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Programs and Curricula development - comparing realities

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SPFis -Sociedade Portuguesa de Fisiologia

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Introduction

Physiology education has seen significant evolution in recent years, with diverse programs and curricula tailored to meet the demands of modern healthcare. However when we compare the Portuguese Physiology with other known references in Physiology education and research, as it happens in the United Kingdom (UK) or in North-America (United States USA and Canada CAN) the first difference noted is that in those counties Physiology is regarded as a profession while in Portugal Physiology is a basic component of all health related profession courses. Recently a new profession within the public hospital careers emerged involving physiology – the Clinical Physiology. This work is meant to compare these differences with our reality. A better understanding of different systems their foundation and purposes is important to shape our options for the future.

Physiology in USA and North America

No matter an educational structure close to the European model, from basic to high school, the higher education component is quite differently organized, offering multiple accesses to professions, to meet a wide variety of public with different objectives.

Regarding Physiology, physiologists are highly regarded as trained biomedical experts with a bachelor (major) degree or a MSc or PhD degree. Their professional expertise lies mostly in studying how humans, plants, animals and cells function, providing a wide range of sub-specialities and opportunities in different fields such as Clinical, Cell Biology, Exercise, Industry, Animal and Plant Physiology.

Those seeking to enter the field of physiology typically begin building a foundation with a Bachelor’s degree in physiology, biology, physics, math, or engineering. This is often followed by a master’s degree (M.S.) in physiology to gain specialized training and increase their physiological research skills. Students in graduate school often participate in internships and gain lab experience to build experience in the field. Doctoral programs provide opportunities to specialize and individualize career interests in physiology, helping students to fulfill full-time faculty positions and publish scientific research in academic journals in the field of physiology.

Physiology in UK countries and within the European Higher Education Area

UK countries represent an important part of the European Higher Education Area (EHEA). Regarding Physiology teaching and research, UK clusters depicts a similar context to the previously described for North America where Physiology is also regarded as a professional area. Here the dominant track involves specialized Masters of Science (MSc). Other advanced Masters more directed to research, such as Master of Philosophy (MPhil) or Master by Research (MScR) might also be found, not only in UK countries but also in other countries within the EHEA. More recently, a few Masters in Integrative Physiology and Biology (Aix-Marseille, France) and in Physiology (Valencia, Spain) started to show outside the UK countries. However, in the wider EHEA space, these offers are still limited, and are mostly focused on a research/dissertation project.

The Portuguese reality has been shaped by the Bologna Process, the origin of the EHEA thought to develop a more globally competitive and attractive academic system within Europe [1]. In consequence and in parallel with the UK clusters, Physiology developed as part of all health related profession programs within the EHEA as a mandatory component of health profession related programs, in a wide variety of modalities since there is no single model of degree programs (Figure 1).

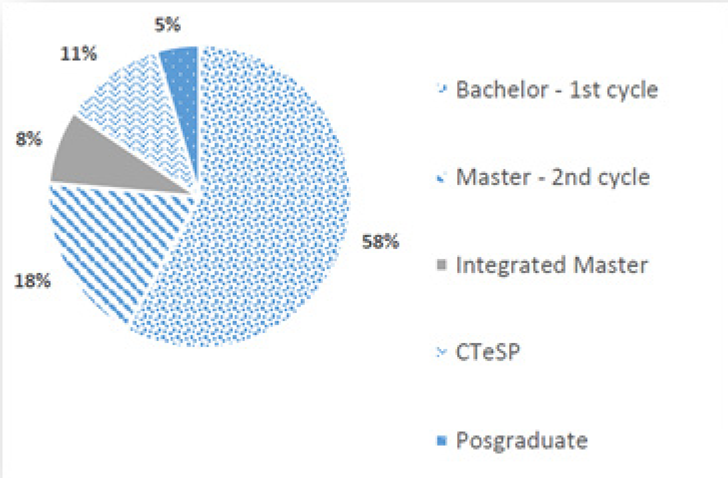

Figure 1. Proportion of type of health-profession related degree (all levels) where Physiology programs are present (CTeSP- professional higher technical course, offered exclusively in Technical Colleges) [2].

