32%) o de componentes de la sangre (5%). El 30% de los alumnos lo asoció con funciones vitales (estar vivo (27%) y estar sano (3%)). Por último, un 5% de los alumnos lo asoció a funciones impropias como “para las manos” o “para sujetar partes del cuerpo”.

Finalmente, el 32% del alumnado concluyó que había más venas por el cuerpo además de las del dibujo proporcionado (Q9). Como se puede apreciar en la figura 19, un gran porcentaje de las respuestas mencionan la existencia de venas por todo el cuerpo (21% de las respuestas). El resto de las respuestas localizaban las venas en lugares específicos del cuerpo humano, destacando los huesos (16%) y la cabeza (11%).

Figura 19.

Gráfico con los resultados de la localización de venas adicionales por el cuerpo.



4.4.2. Antes y durante la propuesta

Al igual que con el bloque de la respiración, el alumnado tuvo que diseñar un modelo (dibujo) del aparato circulatorio y su relación con la respiración (Figura 20). Sin embargo, hubo trabajo previo a la realización de este modelo ya que la circulación es un proceso más complejo y la mayoría de estudiantes desconocía su funcionamiento. En las dos sesiones previas (sesiones 9 y 10), se trató de hacer al alumnado ver la relación entre el sistema respiratorio y el circulatorio a través de diferentes simuladores e incluso sensores (de oxígeno y dióxido de carbono). Estas herramientas dieron lugar a la discusión de ideas para diseñar sus modelos (sesión 11). Como se puede ver en la tabla 9, un 86% de los grupos demostró entender la relación entre el sistema respiratorio y el circulatorio. Como se puede ver, el 100% de los grupos representaron el corazón, las venas y los pulmones. Además la mitad de los grupos incluyó elementos de la anatomía fina del sistema respiratorio (bronquios y bronquiolos). Por otro lado, un gran porcentaje de grupos representó o habló sobre oxígeno (79%) y dióxido de carbono (43%) refiriéndose al intercambio gaseoso.

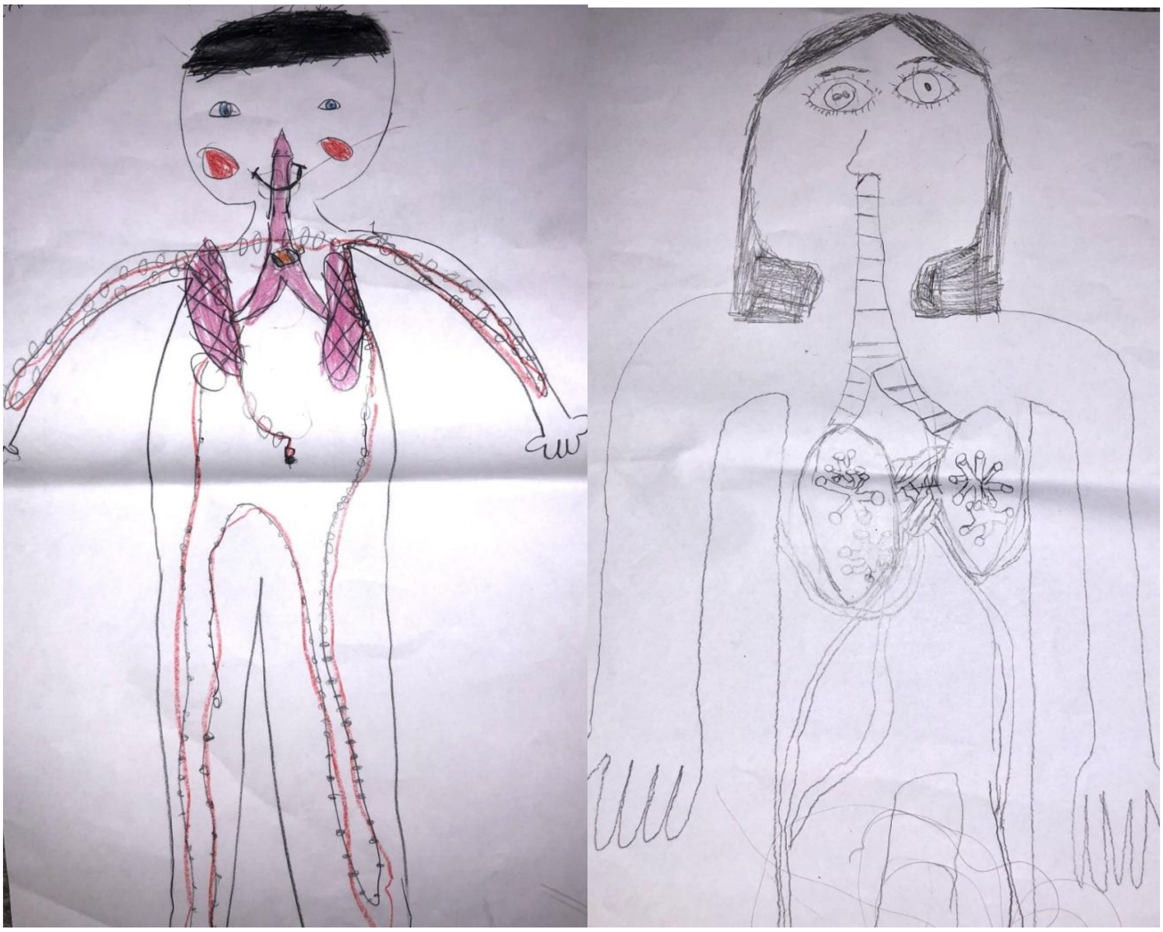
Tabla 9.

Elementos del aparato circulatorio y del respiratorio representados en los modelos de los escolares.

	CIRCULATORIO	
Anatomía	Corazón	100%
	Venas y arterias	100%
Recorrido sangre	Ida y vuelta por el mismo sitio	7%
	Circular	79%
	RESPIRATORIO	
Anatomía	Pulmones	100%
	Bronquios / bronquiolos	50%
	Tráquea	71%
Componentes del aire	Oxígeno	79%
	Dióxido de carbono	43%
Conexión circulatorio-respiratorio	Conexión con el sistema respiratorio	86%
	Tubo directo de los pulmones al corazón	14%

Figura 20.

Ejemplos de modelos de aparato circulatorio creados por el alumnado.



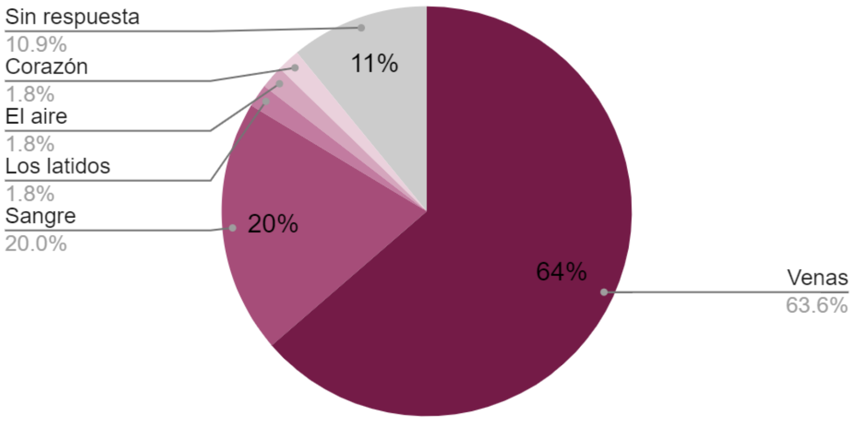
1. Circulación de la sangre circular, puntos representando el oxígeno (relación con el sistema circulatorio) unión directa de pulmones y corazón; 2. Representación de la tráquea y los bronquiolos, relación con el sistema circulatorio (presencia del corazón y venas).

4.4.3. Tras la propuesta

Finalmente, tras la propuesta, se volvió a medir los conocimientos del alumnado relativos al aparato circulatorio. En primer lugar, preguntamos qué o quién se encargaba de transportar el oxígeno por el cuerpo (Q9). Gracias a la experimentación con modelos del aparato circulatorio en los que debían transportar el oxígeno por los carriles de las venas y también gracias a los simuladores del aparato circulatorio que mostraban el recorrido del oxígeno por la sangre, el 64% respondió que las venas, el 20% respondió que la sangre, el 6% del alumnado dió otras respuestas como latidos (2%), aire (2%) y corazón (2%). El 11% restante no respondió a la pregunta (figura 21). Esto supone una leve mejora respecto a los resultados iniciales donde el 51% reconocía las venas y el 21% asociaba el dibujo de las venas a la sangre ya que ahora gran parte del alumnado reconoce no sólo la anatomía sino que también la función de las venas.

Figura 21.

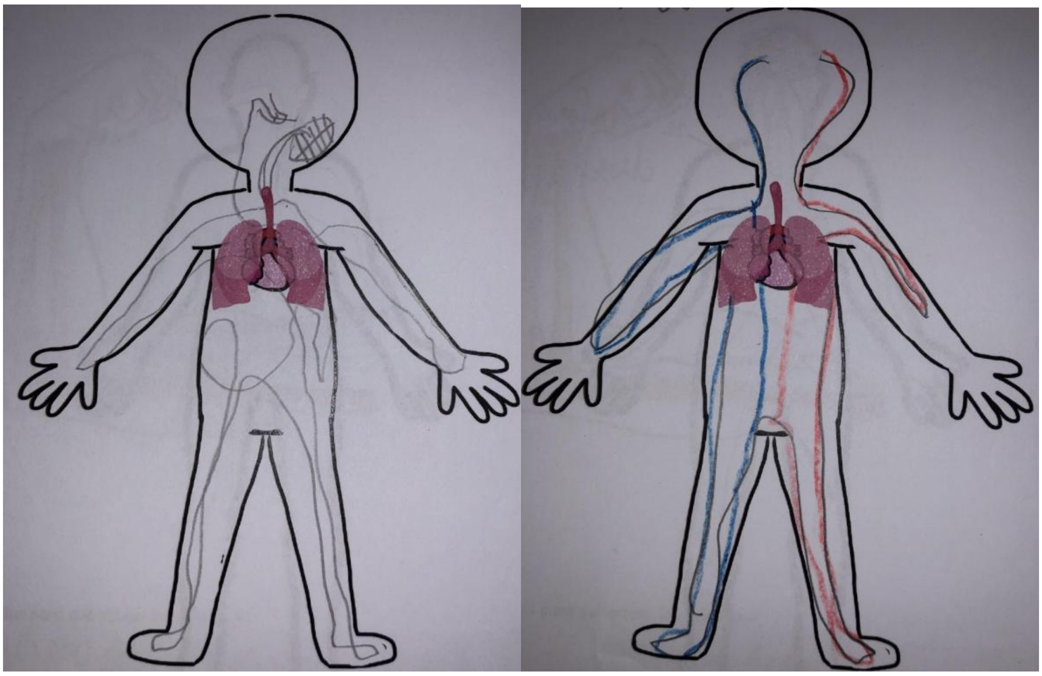
Gráfico con los resultados sobre qué transporta el oxígeno por el cuerpo.

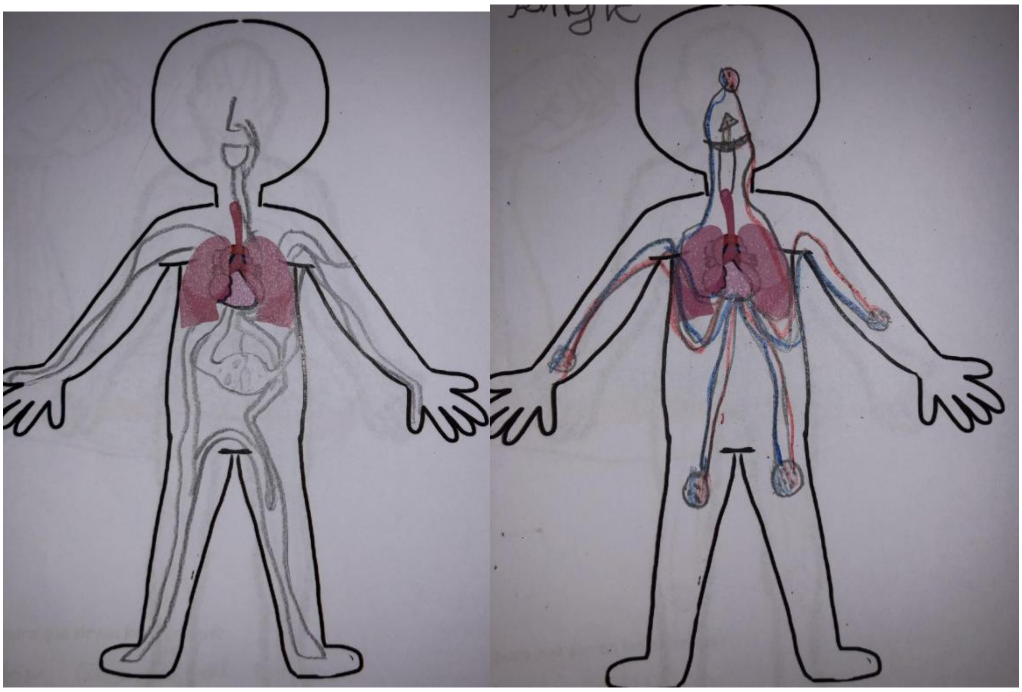


Por otro lado, se les pidió dibujar en una silueta humana (con pulmones y corazón incluidos) como el aire viajaba por nuestro cuerpo (Q9). Casi todos los alumnos representaron las venas en sus dibujos (98%), el 67% dibujó la nariz, el 58% la tráquea y el 35% la boca (figura 22). Por otro lado, el 24% mencionó el intercambio gaseoso ya sea hablando sobre la presencia de oxígeno o dióxido de carbono o representando las zonas de intercambio gaseoso. Finalmente un 40% utilizó los colores rojo y azul en sus representaciones (Figura 23).

