Chapter

Virtual Physiology: A Tool for the 21st Century

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Abstract

Veterinary physiology is a basic curricular unit for every course within the veterinary field. It is mandatory to understand how the animal body works, and what to expect of a healthy body, in order to recognize any misfunction, and to be able to treat it. Classic physiology teaching involves wet labs, much equipment, many reagents, some animals, and a lot of time. But times are changing. In the 21st century, it is expected that the teaching and learning process can be more active and attractive, motivating students to learn better. It is necessary to understand what students like, and to introduce novelties into the school routine. The use of a game-based learning, using "new" technologies, creating virtual experiences and labs, reducing the costs of reagents, equipment, and especially reducing the use of animals, will be the future for physiology teaching.

Keywords: learning, physiology, teaching, game based learning, Z generation

1. Introduction

It was in the 15th century that anatomy (still undistinguished from physiology) started to strongly develop. It was part of the core of the European society developments, upon the development of the Late Middle Ages, the Early Renaissance, and the early Modern period, the melting pot for important medical developments, announcing the "European miracle" of the following centuries [1]. But for all practical purposes, physiology was considered to be born in the 17th century, most likely upon the publication of William Harvey's book on the circulation of the blood, in 1628 (**Figure 1A**) [2].

It was on Harvey's work that for the first time traditional (and unquestionable) beliefs about the heart and the circulation (dating back to Galen, 1500 years earlier) have been dethroned. Harvey declined to consider uncritically what he had been taught and insisted on relying on his own scientific observations. This approach is considered to be one of the most revolutionary ideas in science in the 17th century, and Harvey's greatest contribution to science [3].

However, this was not without controversy. Many have initially opposed to the concept of physiology however great names such as Marcello Malpighi (**Figure 1B**)

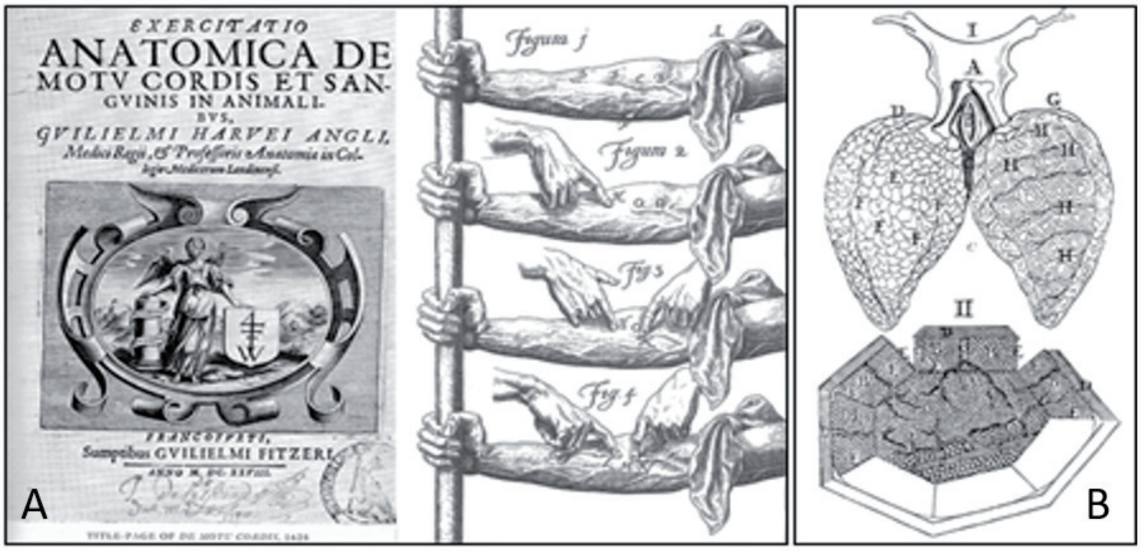

Figure 1.
A: Title page of William Harvey's De Motu Cordis (1698) to the left and demonstration of blood flow in the veins of the forearm to the right. B: Above; Malpighi's drawing of the pulmonary capillaries and alveoli: 2 lungs with the alveoli on the left and the capillaries on the right. Below; pulmonary capillaries in a diagram of an alveolus that has been opened up.

and Antoni van Leeuwenhoek have supported the thoughts on human function, joining efforts in developing modern physiology.

Following the initial scientific developments, a halt followed between 1750 and 1850 throughout Europe with critical thinking of medicine as a science coming to a stop and being replaced by an artistic view of medical science, resourcing to texts in Latin. This came to such an extent that the microscope was not made available to students in Leiden as was auscultation not included in the teaching curricula, albeit having been discovered in 1819 [4].

In the middle of the 1800's German doctors proposed the 'medicine equals science' concept and pointed towards the reintroduction of science in the curricula, motivated by Rudolf Virchow (cellular pathology) and by significant scientific advances at that time such as the periodic table (Dmitri Mendelejev) and upon the publication of the "Origin of Species" (Charles Darwin). Noteworthy, important technological advancements were also made at that time such as the development of steam locomotives and railroads, and the first steel steamship crossing the Atlantic. For the above, ideal conditions for the advancing of physiology has also occurred giving rise to physiologists like Carl F.W. Ludwig in Germany and Claude Bernard in France [5].