Recently, less than 10 years ago, a new opportunity career emerged in Portugal, with the offer of a Bachelor and more recently a Master program in Clinical Physiology. This profession profile is framed by the European Qualifications Framework (EQF) comprising professional contents of other former health professions. These aim to act in accordance with the clinical indication, pre-diagnosis, diagnosis and investigation or identification process, being responsible for designing, planning, organizing, applying and evaluating the work process within the scope of their profession, with the objective of promoting health, prevention, diagnosis, treatment, rehabilitation and reintegration.

Other initiatives are rare and, as far as our knowledge goes, we could only identify one advanced course in Physiology and Physical Exercise regularly offered in the last five years [3].

Conclusion

Globally speaking, Physiology is a well-recognized core foundation in health sciences education. Nevertheless huge differences exist between Physiology programs objectives, organizing structure, and physiologist's societal recognition and opportunities between reference countries (North America and UK) and the EHEA countries where Physiology is transversely present in all health-profession programs as curricular units. Here, with the exception of the UK countries, a related professional offer is exceptional, as the one represented by the Clinical Physiology, while a few advanced programs (e.g. Masters, Post-graduations) are consistently emerging. This clearly suggests some progress in preparing the future for a more modern and structured European Physiology, essential to built up a new professional identity.

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SPFisiologia
portuguese physiological society

Teaching and research in Physiology In HEIs in Portugal – a current vision

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Introduction

Having in mind the recognised concerns about the future of Physiology, in particular from Physiology related scientific societies, this study was designed to characterise the present reality of Physiology teaching and research in Portugal, a full member of European Union and part of the European Higher Education Area (EHEA). This EHEA was created with the so called Bologna Process, back in 1999, aiming to facilitate professions recognition in Europe and free mobility for European professionals, to approximate different education systems and experiences, and to promote innovation and foster competitivity among the EHEA members (1). For health professions, Physiology was appointed as a fundamental discipline and regarded as mandatory in basic training. Therefore, in the last years and as a consequence of the Bologna Process, Physiology, once exclusive to Medical Sciences, is now integrated into diverse curricula, from Sport and Physical Education to Pharmaceutical Sciences and beyond. Nevertheless, this is still very different from other countries such as Great Britain and the United States of America, where Physiology is regarded as a profession by itself. As a participating country in the EHEA, Portugal was on the frontline of the adoption of the Bologna Process. As a consequence of the new curricula there are concerns about the loss of importance of Physiology as a fundamental discipline. Therefore, this study aimed to characterize the status of Physiology teaching and research in Portugal, enabling the comprehension of challenges and directions that may contribute to develop this scientific area in the future.

Methods

This descriptive mixed-methods study started with the collection and analysis of data from the government agency DGES (obtained from September to November 2022), meant to identify all curricula featuring human Physiology-related disciplines per institution (university or technical college), professional areas and syllabus. The collected database also incorporated the amount of training hours per week, type of classes (tutorial, laboratorial, other) and credits (ECTS). Names of the curricular unit (CU) chair/coordinator and other staff, and their respective ORCID were also registered, when available. In a second stage, a complementary search of the Web of Science and PUBMED databases was then performed to obtain all publication authorships for these members in the five prior years (2017-2022). All available abstracts were collected for a separate dataset/collection in Zotero® which allowed to complete the bibliometric analysis and obtain the most prevalent research topics. With VOSviewer v 1.6.19, relevant clusters of keywords and terms were obtained allowing a thematic analysis of the words in each cluster to identify common sub-themes and themes (2).

Results

Our search identified 365 courses/degrees and 764 Physiology curricular units/disciplines (CU/D) most of which offered in bachelor (1st cycle) courses. Professional upgrading courses with or without academic degree, represent 23% (18% second cycle Masters and 5% postgraduate no degree involved) of courses where Physiology is present (Figure 1). These programs were then categorized in nine professional areas. Noteworthy, universities are solely responsible for the Integrated Masters degrees, necessary to access medical (as well as dental and veterinary medicine, six-year duration, 360 ECTS credits) and pharmaceutical professions, with a five-year duration corresponding to 300 ECTS credits

Figure 1. Current study cycle and academic degrees with Physiology CU/D in Portugal (left) and respective distribution per professional area (right). Health Technologies involve the major professions in biomedical areas; Biotech includes Biology, Biochemistry and Bioengineering; CTesP is a professional track to access higher education from high school.