Figura 22.

Representaciones del alumnado de las venas en el cuestionario final

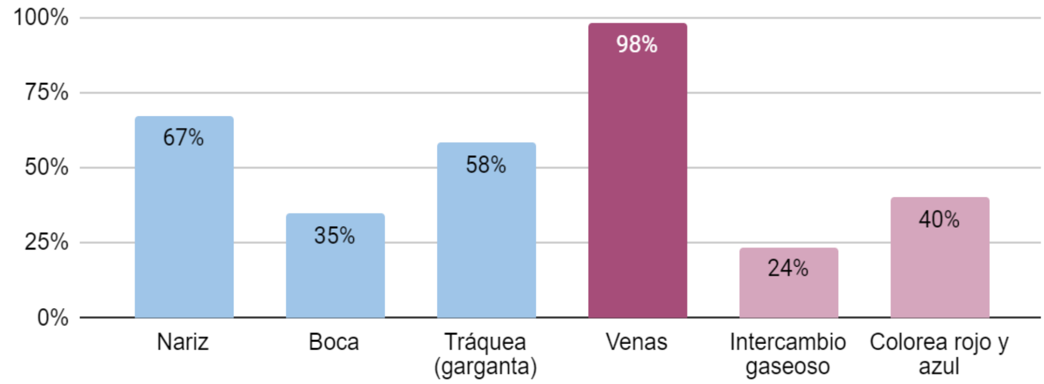




1. Venas, 2. Venas y uso de los colores rojo y azul, 3. Venas y zonas de intercambio gaseoso, 4. Venas y zonas de intercambio gaseoso coloreadas en rojo y azul.

Figura 23.

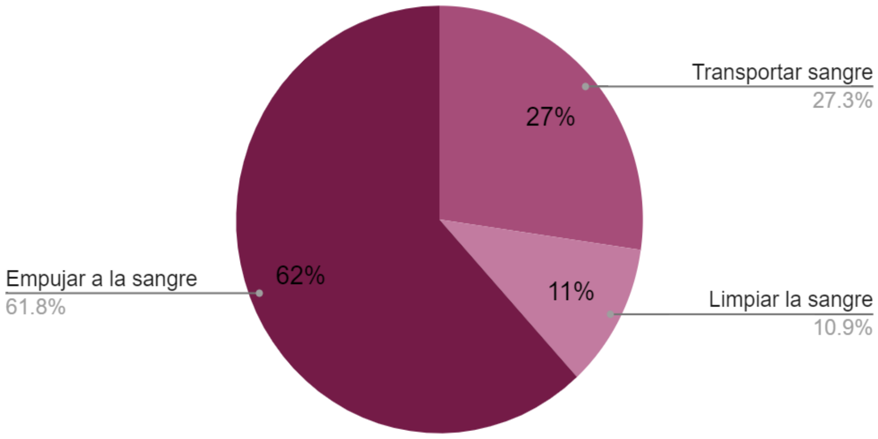
Gráfico con los resultados de las representaciones de la circulación del aire por el cuerpo.



Por último, el cuestionario se cerró con dos preguntas tipo test sobre el aparato circulatorio. En la primera de ellas se les preguntó por la función del corazón (Q10). El 62% respondió correctamente que el corazón sirve para empujar a la sangre, un 27% respondió que sirve para transportar la sangre y un 11% respondió que sirve para limpiar la sangre (Figura 24).

Figura 24.

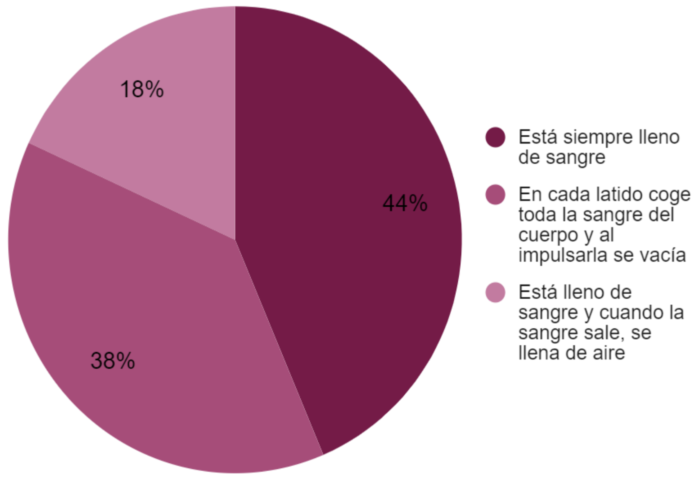
Gráfico con los resultados obtenidos al preguntar la función del corazón.



La segunda y última pregunta se refirió a que encontramos en el interior del corazón durante la sístole y la diástole (Q11). Tras experimentar con el corazón de vaca, un modelo de propulsión de sangre y finalmente analizar una animación y un simulador que mostraban estos dos momentos, casi la mitad del alumnado dió la respuesta correcta diciendo que el corazón siempre está lleno de sangre (44%), un 38% de los estudiantes eligió la respuesta que dice que el corazón en algún momento se vacía por completo y por último un 18% del alumnado escogió la última de las opciones que dice que cuando el corazón expulsa la sangre, se llena de aire (figura 25).

Figura 25.

Gráfico con los resultados obtenidos al preguntar sobre el interior del corazón durante cuando late (se contrae).



5. DISCUSSION

According to the results of the proposal, there have been numerous improvements on students' performance when using a blended method of TIC's and hands-on activities. In addition, this study has also given us some clues about the knowledge of second grade students regarding the human body.

5.1. Initial diagnosis

The initial diagnosis gathered fruitful information on what second primary students know about the inner anatomy of our body. This information can be compared to the one that Reyero et al. (2013) gathered in their studies. The great majority of our data concurs with the one of their studies. However, there are significant differences on some of the systems.

The nervous system seems to be very popular in both of the studies with a high level of representation. Nonetheless, students only represent its representative organ (brain) without reaching a higher complexity level. In addition, according to the data of the study mentioned above, second primary students should easily recognize and represent the reproductive system and other inner elements. In the case of our study, only some students represented this system and other inner elements of our body. Besides, the urinary system is not very popular in any of the studies in spite of having little representation in ours. Finally, the data gathered about the digestive system does not match what Reyero et al. found out. In our study, only 28% of the students represented its main organ and 31% other organs compared to the high representation in the other study.

However, there is not clear evidence if these are different knowledge that students have or it is just due to the question format where they did not have space or they did not know how to represent several systems in the same body.

5.2. Bones and muscles

As in Reyero et al. (2013), the bone system is one of the most common among students, this popularity could be explained with the presence of audiovisual culture in students' lives since skeletons are quite common in cartoons, also they could have had some experience of broken bones and the animals they eat have bones inside (eat chicken wings). Despite the presence of bones in many different environments of their daily lives, students did not reach a high complexity level on their first attempt because if these examples are not taken to the school setting they might remain unseen. This issue tells us that we should not assume that students know about something just because there are explicit examples outside of the school, they might not have had experience with them.

After the didactical unit, the students finally recognized different types of bones due to the manipulative activity with chicken bones and only the 14% of students represented a typical bone. Nonetheless, something interesting is that not all the groups recognized that bones are “soft” inside. Most of the students of one of the groups (group C), answered that bones are hard (inside and outside) (Figure 8) . This gap between the answers of group C and the other two groups could be explained with a timing reason. Group C was the last one on experimenting with the calf bone, this means that when students of this group had to touch the soft part of the bone, it was already hackneyed and they could not properly experiment with it. This demonstrates the importance of first hand manipulation; although explained in words, they retain what they interpreted from their observations.

Furthermore, just the 25% of students mentioned specific bones during the initial questionnaire while in the final questionnaire 96% of students mentioned at least one specific bone. This makes us think that playing repeatedly with the skeleton bone-labels and trying to locate the labels in the correct place with the help of a simulator helps students to memorize and remember better.

On the other hand, the muscular system was quite unrepresented in our study and when represented, was as body flesh or filling. One possible explanation could be the lack of space in the paper for representing them but the real issue is that students had little knowledge on this topic assuming that bones are just force and filling. With the help of the simulators and different experiments to recognize our muscles and their functions, students finally recognized the function of these and their inner anatomy. The experiments with their own body were useful for locating the muscles in our body and put into practice their different functions while the 3D simulator showing the cross-section of the muscle helped students to create an image of the real anatomy of a muscle (muscular fibers) that lately, they experimented by shredding the fibers from a piece of boiled meat. This last experience with the simulators and the boiled meat resulted in 36% of the students drawing muscular fibers on their answers to the final questionnaire and 29% drawing little circles that could represent the cross-section image of a muscle that we explored during sessions 4 and 5. Furthermore, a simulator of the agonist and antagonist movements of the muscles helped students to realize how muscles work (physiology) when we move.

5.3. Respiratory system

The recognition of the respiratory system is one of the main objectives of the proposal. There is clear evidence of improvement on this section where at the beginning 57% of the students represented the lungs and finally in the final questionnaire all of the students represented them. Something interesting is that in the first questionnaire, when students were asked to exclusively represent the respiratory system, the percentage of students representing the lungs raised up to 84%. What is more, at the beginning, students had a naive idea of the functionality of breathing (some of them did not even represent the lungs), they went from giving simple and general explanations such as “we breathe for living” (82%) to specific and more complex explanations related to the circulatory apparatus.

Moreover, we can notice a bigger growth in associated organs. Only 31% of the students drawed the nose in the first question of the initial questionnaire, while when they had to exclusively draw the respiratory system, 91% of the students represented it. This representation remained the same in the last questionnaire. Additionally, the mouth was little represented in the initial questionnaire (16%) and as a result of direct experience, the discussion in class about the organs involved in respiration and the creation of their own models, this number got more than duplicated in the final questionnaire being 41% of the students the ones representing the mouth.

Furthermore, the multiple experiments with real lungs or models clarified the idea of the air passing through the larynx and the trachea and the results improved on a 47% when representing the trachea and they passed from a 67% of students representing two tubes (one for each of the lungs) to all of them representing just one tube that divides into two bronchi. What is more, 20% of students reached higher complexity levels when representing the anatomy of the respiratory system by drawing bronchi and bronchioles in their explanations of the final questionnaire. In addition, the use of air sensors and gas exchange models resulted in 18% of the students recognizing and explaining this process in the final questionnaire. Considering that this item is such a complex and demanding one that students usually learn in secondary education the 18% of students understanding it is a great achievement. It may seem foolish but in the initial questionnaire there were already some students talking about oxygen (23%) and air with oxygen (2%) (Figure 12) without making any relations with the gas exchange process, we should not underestimate students' knowledge.

Furthermore, students finally interpreted the relation between the respiratory and the circulatory apparatus as a result of progressively presenting both systems as dependant of each other with representations of the respiratory system with organs of the circulatory apparatus present (e.g. the real lungs had a heart attached to them), also with simulators showing both systems working at the same time (e.g. simulator of lungs with a beating heart) or models of gas exchange in the section of circulatory apparatus. Alternative explanations for the air circulation decreased from 72% on the initial questionnaire to 14% in the final one, this could mean that students have successfully understood that the air is transported by the blood around the body.

5.4. Circulatory apparatus

The circulatory apparatus is another of the main blocks of the proposal and from the beginning it seemed to be quite popular among students having 91% of representation (at least of the heart) in the first question of the initial questionnaire (annex 2). This data can be compared to the one obtained by Reyero et al. (2013) where only 54% of the students represented the heart. Furthermore, 66% of the students also represented specific elements such as veins and blood, a 20% more than what Reyero el al. (2013) numbers say. In our final questionnaire, the main focus was not on representing the heart but the whole respiratory and circulatory systems so students were already provided with a picture including a heart.

Students were also asked to exclusively represent the circulatory apparatus in the initial questionnaire and all of them represented at least the heart which tells us that in the previous activity they probably forgot about the circulatory apparatus and focused on other systems or elements of the human body.