Specializations within general physiology also started, namely on gastrointestinal physiology (William Beaumont); pathology (Rudolf Virchow) and bacteriology (Louis Pasteur, Robert Koch), with scientific journals being written as the basis for solidification of these new physiology branches such as the "Archiv für Pathologische Anatomie und Physiologie und für klinische Medicin" (Virchow and Reinhardt; today called Virchows Archiv) and Pflügers Archiv (today called Pflügers Archiv - European Journal of Physiology), laying the basis for modern physiology in the 19th–20th century with names such as Pavlov (psychophysiology), Sherrington (neurophysiology), Mosso (ergograph, sphygmomanometer), Golgi (nervous system, malaria), and Ringer (Ringer's solution). This great evolution was supported (and recognized) with the creation of the Nobel Prize of Physiology or Medicine, first awarded in 1901 [5].

The rapid changes observed in modern societies have caused higher level education providers (i.e. Higher Education) to face a variety of challenges in order to cope with today's demands [6]. This has, in all, lead to the training of more enthusiastic students in an array of interdisciplinary fields [7], generating effective pedagogical methods and strategies to the point that these are now recognized as one of the most important necessities of educational systems [8].

Physiology is today recognized as the bedrock of medical curriculum [9] and, as such, the preference for a particular content delivery method has been vastly investigated by to pass knowledge logically and strategically to students [10]. A greater focus has been given now on critical thinking skills in contrast to emphasis on the systems-based didactic lectures [11]. This has been done also due to the longstanding recognition of the Physiology Science as a challenging discipline for students to grasp, assimilate and employ in clinical sciences. Furthermore, as a core science in the disease process, its understanding is of the utmost importance for an integrated knowledge [12, 13].

As such, physiology educationists are making great efforts towards focusing on ways to obtain vertical and horizontal integration in the discipline of Physiology, exceeding the typical periodical assessment of the medical curriculum by further stimulating and introducing a myriad of new teaching and learning approaches to captivate and augment students' knowledge acquisition [14].

2. The teaching and learning experience in the 21st century

The 21st century is demanding profound changes in veterinary education. Scientific knowledge grew at a dizzying speed, so even for researchers, it is difficult to keep up with the literature. The world is completely different and never the expression "times are changing" heard in the transition from our parents' generation to ours, was applied with as true sense as now. As in all sectors of society, Education systems are also changing. Big transformations occurred following the Bologna treaty that changed the educational paradigm, advocating greater student autonomy and self-learning. These changes must now be optimized considering technological evolution, that have begun to change how students acquire information [15]. It is imperative to occupy the fast fingers of students on smartphones in favor of teaching and science. This is a challenge for today's teachers, according to the idea that "The more complex the world becomes, the more creative we need to be to meet its challenges" [15, 16]. Another issue is the curricula reforms, that resulted in a reduction of teaching hours. In some core disciplines such as physiology, this reduction has resulted in serious reviews of the way it is taught [15].

2.1 Who are the 21st century students?

Current higher education students are generally in their late teens and early adulthood (although naturally some are older and a small number may be younger), and belong to the so-called Generation Z, born between 1995 and 2009. Generation Z follows members of Generation Y, more commonly known as Millennials, who were born between 1975 and 1995. Most of them do not remember life without the internet, and have had technology like smartphones, iPads, smartboards and other devices available throughout most of their schooling years [17, 18]. They grew up around gaming and have great affinity with not just technology platforms, but also with game-like settings that provide, among other components such as continuous challenges, captivating storylines, immediate rewards and feedback, and sometimes fun [19].

Students from the so-called Generation Alpha, born between 2010 and 2025, future students in the higher education system, are younger than smartphones, the iPad, 3D television, Instagram, and music streaming apps like Spotify. This will be the first generation to be born entirely within the 21st century and likely to live in the 22nd century in large numbers. They are also the first generation to experience a pandemic situation in their early childhood: the SARS-CoV-19 pandemic (**Figure 2**) [17, 18].

Interestingly, Generation Alpha started at the same year that Apple launched its iPad, Instagram made its debut and the American Dialect Society crowned “app” as its word of the year. Surrounded by technology, this generation does not live without it, as an extension of itself. Digital tools are omnipresent in their lives, being the “most materially endowed and technologically literate generation to ever grace the planet!” [18].

This generation has grown up like no other, surrounded by technology from childhood, making it, certainly, the fittest generation in terms of digital skills. They are immersed in technology, almost as an extension of their way of being. It is widely accepted that technology can bring countless benefits. Let’s think about the SARS-CoV-19 pandemic. Although too early to know exactly the pandemic impact, in early 2020, the coronavirus pandemic forced schools and most employers to operate remotely, and technology was the one who came to the rescue. This crisis has driven unpredictable direct and indirect effects on the entire educational system. Although technology can be extremely useful, when it is overkill, it can create some drawbacks, such as shorter attention spans and delayed social development [17, 18]. The impact of all this crisis is yet to be determined for years and years to come.