In our sample, the prevalence of Physiology CU/Ds is specially noted in the 1st year of the technical college programs (79.8%) being often associated with Anatomy . At universities, Physiology CU/Ds are fairly balanced in the first two years, likely corresponding to knowledge progression. In the 3rd year, a very similar distribution is noted both in universities and technical colleges, likely due to the frequent associations to pathology. Physiology credits in Medicine (Integrated Master') and Non-conventional therapies (Bachelor / Licensure) standout with similar relevance (22.3 and 23.2 respectively) within the respective syllabus structures, far ahead of other vocational areas. Regarding the number of the practice/experimental hours dedicated to training in all these programs, Integrated Masters are leaders. At technical colleges, first cycles Nursing, Non-conventional Therapies and Health Technologies were fairly balanced but away from integrated masters.

For the second stage a convenience sample of persons teachin Physiology was selected considering (a) the identification of one coordinator or responsible scholar on the available webpage for any given Physiology CU/D and a (b) identifiable ORCID ID as indicated before. We found 196 Physiology CU/Ds with the complete information, that is, 25.6% of the total Physiology CU/Ds identified in the first stage. From these, only109 individuals presented a regular publication track between 2017 and 2022. However, almost 48% published less than 10 papers in that period. The large majority (2/3) belonged to university vocational areas, led by Medicine (~ 50%), while the remaining 1/3 belonged to technical colleges, primarily within Nursing and Health Technologies (Figure 2).

Sixty-five different journal thematic areas were identified among the publications. The search in PUBMED and Web of Science yielded 1530 indexed publications (indexed journal articles, conference proceedings and other communications). Of these 1530 publications, only 36 are indexed in journals with the segment "Physio" in the name. The most relevant thematic area is "Medicine (general or internal)" representing 37.6% of publications within this sample. It should be noted that Physiology-Pharmacology/Toxicology journals areas are frequently related, and were selected by 22 authors (20.2%) (Table 1).

Bibliometric analysis revealed a predominant focus on two key research realms that we termed Medical Physiology and Lifestyle Physiology.

Table 1. Most relevant thematics published within the selected convenience sample.

Journal Thematic area	% of publishing teachers	Top 3 main vocational areas
Physiology	4.60%	Sport Sciences; Pharmaceutical Sciences; Medicine
Pharmacology and Toxicology	15.60%	Pharmaceutical Sciences; Medicine; Biotech
Nursing	14.70%	Nursing; Sport Sciences; Biotech
Neurosciences and Neurology	14.70%	Health technologies; Medicine; Biotech
Microbiology and Immunology	14.70%	Medicine; Pharmaceutical Sciences; Nutrition Sciences
Medicine (general, internal)	37.60%	Medicine; Sport Sciences; Biotech
Genetics, Molecular and Hereditary Biology	22.00%	Medicine; Biotech; Nutrition Sciences
Environmental and Health Sciences	14.70%	Sport Sciences; Health technologies; Pharmaceutical Sciences
Chemistry and Chemical Engineering	14.70%	Sport Sciences; Biotech; Medicine
Biomedical Engineering and Engineering (general)	13.80%	Medicine; Sport Sciences; Biotech
Biochemistry	22.90%	Pharmaceutical Sciences; Medicine; Health technologies