Furthermore, as we have previously seen in the results section, the great majority achieved a higher complexity level representing also some specific elements of the circulatory apparatus such as veins or even the lungs. The circulatory apparatus was presented right after understanding how the respiratory system works and they were presented as related systems (e.g. bring real lungs with a heart attached to them) which makes it normal to see students assume that when they are asked about the circulatory apparatus they should also draw the lungs and other elements of the respiratory system. This assumption is reflected in their models where all of them represent the lungs (some of them even bronchi and bronchioles) and before the didactic proposal, only 18% of the students drew lungs in their representations of the circulatory apparatus.

Moreover, at the beginning there was no evidence of students representing the trachea but then in their models, 70% represented it and in their final questionnaires 58% did it. The decline in the percentage of representation from the models to the final questionnaire could be justified by the previous recalling activity done before the design of the models. The use of simulators representing both respiratory and circulatory apparatus together, such as the one that you can see in figure 26, help students to have a complete vision of the process and later represent it.

Figure 26.

Screenshot of the respiratory and circulatory system simulator

Screenshot from BiodigitalHuman.com

Students showed evolution in their representations since all of them represented both the heart and veins in their models created during the proposal (only 66% of the students did it at the beginning). It is true that in the final questionnaire the heart and the lungs were already drawn but students had to draw the rest and there was a significant improvement in the veins' recognition. This could be due to the importance that it was given to those "slides" (*toboganes*) or tubes that transport blood. At the beginning, only 51% of the students recognized those lines of the circulatory apparatus as veins, the rest of the students assumed that they were blood, components of the blood or other non-related functions. With the help of simulators of the circulatory apparatus and models with the ones students played, they finally related veins to the function of transporting blood being 64% of the students, the ones recognizing that veins carry oxygen through the body and another 20% stated that the blood enrolls this transport function. When students talk about blood instead of veins it is not difficult to understand that both should be valid since the reality is that the blood which is inside of the veins transports the oxygen (in this case).

In spite of being one of the most popular systems among students, they mainly recognized the representative organ but not its functions. When students were asked about the function of the heart, some of the students (32%) got confused affirming that the heart was in charge of cleaning the blood. At the end of the proposal, this number decreased to 11% of the students affirming this. On the other hand, the majority (62%) recognized the heart as the impulsor of blood. The animation about the heart clearly showed how it contracts and expels the blood to the veins, students experimented this route with one of the circulatory models created. Furthermore 44% of the students recognized that the heart always has blood even if it gets expulsed. The same animation also showed how the heart expulses the blood inside the ventricles while it beats and its auricles get filled.

5.5. Global reflection

The overall development of the proposal has been positive and we have noticed many different improvements in students' knowledge thanks to the blended method of direct experience (experimentation) and use of ICTs. The first hand experimentation has brought the subject closer to the students by making them explore what we can see, in other words students have experimented with the structure or anatomy or different parts of the body and their function. On the other hand, the use of ICTs has made students go a step further by allowing them to explore the physiology of these organs and systems. In short, we can say that experimentation helps to understand concepts that we can see and ICTs complete this knowledge by showing how they actually work which may not be advisable at first sight and without technological tools.

A good example is the heart, students experiment with the heart's anatomy in order to fully understand its physiology. If students do not recognize the auricles and ventricles of the heart by experimenting with them, it is probable that lately they will not understand how the heart expulses the blood when it beats.

We consider that this proposal has adequately integrated the ICTs since as Punie et al. (2006) recommend, the use of those has not been the main goal of the proposal but they have been used as a tool to reach the main goal of getting to know more about the human body. If we think about the SAMR integration model, it is not difficult to see that the proposal has reached in many activities the second level of Augmentation. For instance, the introduction of human body simulators such as Zygotebody of BiodigitalHuman, has Substituted the traditional human body posters and it has even reached the augmentation phase since these platforms offer multiple functionalities such as 3D vision and live movements of the organs. Furthermore, the use of oxygen and carbon dioxide sensors could be also considered to have reached the third phase of modification since it definitely redefines the task and it shows in a simple way the amount of these gases in the class and before and after breathing out.

We can also relate the proposal to the other integration model of TPCK since new technologies are definitely integrated with the contents and the class methodologies. We have been completely conscious about the utility of each of the tools depending on the task, putting into practice all the technological and pedagogical skills in order to properly teach the desired contents. One example seen in the proposal is choosing to use a simulator to see how the lungs swell instead of an animation because the simulator allows students to zoom in, turn it around and remove layers among others.

5.6. Limitations

During the study we have also noticed some limitations or issues to improve for future studies. The first issue deals with the questions posed to students. This study was meant to be applied in second grade where the written expression is not fully developed or at least it is not one of the strongest points of students, thus, we created a questionnaire in which students had to answer mostly by drawing. It is necessary to say that the analysis of the drawings can be quite inexact since the interpretation of the drawings is kind of difficult and subjective. Furthermore, open questions with a broader scope of answers overload students and do not gather all the information that they actually know, however, these questions are really useful for having a global view and the relations between the systems.

Besides, the use of ICTs has been very limited since second grade students are not included in the Ikasnova project yet. Luckily, we had a projector and a computer in all of the classes and students were provided with the links of the simulators in order to freely explore the platforms at home but it would have been preferable to count on having these tools and let the experiment themselves the different platforms making the sessions more dynamic.

CONCLUSIONS

Firstly, it is obvious that students had prior knowledge on the subject and this allowed us to address the didactic unit with relative ease. However, this previous knowledge included several misconceptions regarding system bonding and physiology of the organs. Students justified these phenomena with simple or rudimentary explanatory models which are not completely incorrect but needed to be completed.

Secondly, there have been a lot of improvements on students' knowledge regarding the human body. Students have progressed from a stereotyped idea of bones and muscles representing typical bones and flesh as filling to a deeper perception of bones' structures and functions and muscles made of muscular fibers. Respecting the respiratory system, students have completed their idea of ventilation by including the gas exchange phenomenon in their explanations, as well as the idea of gas circulating through the body and the increased breathing frequency associated with doing sport. Finally, in terms of the circulatory system, students have evolved from the simple representation of an isolated heart to the representation of a complete system related to the respiratory system.

Thirdly, all these improvements may be due to the use of TEs which assisted students in determining the relative position of organs as well as their physiology. They enabled us to move from abstract to concrete ideas, allowing students to encounter previously unimaginable concepts. On the other hand, direct experimentation has also helped students in their interpretation of the anatomy and the function of our organs.

Finally, we can conclude that a didactic proposal combining both direct experimentation and Educational Technologies is effective, highly motivational and reachable for students. Both approaches are necessary and complementary but should be adequately integrated in order to generate an efficient and real impact. This is to say, we should be conscious of the strengths of each of the approaches and of how to make the best of them to have an optimal yield.

OPEN QUESTIONS

Following this, we would like to discover the impact of a proposal close to this one but with a longer time frame. Furthermore, for future studies we would recommend to follow a more accurate data tracking by comparing the before and after of each of the students in order to see the specific improvements on each of the cases. Also, we would suggest collecting more data during the proposal in order to analyze the evolution step by step. Besides, having chrome books for each of the students would have facilitated the understanding of the simulations since they would have explored the platforms themselves.

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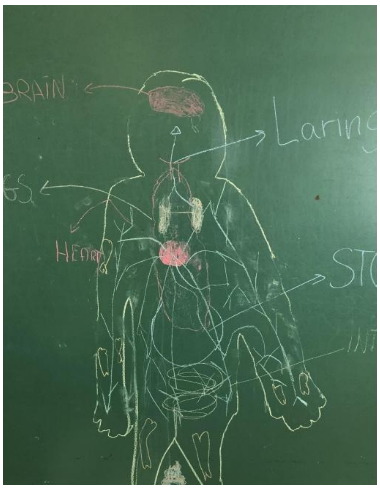
ANNEXES

Annex 1: Didactic proposal

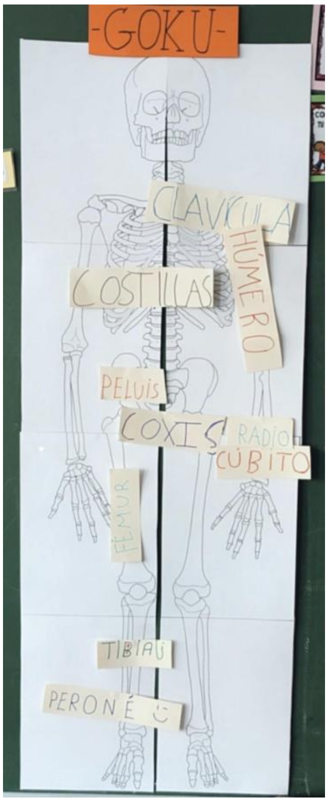
<table>
<tr><th colspan="3">Session 1- A look inside our body</th></tr>
<tr><th>CLASS ORGANIZATION</th><th>MATERIALS</th><th>TIMING</th></tr>
<tr><td>Big group</td><td>Human Biodigital simulator [Annex 4]
Blackboard and colour chalks</td><td>45’</td></tr>
<tr><th colspan="3">Objectives (teacher)</th></tr>
<tr><td colspan="3">Unveil the previous knowledge and misconceptions about human body of the students</td></tr>
<tr><th colspan="3">Learning outcomes</th></tr>
<tr><td colspan="3">(1) To recognize the inner anatomy of our body and its different layers (bones, muscles, circulatory apparatus, respiratory system, digestive system, nervous system…).</td></tr>
<tr><th colspan="3">Key concepts</th></tr>
<tr><td colspan="3">Locate organs in the body</td></tr>
<tr><th colspan="3">Activity development</th></tr>
<tr><td colspan="3"><u>Introduction and retrieving of previous knowledge</u>
The final questionnaire has served for detecting students’ difficulties and adapting the proposal to them. In order to introduce the unit and to retrieve what students have drawn in their answers to the questionnaire, we draw together a human body with its insides. The idea is to recover as much information as we can in this drawing and afterwards compare it with a human simulator (Human Biodigital simulator).

Students come out to the blackboard and draw with different colours the inner parts of our body, discussing at the same time their location and their importance. Then, this drawing will be compared with the simulator so as to see what is missing.</td></tr>
</table>

Notes
Bring next day a list of 3 bones of our body and an interesting fact about bones. It can be really interesting if we show both male and female bodies since there are some interesting anatomical differences that we can not see depending on the layer of the body in which we have a look.

Session 2 - Our Skeleton		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Big group	Zygotebody [Annex 5] Life-size skeleton Labels	45’
Objectives(teacher)		
Challenge and transform misconceptions, by comparing the drawing with a simulator. Mobilize and expand previous knowledge about bones		
Learning outcomes		
(1) To recognize the inner anatomy of our body and its different layers (bones, muscles, circulatory apparatus, respiratory system, digestive system, nervous system…). (2) To identify and locate at least 3 bones in our body.		
Key concepts		
Structure of the musculo-skeletical system Name of some bones		
Activity development		
Comparison with simulator: Open zygotebody [5] and explore the different layers of the human body comparing it at the same time with their drawing of the first session. Have a look at the different layers of the body: skin, muscles, digestive system, skeleton…		

Skeleton labels:

The life-size skeleton is presented to the class (you can give him a name) and compared to the skeleton of zygotebody. In addition, with their homework about bones (check notes of session 1), we choose the 10 most popular bones of the classroom and make labels of them. With the help of the simulator, students stick the labels in the correspondent place.



Notes
Give to students' access to the simulator so that they can access it from home.

Session 3 - Where is the bone?		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Big group Individual	Life-size skeleton Bones' simulator [annex 6] Individual skeleton photocopy [annex 7] Human Biodigital simulator [annex 4]	45'
Objectives (teacher)		
Synthesis: recall and reinforce newly acquired contents about bones.		

Learning outcomes
(2) To identify and locate at least 3 bones in our body.
Key concepts
Name of some representative bones (fémur, costillas, cráneo, tibia, radio...)
Activity development
Place the bones: Students receive one label to place on the skeleton with the help of their classmates and the simulator. Furthermore, only five bones out of the ten are chosen to stay in the skeleton. These five bones are used in the next activity. My skeleton: Students receive a skeleton photocopy that they need to complete by colouring the five bones chosen and writing their names. Interesting facts about bones: Finally students discuss the different interesting facts that they have discovered while investigating. This information can be used in other subjects as language or English in order to make them speak or write.