At this point we all understand that the entire educational system (including higher education), must undergo a phenomenal adaptation to keep up with this distinct new generation of students [18]. Past/traditional methods of teaching and learning may already make little sense to today’s students who learn and think differently, and to their future workplace, where change is a constant, and where making use of information is now far more valuable than simply knowing things. Schools are probably failing to teach students to respond to rapid changes and how to handle new information because they are clinging to obsolete methods, namely memorize facts for a test when all the information will be fully available at a click [17]. To avoid demotivation, the learning process has been advocating new strategies, including activities student-centred, to achieve the expected learning outcomes and at the same time, to maintain student’s engagement [20, 21]. In order to increase students’ knowledge, understanding, and at same time enhancing their motivation and engagement, teachers must create a joy, an excitement, and a love for learning, while inspiring students. It is imperative for teachers to demonstrate

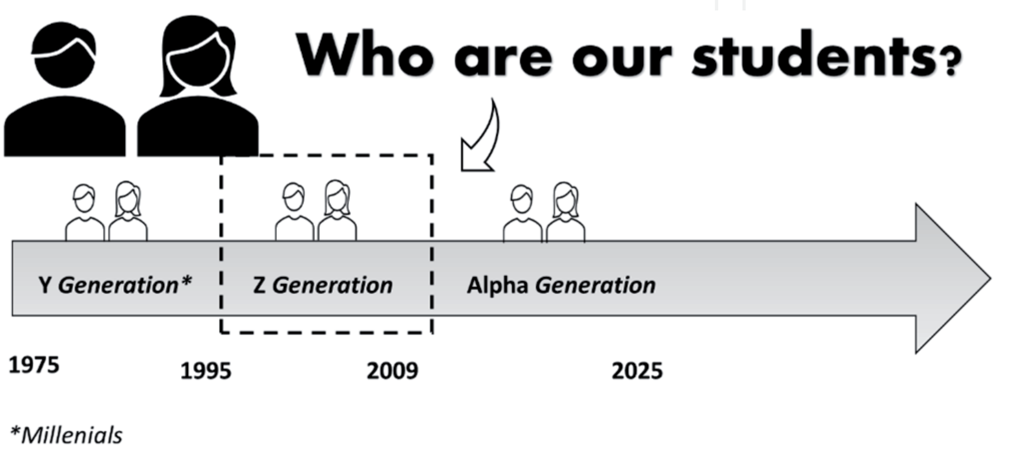

Figure 2.
The 21st century students in higher education system in 2021.

how to learn, rather than dictating what they know [22]. New strategies will lead to success, reducing the frustration of a lonely, passive study, reducing despair, depression and poor quality of life.

2.2 How do they learn?

Designing learning interventions requires careful consideration of how information is perceived and cognitively processed by students. Perceptual preferences refer to the preferred way to receive information and include visual, auditory, and kinesthetic learners [23, 24]. It was observed that 73% of students learn effectively if the teacher combines visual, auditory, and kinesthetic activities, but the remaining students fail to understand the subject matter unless it is presented in their preferred way [25].

Visual students learn by watching, have a keen visual memory and are very imaginative. They are targeted by the presence of models and demonstrations, and extract detail from the background information, remembering faces rather than names. These students usually sit in front of the room and take notes or doodle. They understand better if they can see the facial expression and the body language of the teacher. Visual students normally prefer a quiet environment to study. Computer assisted learning (CAL) is an interesting option for these students, because it allows the schematic representations of information, through charts, graphs, diagrams, and flow charts [23, 24, 26].

Auditory learners prefer verbal instructional methods, such as lecture, discussion, work in groups, debates, games, and answering questions. They find it hard to study from notes and have difficulty with reading and writing tasks. Distinctions that are important to them include pitch, time, volume, rhythm, and resonance. These students often remember names but not faces, do not take notes in class, humor talk to themselves when bored or concentrating, and read aloud. They prefer to study in a noisy environment, as sounds can evoke memory of information [23, 24, 26].

Kinesthetic students also called as tactile learners require whole body movement and real-life experience to absorb and retain information, appreciating to manipulate models and role playing. They learn from external stimuli and movement and are often risk takers and disorganized. These students use highlighters and pictures to study. They learn best when there is music in the background and snacks are available. Kinesthetic learning methods include build, design, visit, interview, and play [23, 24, 26].

Thus, learning interventions need to incorporate the perceptual preferences of the students and help them to develop alternative modes of learning [23] through the incorporation of multisensory and diverse instructional methods (**Figure 3**).

2.3 Learning outcomes for 21st century

The competitive workspace of the 21st century requires students to develop expertise across the four domains of knowledge, that includes the ability to think (cognitive skills), the capacity to valuing (affective skills), a skilled behavior (psychomotor skills), and strive to perform at highest levels (conative skills). However, the acquisition of expertise across all four domains of learning requires appropriate training [23, 27] and assessment [27].