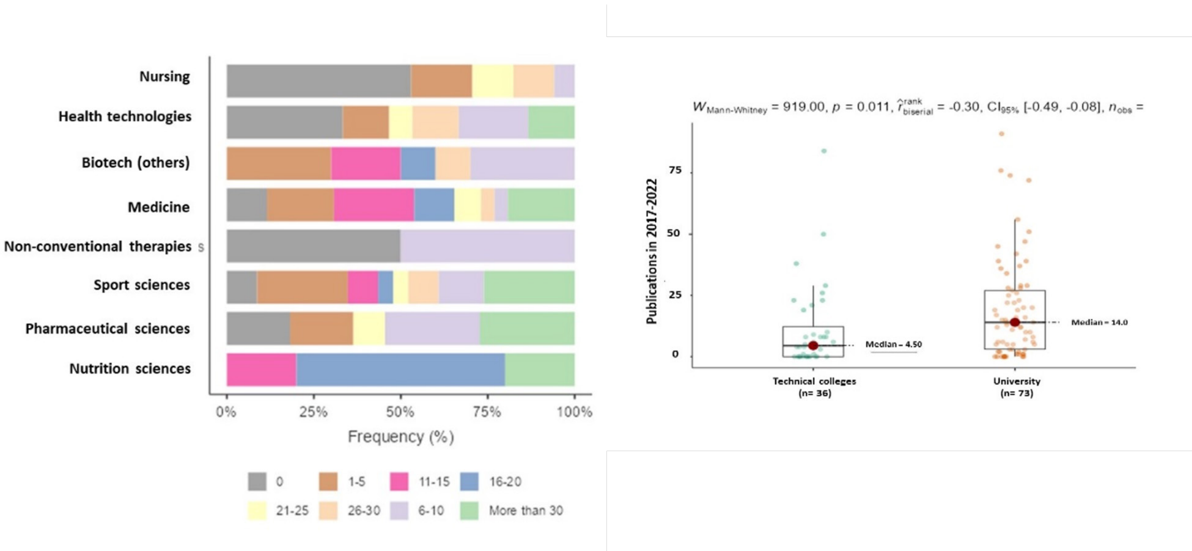

Figure 2. Number of publications per professional area and publication output comparison between technical colleges and universities. As shown (right) a significant difference is noted between institutions

n conclusion, no matter some recognised limitations, this study provides a rigorous picture of Physiology teaching and research in Portugal, successfully identifying all syllabi in Portugal where Physiology was ministered. Physiology is clearly present in all HE health courses confirming that it is regarded as a principal discipline for Medicine and any human health related profession education (3). Nevertheless, regardless its presence in universities and technical college programs, and similarity in terms of attributed credits and class type, some differences are clear, mostly in the hands-on component and structural organization. Medical Physiology and Lifestyle Physiology seem to be the two major areas of scientific production, with these researchers' preferences focusing on biomedical research and innovation, cardiovascular function, sport performance and physical well-being.

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Remote / online teaching versus masterful teaching – lessons learned (after the pandemic)

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Abstract

The current higher education pedagogical context is characterized by an increasing number of enrolling students which is not being followed by a proportional rise in university assistants, which further aggravates the pupil-tutor ratios and, consequently, overall students' satisfaction. The use of new digital tools and remote teaching serve as potential solutions to (partially) overcome these challenges, and their incorporation in the educational environment was accelerated during the pandemic lockdown. There is evidence suggesting that remote teaching is associated with higher academic performance, as well as more class attendance, and students are overall satisfied with remote teaching policies.

Several tools are progressively being used in physiology teaching at FMUP, including interactive audience inquiry platforms, introductory (briefing) videos to practical lessons, digital flashcards, collaborative question models and use of simulation models.

Regarding final approval and results, courses including medical physiology (cardiovascular morphophysiology, respiratory and urinary morphophisiology) had a global approval rate and results during the pandemic comparable (or even numerically higher) to pre-pandemic years.

Although physiology teaching cannot go fully remote, it is recognized that distant lecturing overcomes some of the current pedagogical challenges, while allowing a more profound interaction during contact hours.

Introduction

Over the past two decades, medical schools have seen a significant rise in student admissions, increasing by approximately 60%. This surge in medical graduates has not been matched with a proportional increase in teaching staff, leading to concerns about the quality and satisfaction of medical education (1). Additionally, there is a potential decline in the number of permanent medical teachers in the coming years. As medical teachers face growing pressures to research and publish, their dedication to lecturing and guiding undergraduates is diminishing. This situation is exacerbating the imbalance between tutors and students, potentially impacting the preparation and satisfaction of future doctors (1). In parallel, the field of medical research is constantly evolving, introducing more complex pathophysiological descriptions and an expanding array of treatment options, often leaving students feeling overwhelmed with the vast amount of information they need to learn. Therefore, the current challenge is how can high educational standards be kept when there are more students, fewer teachers and teaching time, and more contents to approach.