Session 4 - My muscles		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Big group Small groups	1kg weight Biceps and triceps simulator [Annex 8] Timer Muscle cross section [Annex 9]	45’
Objectives (teacher)		
Mobilize and expand previous knowledge about muscles Proof and apply newly acquired content about muscles		

Learning outcomes
(3) To understand the main functions of bones and muscles (movement, protection, stability). (4) To recognize the anatomy of a muscle (5) To understand the agonist-antagonist movement of the muscles.
Key concepts
Recognize the muscles and their functions (protection, movements and stability). Anatomy and physiology of a muscle.
Activity development
Introduction of muscles with a simulator: The muscles layer of the body is shown explaining that it is the first thing that we see if we “remove our skin”, our “second layer of the body”. 5 minutes discussion: - What are the muscles? - Which is their function? *Protection, movement, stability* - How do they look like? Can you draw the inside of one muscle? Conclusions: After the five minutes, each of the groups shares the conclusions with the rest of the class. From these conclusions, the teacher summarizes the main functions of the muscles: protection, movement and stability giving some examples and experiencing each of the functions.. <u>Protection</u>: muscles that protect us: Abs, eyelid… Give examples of muscles that protect us. Example: Abs serve as a defense if someone punches us in the stomach. <u>Moving</u>: Muscles that help us moving (locomotion): biceps and triceps, quadriceps… In small groups, students have to move their arm while leaving their hand on the biceps. They have to see if anything under their skin is moving. If they cannot see any movement they can take a 1kg weight to make it more evident. After this first

hand experience, the movement is also analyzed in a simulator that shows the agonist and antagonist movements (when one lengthens, the other shrinks). Furthermore, they can stand on their tip toes for one minute and walk around the classroom to see if they feel how the muscle is working (how it gets tense).

Stability: muscles that help us to stand: abs, quadriceps...
Students in groups try to destabilize one of the members of their group with little jostlings (without hurting). The student in the middle has to recognize which muscles is he using for maintaining his stability.

How is a muscle?:
Finally, a muscle cross section simulator [annex 9] is shown to analyze how muscles are inside. This simulator helps them to understand that muscles are made of thin fibers called muscular fibers that look like spaguettis.

Session 5 - Corners of bones and muscles		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Small groups	Chicken and calf bones Bone information charts [Annex 10] Veal boiled meat Muscle information chart [annex 9] Anatomy sets Simon says scaffolding	45’
Objectives		
Recall, apply and reinforce newly acquired contents about bones and muscles.		
Learning outcomes		
(3) To understand the main functions of bones and muscles (movement, protection, stability).		

(4) To recognize the anatomy of a muscle

(5) To understand the agonist-antagonist movement of the muscles.

Key concepts

Experiment in corners with bones and muscles

Activity development

Corners:

This session consists of 4 different corners around the classroom with materials for experimenting different issues about bones and muscles. Students in small groups, go around the classroom changing corners until they experiment with all of them.

1. Bones 1: on this corner students find clean chicken bones of different shapes (long, short and flat). Students have to classify the bones according to their shape or their length with the help of a printed photocopy with information. They can also try to break them or to see if they float.

2. Bones 2: this corner has a calf bone cutted in half. Students have to carefully observe and touch the different layers of the bone, comparing it with a picture that will be provided with information of a long bone cross-section.
3. Muscles: students find boiled meat and information about muscles. The boiled meat is really useful for showing students the muscular fibers since one can easily shred the meat and see the individual fibers. They also have some information to compare the real experiment with.
4. Research: students can find many different books and anatomy sets about the human body.

5. Simon says (optional): students play to simon says with the name of the bones or the parts of the body. They have some vocabulary scaffolding in order to easily play.

Session 6 - How do we breath?		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Individual, pairs and small groups	A3 sheet of paper	45’
Objectives(teacher)		
Introduce the breathing block, recall previous knowledge and unveil the misconceptions of students about the respiratory system		
Learning outcomes		
(6) To identify and describe respiration as a vital function and know and perform exercises for its correct execution. (7) To identify the main organs of the respiratory system. (8) To design a drawing and formulate an explanation for the breathing process.		
Key concepts		
Reflect on the breathing process and create a model that explains it		
Activity development		
For this session, we use the think-pair-share method. The teacher makes some questions that students think individually and then, they share them in pairs and in groups. - Let’s breathe together. Do you see any changes in our body when we breathe? Practice in pairs: put the hands on the classmate’s dorsals while he/she breathes so as to feel the chest inflating. Furthermore, students can lay on the floor and breathe in as much air as they can so as to see how the abdomen moves (you can place an object on the abdomen to make that		

movement more evident). - What do you use for breathing? What happens when you close your nose and try to breathe? - Do you feel the air entering your body? - How do we breathe? Do you make any effort? After thinking about all these ideas, students get in groups and design a drawing for giving a possible explanation to the breathing process.

Session 7 - How do we breath? (2)		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Small groups	Evaluation rubrics Model lungs 1: plastic bottle, straws and balloons [annex 11] Model lungs 2 : plastic bags, cardboard and straws [annex 12] Calf lungs	90’
Objectives (teacher)		
Unveil students’ misconceptions about the respiratory system and reconstruct their knowledge by applying and experimenting new concepts about the respiratory system		
Learning outcomes		
(6) To identify and describe respiration as a vital function and know and perform exercises for its correct execution. (7) To identify the main organs of the respiratory system. (8) To design a drawing and formulate an explanation for the breathing process.		

Key concepts
Present breathing models and experiment with breathing in corners
Activity development
Presentations: Students finish the drawings that they started on the last session and after this, give a brief explanation of them. At the same time the teacher collects information about their ideas on breathing. Corners: There are 3 different corners in which students experiment with breathing. One of the corners has real lamb lungs that students touch, explore and even inflate to see how they grow: Furthermore, they examine the tissues, the fluffy texture of the lungs in relation to their function. On the second and third corners they find two different lung models (annex 11 and 12) that show them how lungs inflate and deflate, the anatomy and the proximate functioning of all the elements, and the important role of the diaphragm. Reconstruction: students reflect on what they have experienced and compare this reflection with their prior explanation of the process so as to reconstruct it.

Session 8 - Move and breathe		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Big group and individual	Breathing dynamics simulator [annex 13] Breathing with beating heart simulator [annex 14]	45’
Objectives (teacher)		
Expand knowledge about the respiratory system to understand the relation between the respiratory and the circulatory systems. Apply newly acquired concepts about breathing		

Learning outcomes
(9) To notice the relation between lungs and heart (11) To identify the main organs of the circulatory apparatus (heart and veins) and their function. (impulse blood and transport blood leaving the “good things” and bringing back the “bad things”)
Key concepts
Compare their breathing models with breathing simulators and experiment breathing by measuring the breathings per minute
Activity development
Movement of the lungs: Students have experimented with real lungs and breathing models but they also need to see this breathing process together with the rest of the body with the help of simulators. First, they see the breathing dynamics simulator [13]. This simulator also shows the heart beating and this can lead the class to ask questions such as: why is the heart so close to the lungs? Why does it also move? Are lungs and heart related? Do the lungs have veins? Students usually have difficulties in seeing the relation between lungs and heart but the second simulator [14] projected shows the inside of the lungs and the heart beating. This way, students can see that lungs “have veins” inside and start to understand the relation between lungs and heart. Furthermore, they can also notice the bronchi and bronchioles inflating when breathing. Let’s breathe: students are going to measure how many times they breath in a minute. This activity helps them to go a step further in understanding respiration. They make two measurements. The first measurement is made when all of them are sitting down and relaxed and the second one is made after some minutes of movement (dancing, jumping, running…). The difference between these two measurements makes them understand that when we move we need to breathe more times and that happens because the air has something that we need when we move. Furthermore, they also make some

connections between respiration and circulation. They can see that when we move we need to breathe more times but also the heart beats faster and harder.

Session 9 - What does the air have?		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Big group	Sensors of oxygen and of carbon dioxide [annex 15] Breathing with beating heart simulator [annex 14]	45’
Objectives (teacher)		
Recall and expand previous knowledge about air composition Understand the relation between respiratory and circulatory systems.		
Learning outcomes		
(9) To notice the relation between lungs and heart. (10) To design a drawing and formulate an explanation for the circulation and gas exchange processes. (11) To identify the main organs of the circulatory apparatus (heart and veins) and their function. (impulse blood and transport blood leaving the “good things” and bringing back the “bad things”) (12) To discuss the importance of oxygen in the air and why we need it.		
Key concepts		
Understand the importance of breathing by analysing what the air has (oxygen and carbon dioxide). Reflect on the gas exchange taking place inside of our body.		
Activity development		
Simulator: The teacher projects again the simulator that shows the bronchi and bronchioles so as to recall what they did during the last session and also focus on how these bronchioles inflate when we breathe. Students will be asked about the veins inside		

of the lungs: Why do we have veins inside of the lungs? Furthermore, the teacher makes students reflect about the importance of breathing: what does the air have? Why do we need air to live? Sensors: After a short reflection on what the air has. The two sensors are presented. With both of the sensors the teacher starts measuring the oxygen or carbon dioxide of the classroom so as to show in the graphic that there is a straight line which means that the air of the class remains the same. After this general measurement, one student helps to make the experiment breathing in air and breathing it out on the sensor. Before the experiment, students have to guess if the straight line is going to change (increase, decrease or remain the same). Reflection: After the two experiments students reflect on why we breathe in oxygen but then we do not breathe out the same amount of oxygen, but less (the opposite happens with the carbon dioxide). This leads the class to talk about the transformation of oxygen into carbon dioxide and to think where and how this happens (a little introduction to the circulatory apparatus).

Session 10 - Tell me how		
CLASS ORGANIZATION / SPATIAL ORGANIZATION	**MATERIALS**	**TIMING**
Small groups	A3 sheet of paper	45’
Objectives (teacher)		
Recall, mobilize and expand previous knowledge about the circulatory system Unveil students’ misconceptions		

Learning outcomes
9) To notice the relation between lungs and heart. (10) To design a drawing and formulate an explanation for the circulation and gas exchange processes. (11) To identify the main organs of the circulatory apparatus (heart and veins) and their function. (impulse blood and transport blood leaving the “good things” and bringing back the “bad things”) (12) To discuss the importance of oxygen in the air and why we need it.
Key concepts
Understand that veins are all around our body, that blood is not static and that it has a transport function. Create a circulatory model
Activity development
Discussion: At this point, students already have many concepts about circulation clear. Anyways, this session consists of recalling all this information that they already know and making them express it by drawing and discussing. The first idea is that we have veins all around the body. The second idea is to understand that blood is not static but always in movement thanks to the heart. Finally, the idea that blood has a transportation function (in this case, transport oxygen and carbon dioxide). Models: Students in small groups design a drawing for explaining how and where the gas exchange takes place (as they did with the respiration).

Session 11 - The beating heart		
CLASS ORGANIZATION	**MATERIALS**	**TIMING**
Small groups	Heart animation [Annex 16] Heart cycle simulation [Annex 17] Circulation and gas exchange simulator [Annex 18] Veal and calf hearts	90’

Objectives (teacher)
Unveil students' misconceptions Apply newly acquired knowledge about both respiratory and circulatory systems
Learning outcomes
9) To notice the relation between lungs and heart. (10) To design a drawing and formulate an explanation for the circulation and gas exchange processes. (11) To identify the main organs of the circulatory apparatus (heart and veins) and their function. (impulse blood and transport blood leaving the "good things" and bringing back the "bad things") (12) To discuss the importance of oxygen in the air and why we need it.
Key concepts
Present the circulatory models. Analyze how the heart is and how it works and experiment with circulatory models and real hearts.
Activity development
Presentations: Students present the models they designed during the last session and as in session 7, the teacher collects information about their ideas on circulation and gas exchange. Simulator and animation: The teacher shows different simulations and animations in order to prepare students for the last corner session. With the help of a circulation and gas exchange simulator, students can see the complete cycle of respiration and where the gas exchange takes place. Furthermore, with a cardiac cycle simulator, students can see the cross-section of a heart, the different "rooms" (atriums and ventricles) that it has and the route that blood makes. Finally, a heart animation helps to see which movement does the heart make when beating. Corners: On the first corner students, with the help of the teacher and of a cross-section picture of the heart, can touch and experiment with two real hearts (calf and veal