Cognitive skills include six levels of complexity [28], ranging from lower-order skills (remember, understand, and apply) that require less cognitive processing to higher-order skills (analyze, evaluate, and create) that require greater degree of cognitive processing [29]. These cognitive skills can be contextualized into four types

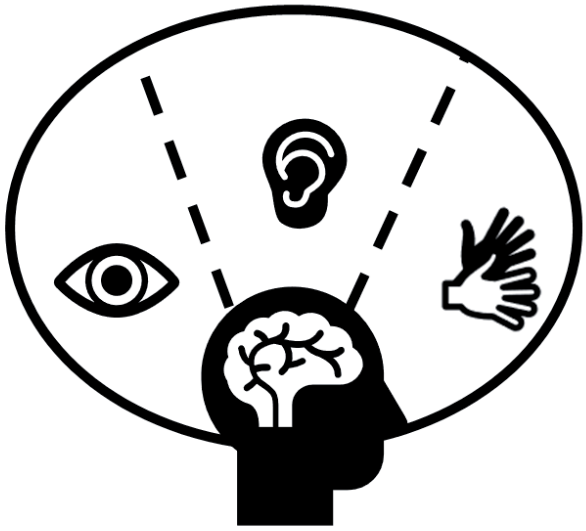

Figure 3.
Learning preferences (visual, auditory, kinesthetic).

of knowledge (factual, conceptual, procedural and metacognitive) that need to be achieved in the learning activities [28]. Factual knowledge refers to the acquisition of basic elements (terminology and discrete facts) that will allow students to solve problems. Conceptual knowledge is related to the generalizable principles (categories, theories, principles, and models) that transcend the specific contexts of a task or procedure and is commonly described as "knowing why". Procedural knowledge refers to the technique, process, or methodology that allow executing a task or procedure proficiently and is described as "knowing how". Finally, metacognition includes self-assessment ability and knowledge of various learning skills and techniques [23, 29, 30].

Most instruction in higher education is focused on the cognitive learning skills [29, 31], however, the development of the affective and psychomotor domains are crucial to the success of health professionals [29]. The affective domain refers to emotions and feelings, especially in relationship to a set of values, and is related to the way in which we deal with things emotionally. This domain includes five categories listed from the simplest behaviors (receiving, responding and valuing a particular phenomenon) to the most complex ones, related to organizing and characterizing values [23, 27]. The development of affective skills is fundamental in the veterinary field. Veterinary health professionals face difficult situations on a daily basis. It is necessary to be empathic with clients, to deliver bad news, to deal with animal cruelty, and to see clients struggling to balance financial needs with the needs of their pets. It is imperative for these students, future professionals, to develop affective skills, to create a culture of wellbeing that will allow to deal with all difficult and stressful situations.

The psychomotor domain is related to the mastery of physical skills, including reflective movements, fundamental movement, perceptual skills, physical abilities, skilled movement, and non-discursive communication [23]. Psychomotor skills are important in the veterinary field, since professionals perform delicate/sensitive physical tasks, handle sensitive medical equipment and frightened animals. The exhibition of an appropriate body language is also highly desired to efficiently communicate with colleagues/peers and clients.

The conative domain refers to the will, desire, drive, level of effort, mental energy, intention, striving, and self-determination to perform at the highest standards possible [27, 32]. It is important that students understand the importance of physiology for their professional career and have the internal desire to understand it, rather than memorizing concepts for assessment, which are soon forgotten and do not lead to effective learning (**Figure 4**) [23].

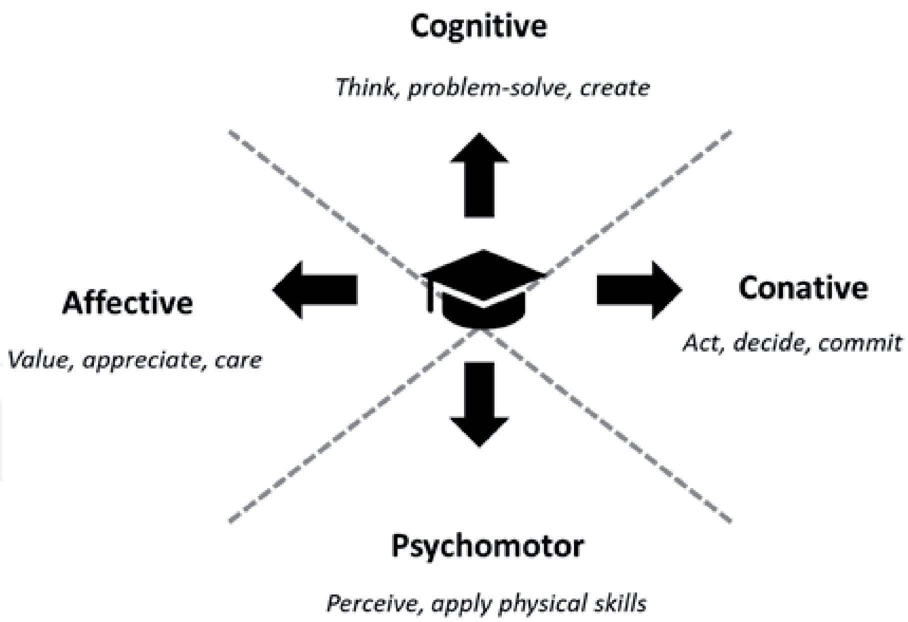

Figure 4.
Comprehensive learning outcomes for the 21st century college graduates.