Methods

A non-systematic literature review was conducted regarding the comparison of in-person versus remote lessons regarding academic performance and overall satisfaction, and the impact of COVID-19 lockdown periods on teaching practices. Furthermore, an overview was carried on different physiology teaching strategies adopted over the last years at Faculdade de Medicina da Universidade do Porto (FMUP) and how grades compared throughout the pandemic periods.

Figure 1. Current and future challenges in teaching.

Results

The use of new digital tools, accessible to both educators and learners, and remote teaching serve as potential solutions to (partially) overcome these challenges, and their incorporation in the educational environment was accelerated during the pandemic lockdown. In fact, studies suggest that students participating in online education may outperform those in traditional face-to-face programs (2) and, specifically during COVID-19 pandemic, research has shown higher academic scores with remote teaching, as well as higher attendance (3). Students perceived the quality of remote teaching as equivalent to in-person classes, with good interaction between teachers and students and overall satisfaction towards remote teaching (4). Several tools are progressively being used in physiology teaching at FMUP, including interactive audience inquiry platforms, introductory (briefing) videos to practical lessons, collaborative question models and use of simulation models. One particular tool that has been deeply studied was the incorporation of digital flashcards, which has shown a consistent, positive, dose-dependent association with higher physiology theoretical exams in short- and medium-terms (5). Regarding final approval and results, courses including medical physiology (cardiovascular morphophysiology, respiratory and urinary morphophisiology) had a global approval rate and results during the pandemic comparable (or even numerically higher) to pre-pandemic years.

Conclusions

Although physiology teaching cannot go fully remote, it is recognized that distant lecturing overcomes at least some of the current pedagogical challenges, while allowing a more profound interaction during contact hours.

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Discussion Panel – The same Physiology for all?

Moderators: Carlos Filipe (NMS) & Luis M Rodrigues (ULL)

Participants: P. Castro Chaves (FMUP), Ricardo Afonso (NMS), Arménio Cruz (ESENFC-IPC), Paulo Matafome (ESTeSC-IPC), Almeida Dias (CESPU), Daniel Gonçalves (FCDUP), Carmen Brás da Silva (FCNAUP)

ANÁLISE DO DEBATE SPFIS 14/11/2023

Apresentam-se as questões postas a debate seguidas de um resumo do que foi dito pelos participantes

QUESTÃO: Se a disciplina "Fisiologia" ainda tem razão de ser num tempo de grande especialização? Se tem futuro, que futuro acham que pode ter? Quais as razões pela preocupação recorrente com o futuro da disciplina?

- A fisiologia é uma ciência integradora, que integra conhecimentos de outras áreas (biologia celular, molecular), dando-lhe uma lógica. A chave da importância da Fisiologia é a Integração de conhecimentos de áreas científicas diversas.

- A fisiologia transporta-nos para uma quarta dimensão que é o tempo. Quer dizer, um mesmo mecanismo pode ter um determinado comportamento num ciclo e outro comportamento completamente diferente noutra fase do mesmo ciclo. Dá-nos a capacidade compreender, mais do que saber, os mecanismos.

- A consequência desta integração é que as ferramentas são muito transversais entre áreas científicas. O fisiologista tem a capacidade de olhar para tudo de forma integrada. E esse é o grande desafio para o ensino, passar aos estudantes a capacidade olhar para tudo de forma integrada. No entanto, hoje em dia no ensino existe muita tendência para "compartimentalizar" a informação, o que torna este ensino da fisiologia mais desafiante.

- A principal ameaça vem da sobreposição das disciplinas. Não há uma padronização do que se ensina em Fisiologia nos diferentes planos de estudos.

- Não há razões para preocupação, mas sim alguns desafios. O desafio é ajustar os planos curriculares de acordo com as necessidades específicas de cada curso. O que é importante é que os estudantes retenham para o resto do curso e para a profissão, daí ser necessário adaptar os currículos ao que os alunos necessitam ao longo do curso. Uma estratégia é alinhar com as necessidades das UCs mais avançadas no curso.