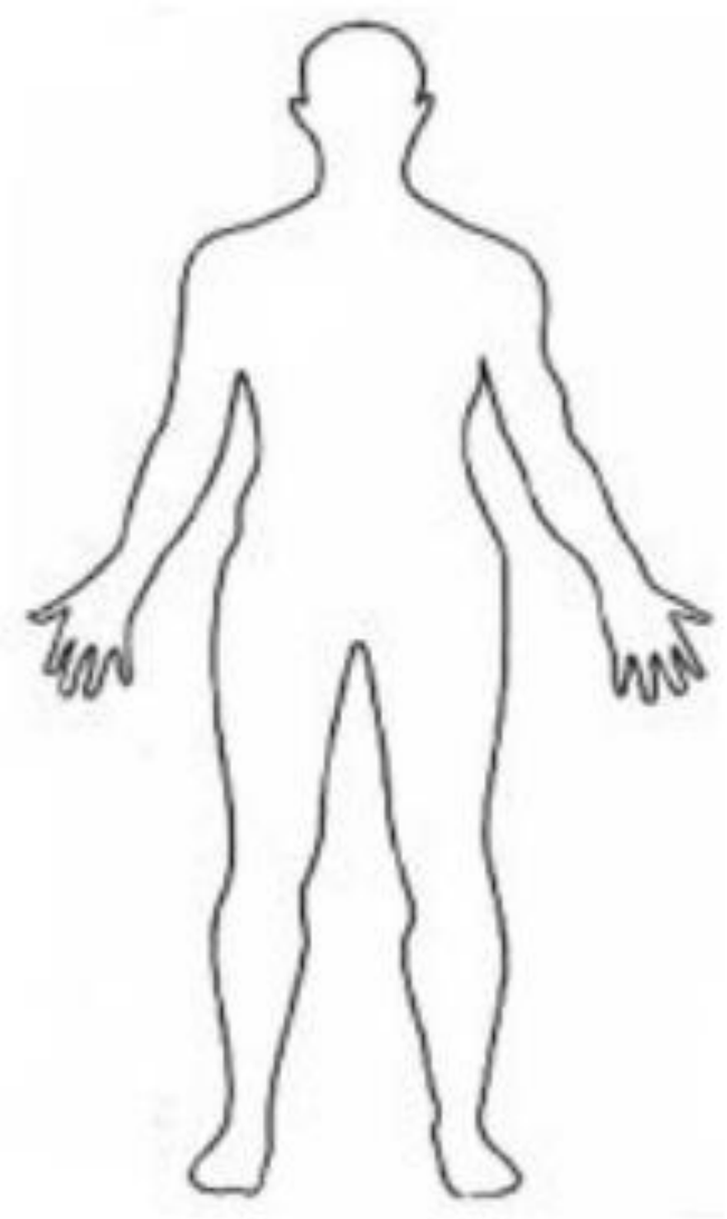
hearts). Students try to find the 4 different rooms of the heart and figure out how the blood enters and goes out from the heart.
On the second corner, students can play with a cardio-respiratory model in which they take oxygen and carbon dioxide cards and make the route that oxygen makes (from the mouth or nose, to the lungs, to the blood, to the heart, gas exchange and the way back).
Finally, on the third corner, students experiment with a beating heart model in which they can find a pear enema attached to a balloon through a plastic tube. Students by beating the enema can see how blood (water) fastly moves to the parts of the body (balloon) and how the blood returns by inertia. This model is not really accurate because blood does not return through the same way but it is a clear example of how the blood moves when the heart beats.

Annex 2 : Initial questionnaire

Sección 1: EL CUERPO HUMANO

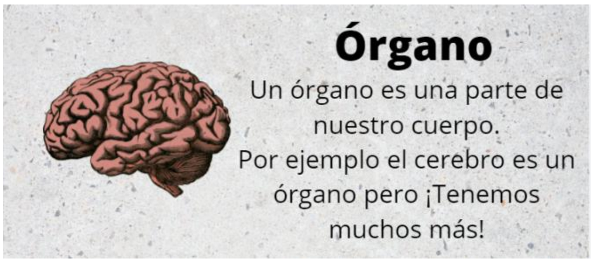
1. ¿Cómo somos por dentro?

Dibuja todo lo que creas que tienes en el interior de tu cuerpo (desde la cabeza hasta los pies).

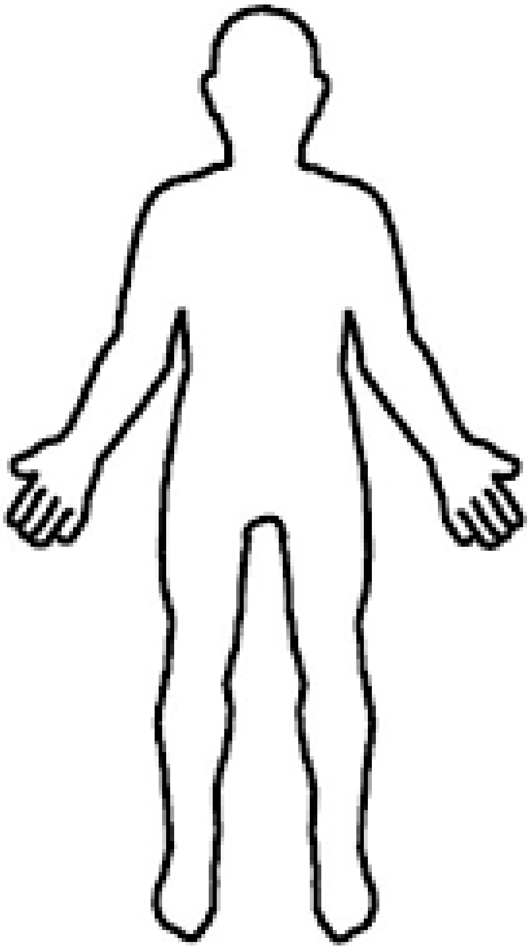


Sección 2: sistema circulatorio

2. Tenemos un órgano que hace este sonido ¿Sabes qué **órgano** es?



3. ¿puedes dibujarlo y explicar en tu dibujo cómo funciona?

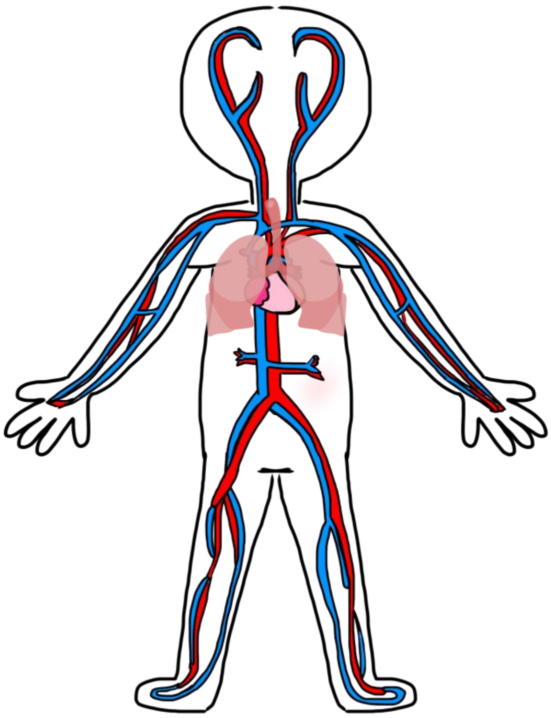


4. ¿Por qué crees que lo tenemos?

Señala si es Verdadero (V) o falso (F) y explica por qué:

5. El corazón limpia la sangre

6. El corazón produce la sangre del cuerpo



7. ¿Qué crees que son esas líneas?

8. ¿para qué sirven?

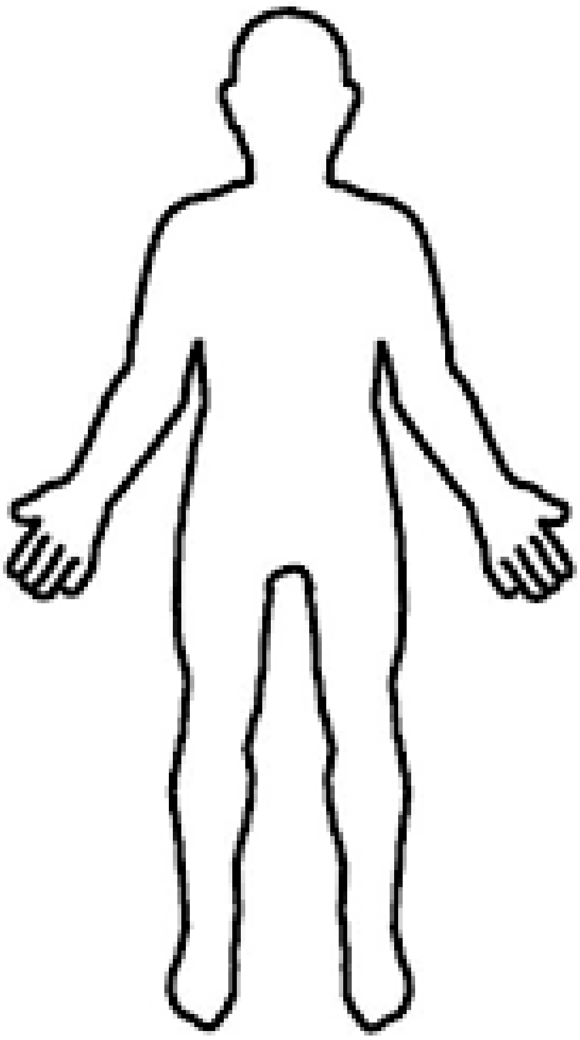
9. ¿Crees que hay más en el cuerpo? ¿Podrías dibujar dónde se encuentran?

Sección 3: sistema respiratorio

10. ¿Cómo se llama esto que estamos haciendo?

11. ¿Qué está entrando por nuestra nariz?

12. Imagina que tú entras por la nariz, dibuja el recorrido que haces hasta que sales de nuevo por la nariz y pon el nombre de los sitios por los que pasas.



Recuerda que el aire tiene que llegar a todas las partes de nuestro cuerpo.

13. ¿Para qué crees que respiramos?

Annex 3: Final questionnaire

EL CUERPO HUMANO

Sección 1: Los huesos

1. ¿SON TODOS LOS HUESOS DE NUESTRO CUERPO IGUALES?
SI CREES QUE HAY ALGUNO DIFERENTE, ¿PODRÍAS DIBUJARLO Y EXPLICARLO?

TEST:

2. En el cuerpo tenemos:
   a) Más de 10 huesos
   b) Más de 50 huesos
   c) Más de 100 huesos

3. Tenemos:
   a) Solo un tipo de huesos
   b) Varios tipos de huesos

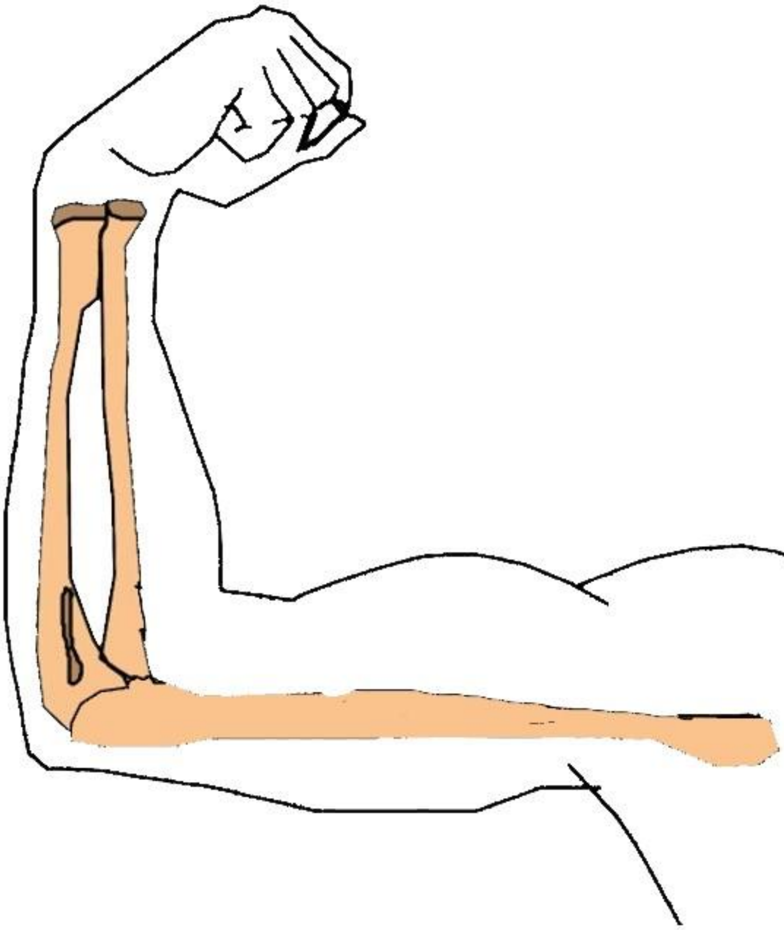
4. Los huesos son…
   a) Duros por fuera y por dentro
   b) Blandos por fuera y por dentro
   c) Duros por fuera y blandos por dentro

5. ¿Te acuerdas del nombre de algún hueso?