Learning outcomes that cut across the four domains of the knowledge include the capacity to access and use information, communicate using multiple media, demonstrate understanding, apply rules and procedures, be creative and curious, think critically, make sound judgments, solve problems, be committed to life-long learning, proactively seek to extend knowledge and exhibit an ethical behavior [27]. However, these meta-outcomes must be assessed to guarantee that they are learned, since students choose to focus their study efforts on subjects, they know that will be tested [27, 33].

3. Teaching-learning approaches

It is not new and has been assumed since the Bologna treaty that the teaching and learning processes should be student centered, and a shift from an "instruction paradigm" towards a "learning paradigm" should be followed. Therefore, students must build their own understanding of concepts, relationships and procedures, and teachers can encourage this process by carefully considering the type and organization of information, as well as instructional strategies. Specifically, teachers should reduce the total amount of factual information students are expected to memorize, reduce passive lecture format, and devote much more effort to helping students to become active, independent learners and problem solvers. Collaborative learning activities, interactive models, educational games, and establishing a culture of inquiry/scholarship are critical for achieving these goals [22]. In this context, the teacher assumes the role of facilitator of learning experiences, designing structured classroom environments to maximize student learning, and promote at the same time "classrooms equity" [34, 35].

3.1 Active learning methodologies

Active learning strategies meet perceptual preferences of all types of learners. [22, 36, 37]. The implementation of evidence-based active learning interventions, physiology-specific, particularly in large-enrolment class environments can be a challenge [35, 38]. However, active learning strategies range in scale from simple, "low risk" to more complex, "higher risk" activities.

3.1.1 From "simple" to more "complex" active learning activities

Simple activities require little planning from the instructor and little involvement from the students (did not require verbal feedback to the teacher) and are easy to implement. They include pause procedure, minute papers, think pair-share activities, and classroom assessment techniques. More complex activities require more interaction and commitment of the students and more planning by the teacher. Students can work in informal, cooperative learning groups to solve problems, answer inquiry-type questions, analyze case studies and discuss articles among themselves and with the class. These active learning activities can be interspersed between lecture periods (basic active-learning lecture) [39] or replace completely lecturing. In this case, content can be transmitted before class, asking students to watch videos, or read certain material and then lecturing time can be exclusively used for active learning [35].

3.1.2 Game-based learning

The use of games for teaching and learning purposes is not new. Games although fun and entertainment provides engaging experiences, interactive learning environments and collaborative learning activities [40].

Game-based learning (GBL) is an active learning approach that uses different types of game with defined learning outcomes [41, 42, 43]. It includes the so-called serious games, when its main goal is teaching and learning, besides entertainment [36, 44]. GBL is useful whether we are addressing basic disciplines or more specific ones. Physiology is considered difficult by many students from different courses in the area of veterinary health, namely veterinary medicine and nursing. They attribute the difficulty to the need to memorize content, an excessive quantity of information, difficulty in understanding the relations between the morphology and function of organs and systems, and the perception of some topics as being too abstract [45]. GBL creates a beneficial learning environment, requiring the interaction of the students in questions and answers that assist in retaining information and improving performance. In addition to the positive impacts on student learning, the use of educational games can increase involvement with activities related to the content of the course, as well as promote greater perception of improved learning by the students [45, 46]. On the other hand, games bring an element of pleasure and can reduce anxiety; students are promoted as participants and share their knowledge and engage in teaching each other; and students can combine theory and practice [47, 48].

3.1.2.1 Digital games/ board games

Games used can be digital games, but it also can be other types of games, like board games.

Digital games, also called computer games, are games that use the advance of digital technology and offers new and engaging teaching method that allow students a most effective learning, once it is active, experiential, situated, problem-based oriented and provides immediate feedback [36]. Based in the use of computers and internet, this learning and teaching strategy has been increased, conducting to the production of several games with educational purposes in the veterinary field [49, 50].

Board games are games with rules, a playing surface, and tokens that enable interaction between or among players and facilitate face-to-face interactions with peers and teachers [51, 52].

When comparing board games with computer games, the first are more effective in terms of acquiring knowledge, but computer games yield better results when it comes to motivation, self-efficacy, or skill enhancement [42, 52]. When we combine motivation and engagement in the learning and teaching process, learning outcomes will be successfully achieved.

3.1.3 Gamification

The meaning of gamification varies widely and is often confused with GBL. Gamification is an umbrella term, that involves the application of game elements such as points, levels, time constraints and awards, and use them as non-game settings to other areas of interest [42, 53, 54]. Gamification has been characterized as well adapted to the learning style of Z generation [21, 42, 53, 54, 55]. Applied to an educational context, a gamified learning experience can positively influence student engagement by using gamification principles to affect the cognitive, emotional, and social aspects of the learning experience [54]. The cognitive aspect is stimulated through goal-oriented and learning objectives-based activities that challenge students within the gamified environment. The emotional aspect plays an important part in a gamified learning platform: curiosity, frustration, joy, pride and optimism are present during the experience [42]. Most importantly, the gamified learning experiences give feedback and allow repetition, encouraging resilience and reframing of failure, reinforcing the idea that repeated failures will eventually lead students to level completion and achieving learning goals [56]. The social aspect involves the participation of students within an environment where they interact with their peers and are part of a group. In this learning environment, students can have new identities and roles (using avatars and role play), and through branching mechanisms, they are asked to make choices and decisions. Also, gamification allows students to publicly identify themselves as "masters," once they reach a higher level of mastery, and gain social credibility - for example, via a leaderboard [57] - as well as academic recognition by accumulating points [58].

3.1.4 Simulations/virtual laboratories

A virtual laboratory is any online environment that is based on interactive learning either individually or in groups, allowing students to explore topics in an asynchronous manner that has no immediate physical reality [59].

In the last decade, there has been a gradual shift of conventional physical, in-person laboratories towards virtual alternatives, motivated by several reasons. Physical laboratories are expensive. They need advanced instruments and equipment, space, professional personnel, and maintenance. Moreover, the student population is increasing, conducting to higher experimental costs. Virtual laboratories and tools provide significant long-term cost savings. Whilst the initial development or purchase costs may be large, once developed, the majority do not require the ongoing purchase of consumables, the provision of physical space, laboratory equipment or support staff time [60].

Animal-based laboratories, very useful in the past for physiology teaching and learning, can be associated with ethical concerns, while virtual animal model simulations reduce the ethical dilemmas and broadens the types of experiments that can be conducted. Moreover, virtual laboratories exhibit higher levels of efficiency and safety, enabling students to learn in their own time and pace [61, 62, 63]. This is also another great advantage when we think of all the students undertaking part-time employment to support their studies. For them, the possibility to study at their own time and pace, at home or elsewhere, and to access virtual laboratories and experiments that always work, and with consistent data, is unvaluable. With these simulations, experiments are far shorter; students can undertake more experiments in the time available increasing their learning. Several studies have already proven that virtual laboratory tools were equally effective as traditional laboratories in increasing student knowledge and understanding, when evaluated by student performance in examinations [62, 64–66].

Nevertheless, virtual laboratories have intrinsic constraints and limitations. They do not provide students with the opportunity to develop key practical or technical skills (hands-on experience), or how to use specific items of equipment or to promote awareness of ethical, health and safety issues. They will always give the characteristic and correct data, like a perfect scenario, and we all know that in real life it's not always like that [60, 63].

Although virtual laboratories have become increasingly common as a form of teaching aid in different learning situations, creating a virtual laboratory for teaching and learning is, however, overly complex, incorporating skills in diverse areas such as interaction design, visualization, and pedagogy. It involves design and production of texts, images, 3D environments and interactivity, and the production requires programming and animation [63, 67]. There are some virtual labs already deposited in open educational resource (OER) repositories (https://libguides.mines.edu/oer/simulationslabs) that can be easily used and are invaluable strategies for this demanding learning/teaching process [63]. When asked whether virtual or traditional laboratories should be discontinued, students saw a place for both within the curriculum, recommending that they should be used in parallel [68].

3.2 How we teach?

In this enthusiastic process of teaching and learning physiology, our option is for a blended/mixed approach, meaning a process that brings together what we consider the best from different approaches: experiments hands-on, virtual experiments, digital games/simulations, board games, crosswords and word search games.

This way we intend to avoid boredom, to promote curiosity, motivation, and engagement, and to create learning opportunities for all students (visual, auditory and kinesthetic students) to go beyond rote memorization of terms and processes, and towards developing mental models of physiological phenomena.

Reflecting the importance of technology in the Z Generation, all students own at least one Internet-ready device (e.g., iPad, laptop, tablet, smartphone), enabling the use of online resources in this approach.

3.2.1 Crosswords

Crosswords are an easy and fun way to engage students. Crossword puzzles have the purpose of encourage students to form words or phrases which lead to the answers. It can be used as a means of enhancing general and scientific information, assuming a facilitative role for problem-solving skills.

This is an in-house crossword (**Figure 5**). Starting from physiologic concepts or definitions, and using online free tools (https://worksheets.theteacherscorner.net/make-your-own/crossword/), the puzzle shown in the image is created.

3.2.2 In-house created learning board games

In a combined work of teachers and students, through a Pedagogical project financed by Polytechnique Institute of Viseu (IPV), The MacVet Project (Create, Simulate and Learn), three in-house learning games were created from classic games: Vetpoly, Physiohedbanz and Pictionaryvet (**Figure 6**).

The traditional Monopoly board game has been converted to VetPoly. The original game has been adapted by creating a new board, community box cards and lucky cards, so that the game would reflect the veterinary field environment.