-
-
-

Sección 2: Los músculos

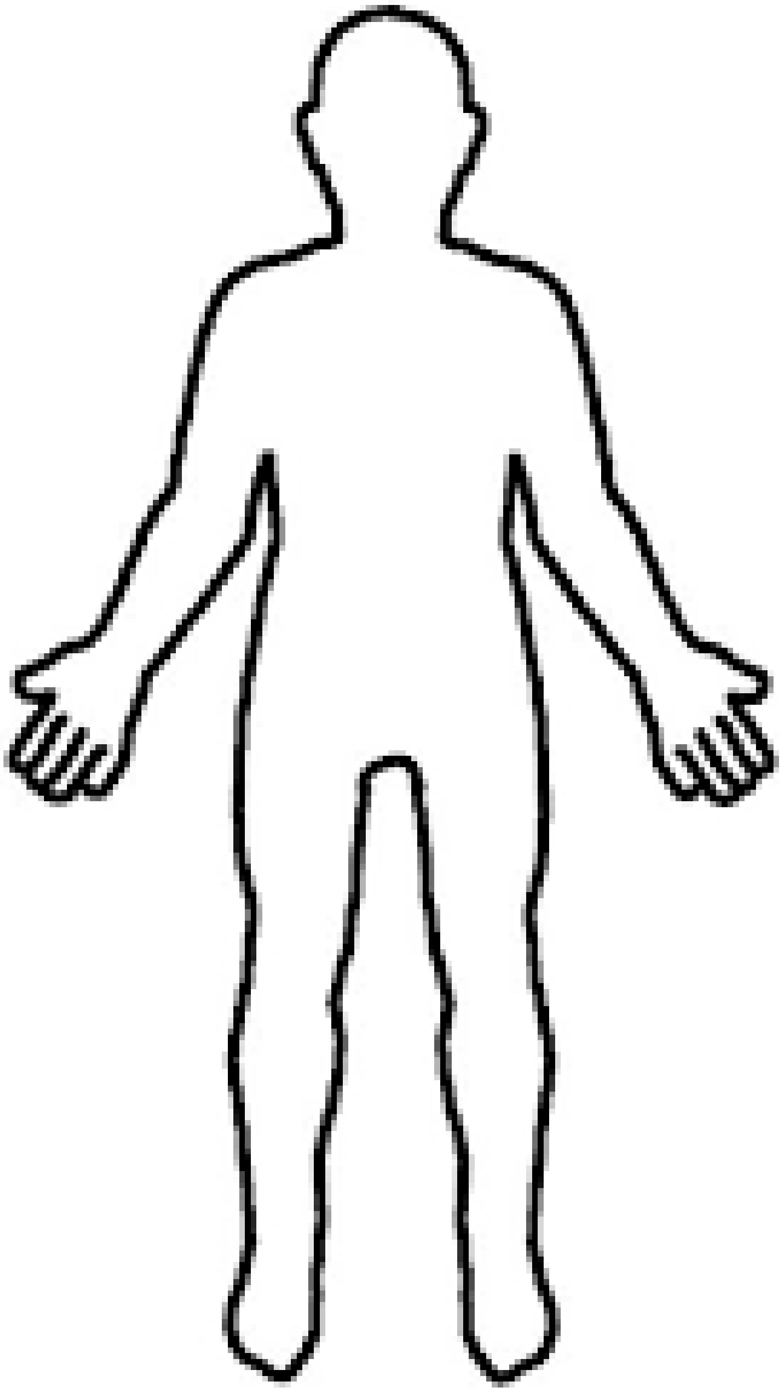
6. Dibuja lo que falta (Recuerda de qué están hechos los músculos).



7. ¿Recuerdas para qué sirven los músculos?

Sección 3: Respiración

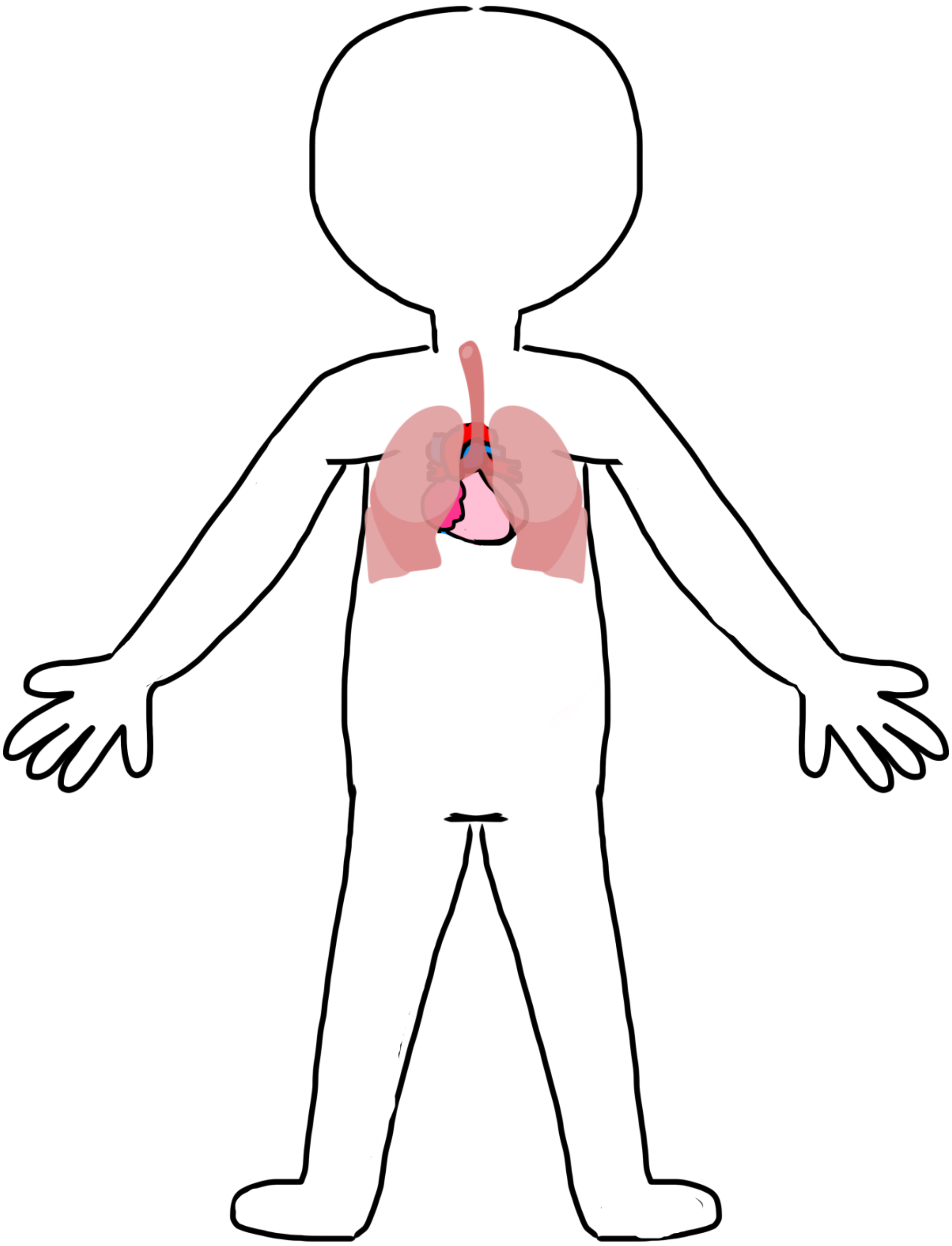
8. Dibuja cómo respiramos. Cómo entra el aire al cuerpo, por qué sitios pasa y



cómo sale.

Sección 4: Circulación

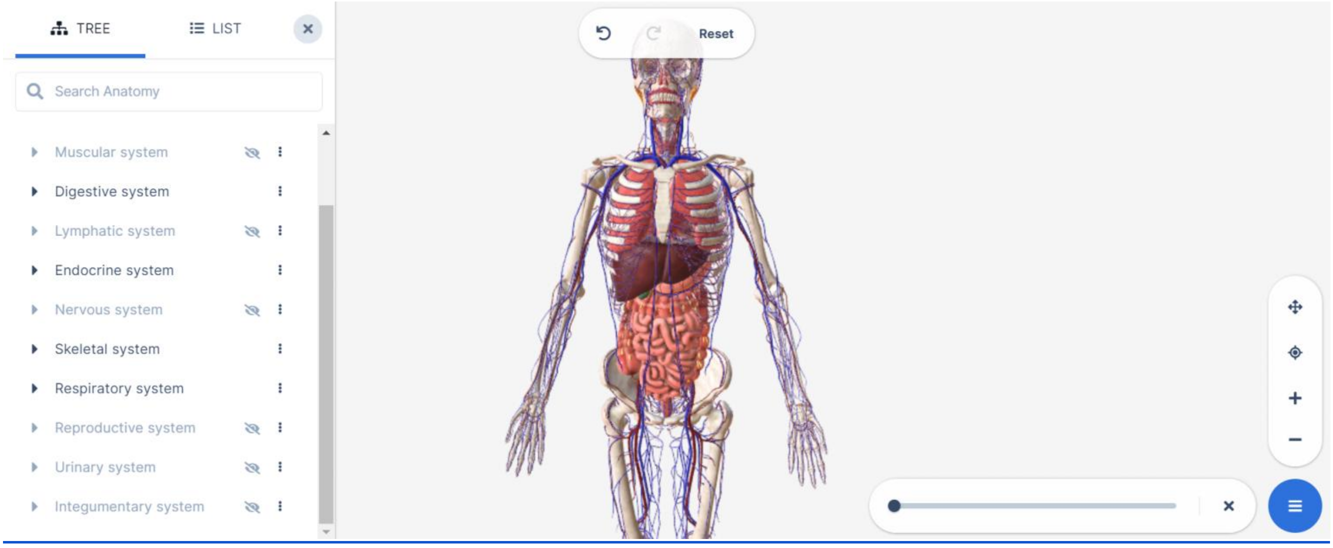
9. Cuando respiramos decimos que el oxígeno se va de paseo por el cuerpo. ¿Quién le lleva de paseo? Dibújalo.



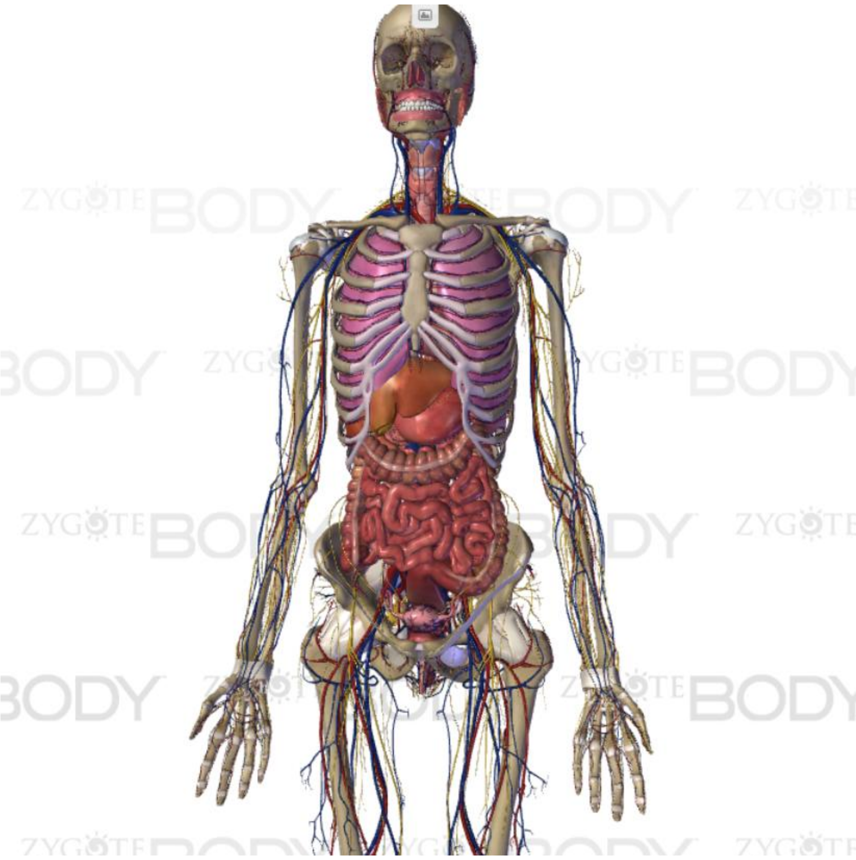
10. ¿Para qué sirve el corazón?
    a) Para transportar la sangre
    b) Para limpiar la sangre
    c) Para empujar a la sangre

11. El corazón…
    a) está siempre lleno de sangre
    b) en cada latido coge toda la sangre del cuerpo y al impulsarla se vacía
    c) está lleno de sangre y cuando la sangre sale, se llena de aire.