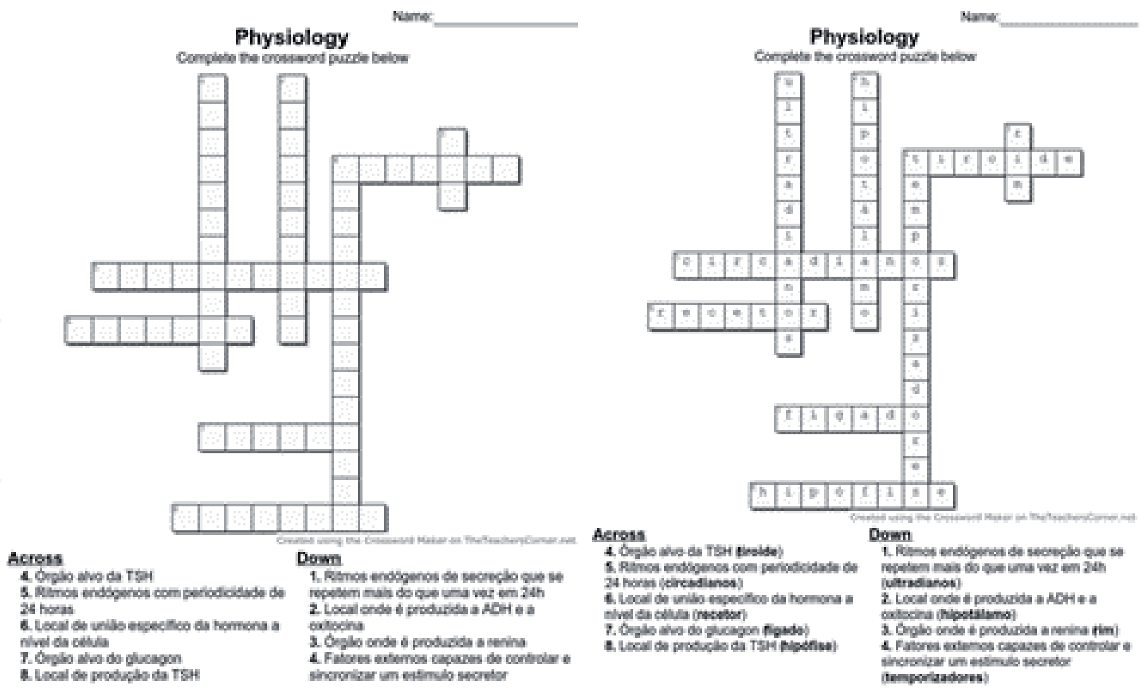

Figure 5.
Physio crosswords. (in English, for example n° 1: Across1: TSH target organ. Answer: Thyroid).

Figure 6.
Vetpoly board and game; Physiohedbanz game and rules' card; Pictionaryvet rules' card.

The community box cards have been turned into Quizz timecards. Whenever the player lands on a Quizz time house they will have to answer a physiology question. If the player gets it right, he will receive a monetary reward; if he makes a mistake, he will be penalized and will have to return the amount indicated on the card to the bank. This game adapts to various curriculum units, just by replacing the Quizz time cards.

The Hedbanz was converted to Physiohedbanz. Using cards with figures/concepts related to physiology, that students must identify without seeing it. The game is based in old game of "What am I?" Player has to ask "yes" or "no" questions before time runs out (e.g., ADH. The student with the ADH card, must ask if it is a hormone, if it acts in the renal tubules, if it inhibits diuresis). In the end wins the player with more scoring badges.

The Pictionaryvet, similar to the classic Pictionary game, requires some drawing skills. Students are invited to draw the concepts/terms/processes, all related to physiology. Like Physioheadbanz, there are time restrictions for each team.

3.2.3 Virtual rats

Animals' experiments, classically used in the learning process of physiology, have been gradually replaced by "virtual animals", with enormous advantages: reduction of the live animals used and replacing them by alternatives. The use of "virtual rats" is one of the best known alternatives. We use, for several years and with remarkable academic success, a "Laboratory exercise using "virtual rats" to teach endocrine physiology" [69] and "Virtual rat: a tool for understanding hormonal regulation of gastrointestinal function" [70]. Although may be considered "old" papers, they remain actual. Through the description of the experiment and by the analysis of the results given, students are invited to actively enhance their understanding of physiology and foster logical thinking and problem-solving skills.

3.2.4 Kahoot and online quizzes

Z generation and technology are always holding hands. Most students (in many cases all students) not only own smartphones and other gadgets but are also attached to them (both physically and emotionally), and in some cases are inseparable. Smartphones provide convenience, portability, comprehensive learning experiences, multi sources and multitasks, and are environmentally friendly. Students use their smartphones for a great variety of tasks: to be connected to their friends, to be on top of every event, and to access teaching materials or supporting information, normally accessible through the Internet. They also use smartphones to interact with teachers and group colleagues outside classes.

Students using interactive quizzing in an online setting reported increased engagement whilst learning due to the fun, joyful and attractive environment, and because of the interaction that occurs. It has also other advantage: the fact that it promotes a healthy competition, conducting to better learning outcomes. A great advantage of Kahoot! is that it is equally effective across both face-to-face and online teaching sessions (**Figure 7**).

Other online quizzes available on the internet, like Socrative, are also utilized in the process of teaching and learning physiology.

3.2.5 Virtual laboratories

As mentioned, simulations can be a practical and effective alternative to traditional laboratory experiences, sparing the need to use subjects (e.g., animals) and/or expensive equipment. There are some online resources available, but our main experience is with Labster [71] (https://www.labster.com/), a platform of laboratory virtual simulations, aiming to increase the learning outcomes. Upon launch a simulation, students are invited to go through a tutorial to know how to navigate in

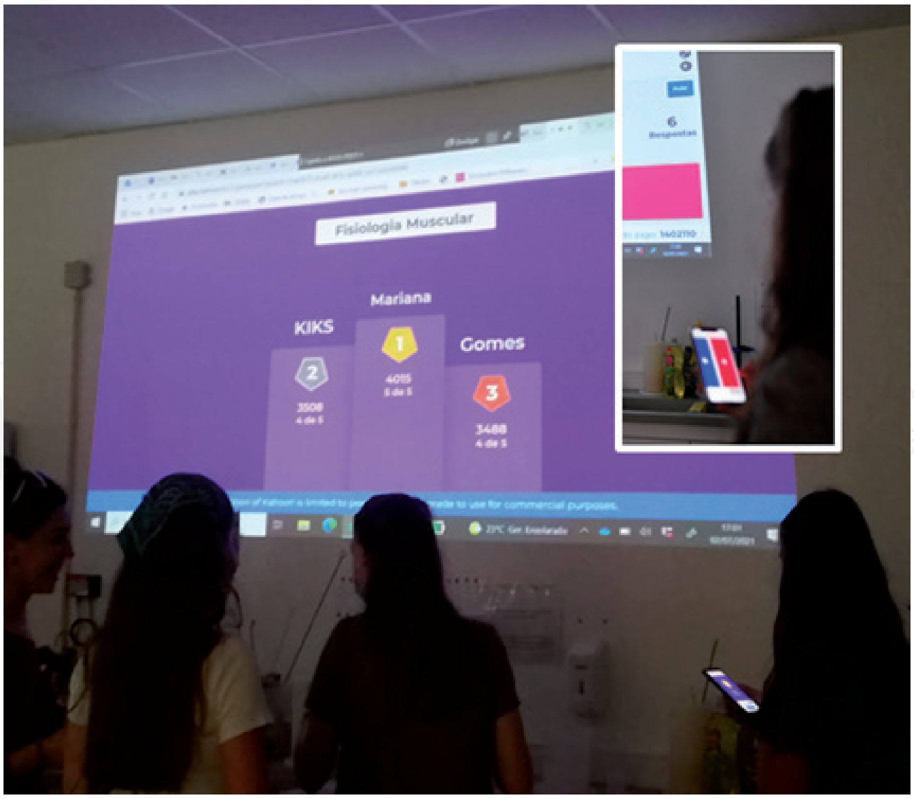

Figure 7.
Muscular physiology Kahoot! Performed in a face-to-face teaching lesson.

Figure 8.
Labster simulation: Hematology. Introduction to blood.

the simulation (arrows that will indicate where to look, or where to go, holograms that show were to go or where to place objects, like pipettes, glass slides, beakers…). There is a lab pad, available during all the simulations that help the student with four sections: the Home page provides instructions and quiz questions, the Theory page gives access to all the information needed in order to answer the quiz questions, the Media page stores all the images seen during the simulation, and finally the Mission page provides an overview of all the simulation steps (**Figure 8**).

4. Conclusions

The benefits of using active learning strategies, and in understanding the student that is in front of us, are tremendous, since the potential of every student can be elevated, resulting in better learning outcomes and student satisfaction and enjoyment.

Remaining in a traditional and lecture-based method of curriculum delivery has been attributed to be one of the causes for school dropout and failure. Z generation is technology oriented and its inclination to turn to the digital world must be faced as a teaching ally. We also showed that besides technology, there are also other strategies, more economic ones, that can be applied. What matters is to stimulate learners. We all know that physiology is a complex science. Our job, as teachers, is to provide the correct tools for the students to learn by developing their cognitive skills, their reasoning ability and their critical thinking, and to develop affective, psychomotor and conative skills. From here, the need for constant learning and the fascination for science will be a natural consequence. We cannot forget that in the 21st century, information is just a click away. What each one does with this information is what it counts.

Acknowledgements

This work was supported by the Polythecnic Institute of Viseu (IPV), through MAcVET – Apoios Especiais PV, and VLAB – Apoios Especiais PV, and by Portuguese Foundation for Science and Technology (FCT), through funds to Global Health and Tropical Medicine (GHTM) UID/04413/2020 and to Centre for the Research and Technology of Agro-Environmental and Biological Sciences UIDB/04033/2020.

Conflict of interest

The authors declare no conflict of interest.

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