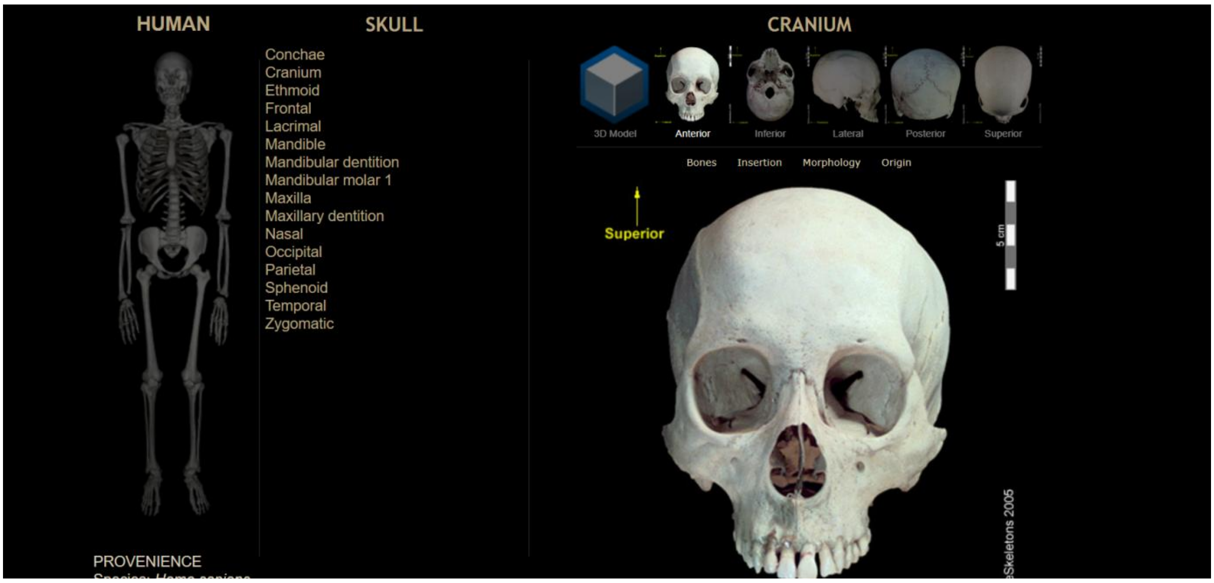
Annex 4: Human Biodigital simulator



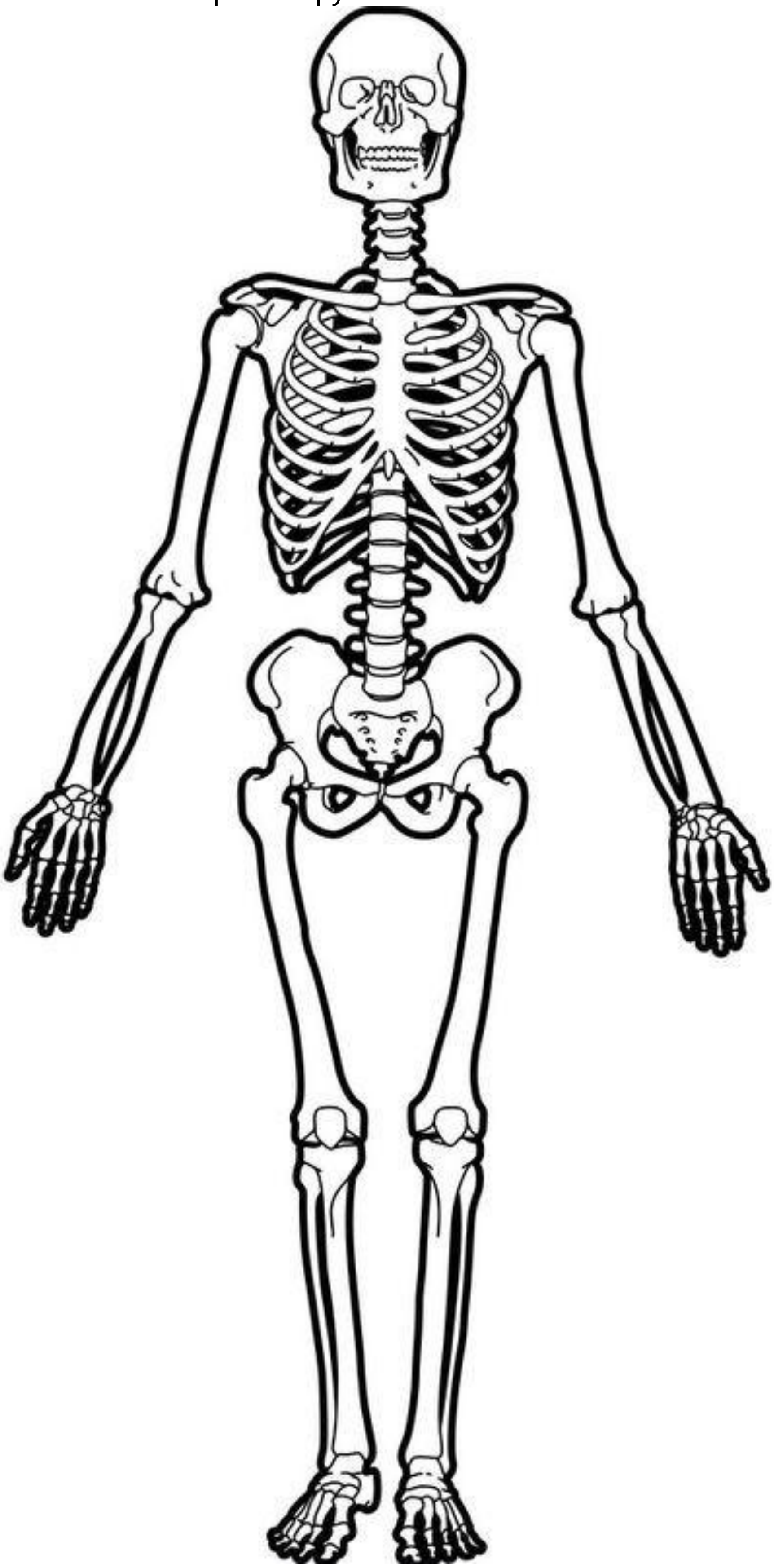
Annex 5: Zygotebody



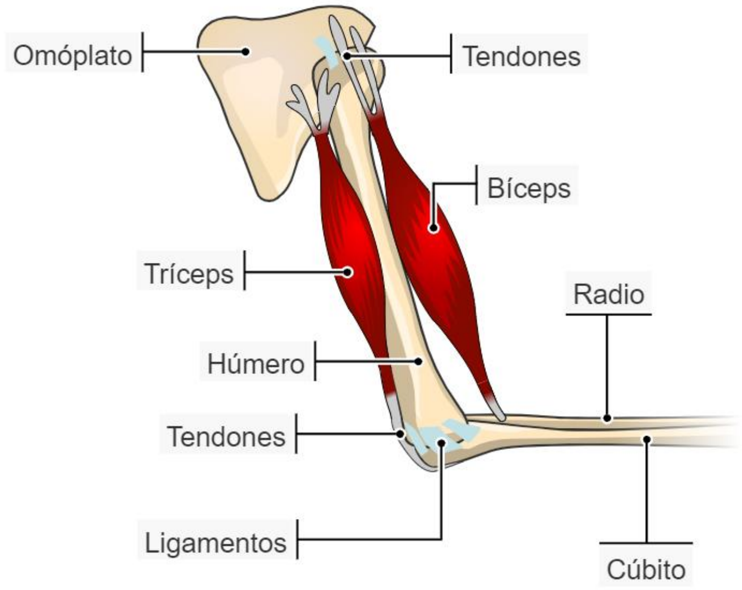
Annex 6: Bones' simulator

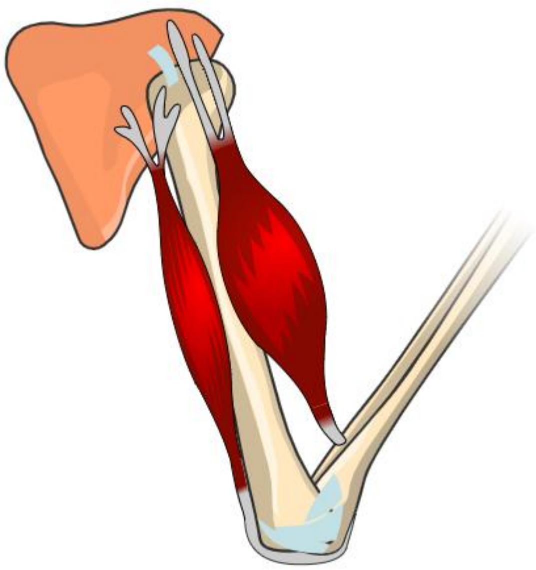


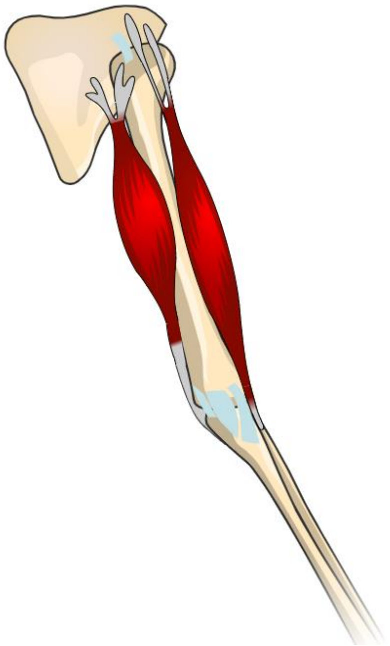
Annex 7: Individual skeleton photocopy



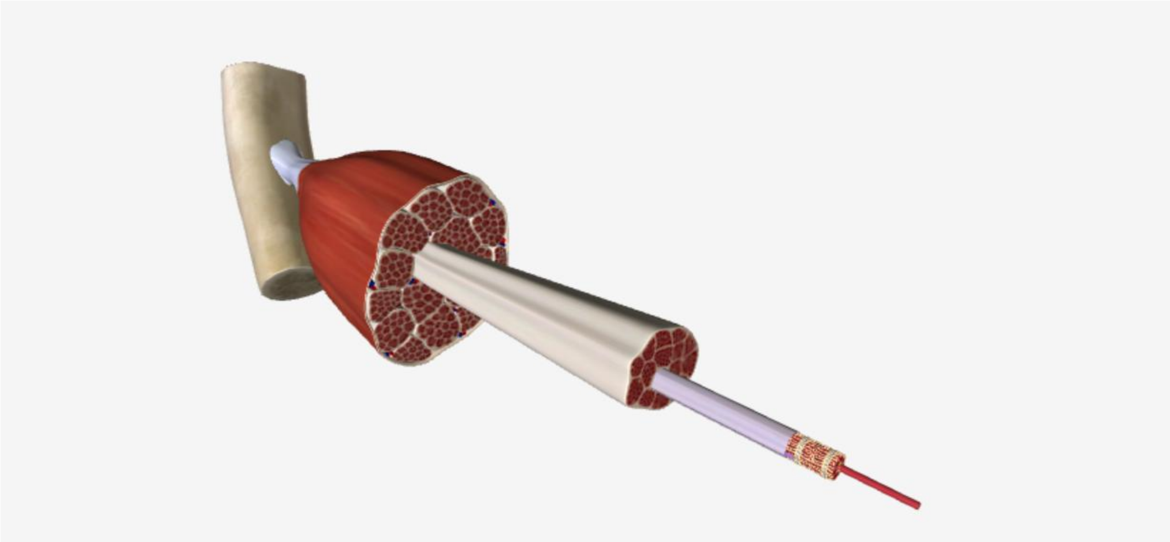
Annex 8: [Biceps and triceps simulator]



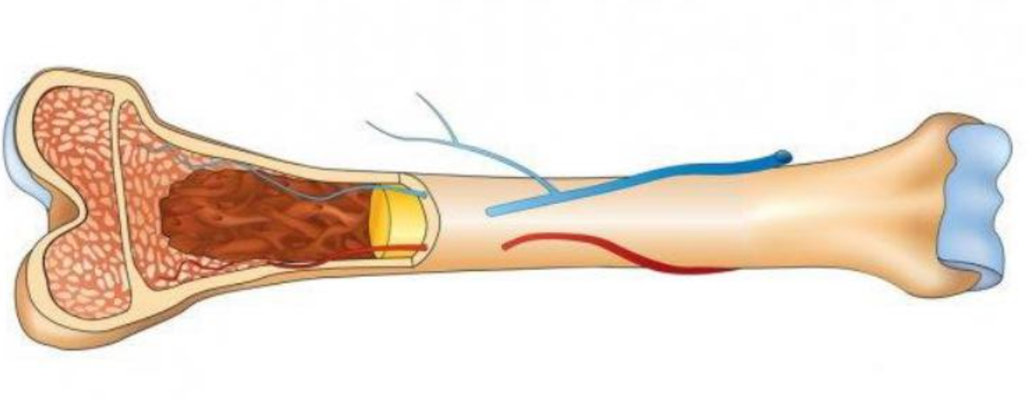




Annex 9: Muscle cross section

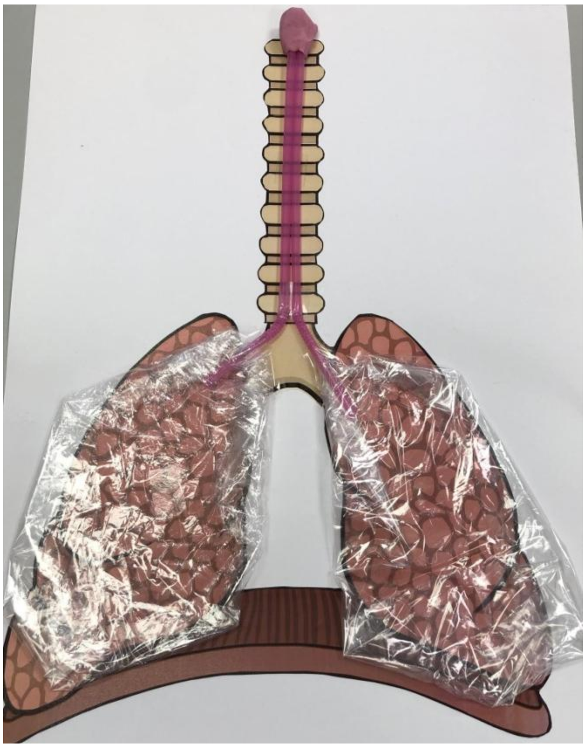


Annex 10: Bone information charts

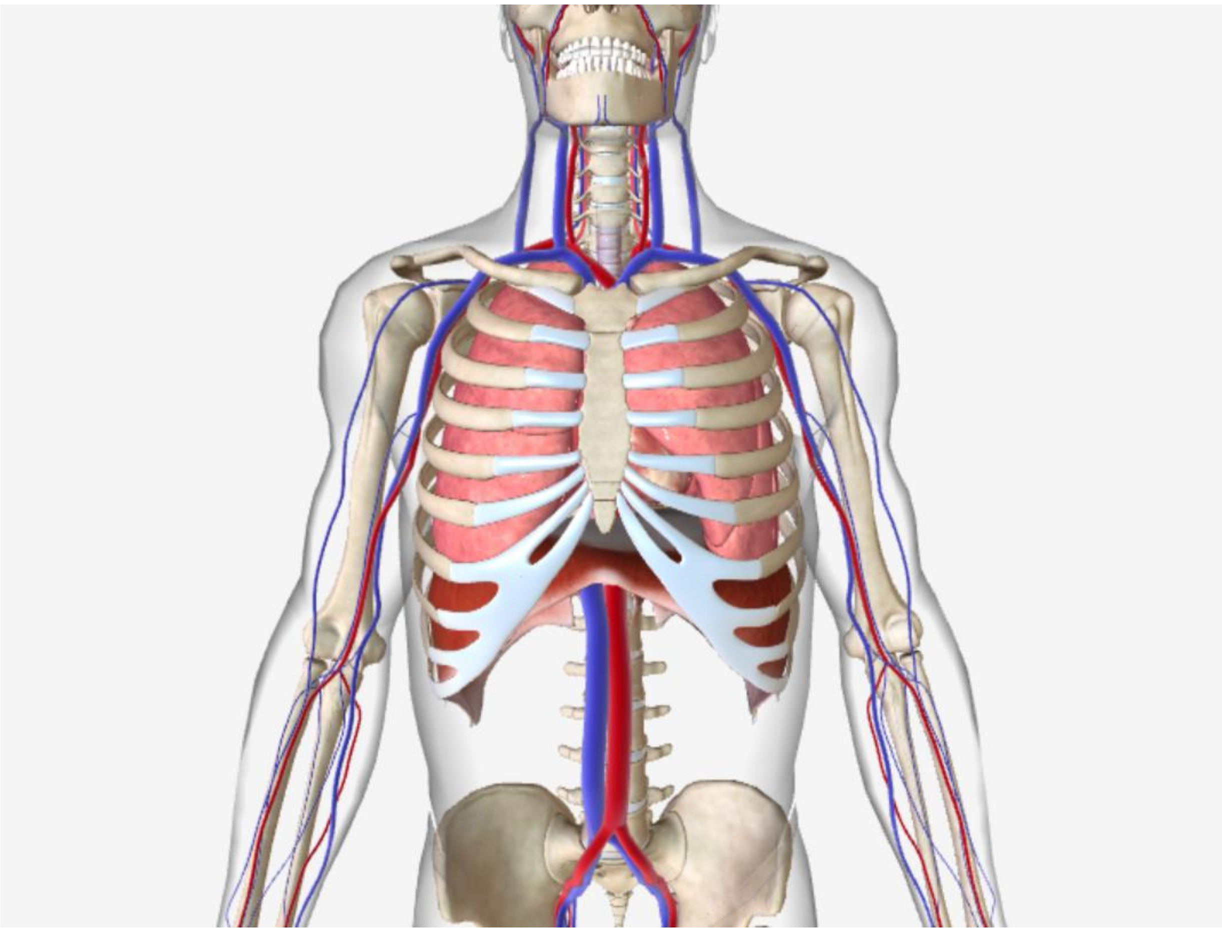


Annex 11: Model lungs 1

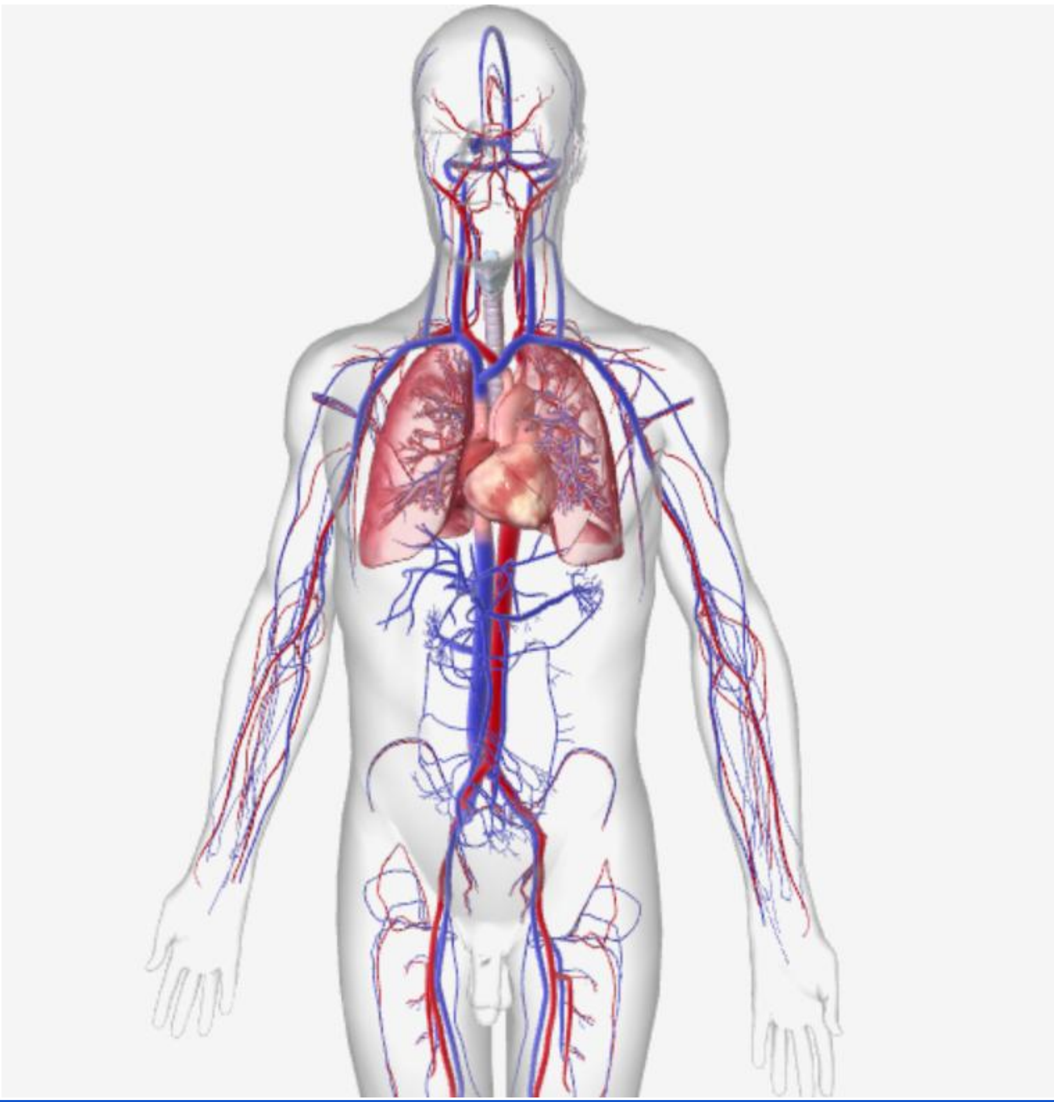
Annex 12: Model lungs 2



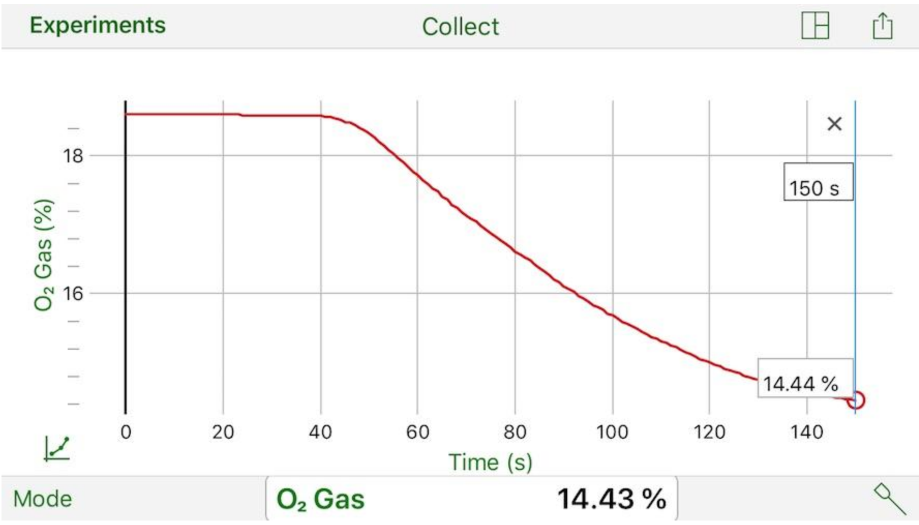
Annex 13: Breathing dynamics simulator



Annex 14: Breathing with beating heart simulator

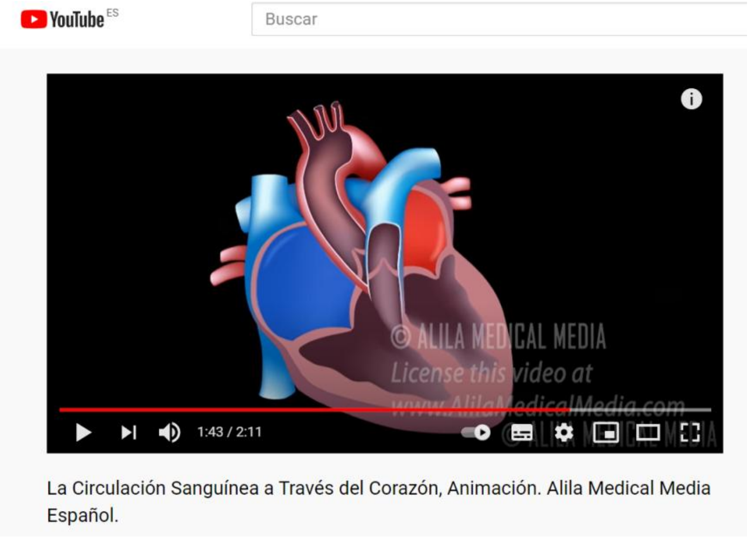


Annex 15: Oxygen and Carbon dioxide sensors' graphics

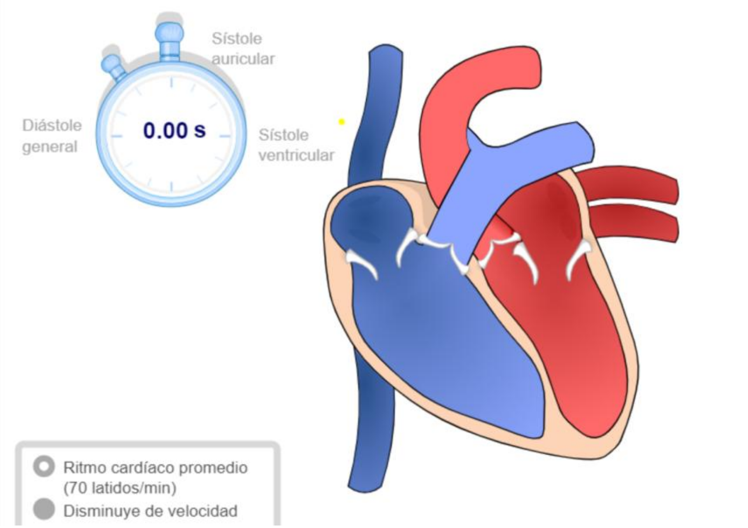


Retrieved from: https://www.nsta.org/blog/fire-air-dephlogisticated-and-vernier-go-direct-wireless-oxygen-sensor

Annex 16: **Heart animation: https://www.youtube.com/watch?v=1GtS7RfoAY0**



Annex 17: Heart cycle simulation



Annex 18: Circulation and gas exchange simulator