- Há alguns anos, quem não tivesse conhecimento de biologia molecular não fazia investigação, e hoje já não é assim, dado que se percebeu a natureza integrativa da fisiologia.

- Quando as disciplinas de Anatomia e Fisiologia foram inicialmente separadas em algumas instituições, houve necessidade dos docentes dessas UCs em integrar o ensino prático entre as várias disciplinas.

- Um desafio é as UCs de Fisiologia aparecerem demasiado cedo em alguns cursos (1º ano), pois os alunos que chegam do secundário não estão preparados para a forma de pensar em Fisiologia.

- Ter especialistas de determinadas áreas (que não a área do curso) a dar aulas práticas de Fisiologia em que essa especialidade pode ser relevante (ex: nutricionista, a dar a aula sobre Fisiologia do Doente acamado num curso de Enfermagem), é visto como uma mais valia.

- A Fisiologia é uma perda basilar nos cursos da área da saúde e da Engª Biomédica. Não tem necessariamente de começar logo por dar aos alunos os exemplos imediatos da aplicabilidade. Esta necessidade, é uma ameaça que decorre de os alunos terem uma expectativa de imediatismo, que é uma consequência da geração "Google", da necessidade que é incutida nos alunos de precisarem de saber a aplicabilidade prática do conhecimento rapidamente. E há um esforço por parte de algumas universidades (ex. NMS, FMUP) de ir de encontro a essa necessidade, trazendo para as aulas alguns casos clínicos, PBL, alguns com simuladores. Essa ligação direta à prática ajuda a prender a atenção do aluno contribuindo para ajudar a ensinar os fundamentos da Fisiologia. Um problema que resulta desta necessidade é encontrar as ferramentas ideais para motivar os alunos (potencial das novas ferramentas de AI – ChatGPT e etc.)

- As restantes unidades curriculares, não tendo muito tempo, podem repetir alguns dos conceitos da Fisiologia. A redundância não tem mal, e pode ser até ser muito positivo e desejável.

- Outro desafio é o dinamismo da evolução do conhecimento. A evolução é muito rápida, e temos de ser capazes de absorver esse conhecimento para o oferecer aos estudantes. Provavelmente, os planos curriculares têm de ser adaptados mais frequentemente para refletir essas mudanças e adaptarem-se às necessidades dos alunos.

- Os desafios que são identificados são uma oportunidade para revistar os conceitos e identificar aqueles que são os conceitos core que devem fazer parte do currículo de uma UC de Fisiologia geral.

- Pode ser importante no final de cada ano letivo haver uma "conversa" entre os docentes de cada ciclo de estudos sobre o que vai/deve ser dado nas UCs de Fisiologia e Anatomia para que os alunos estejam melhor preparados quando chegam às UCs mais específicas e avançadas nos cursos.

- Anatomia Funcional pode funcionar mas precisa de bases anteriores.

O papel da Fisiologia é claramente no ensino, não só do conhecimento puro, mas também na forma do articular. Será que há investigação em Fisiologia, ou há investigação em diferentes áreas que depois são integradas naquilo que se pode chamar investigação em Fisiologia? Será que a investigação em Fisiologia tem como objetivo ultimo publicar revisões integradoras ou continuaremos à procura de publicar artigos nas diferentes áreas científicas de base?

- Na investigação, há uma necessidade de ir à procura do mecanismo, tal como noutras áreas. A diferença é que na Fisiologia há também a necessidade de ir à procura de perceber "para quê que aquilo serve", quase de forma inata para quem está a fazer investigação em Fisiologia.

- As ferramentas da biologia molecular podem ajudar à identificação do mecanismo, e quando integrados, podem ajudar a compreender o funcionamento.

- Pode haver muitos investigadores que não sabem que estão a fazer investigação em Fisiologia. A Fisiologia está lá, mas como ferramenta. Há um viés na Investigação porque as pessoas ou estão a estudar uma patologia e por isso publicam nessa área. Não há grande espaço para publicar nas revistas de "Physiology".

Deveria existir um contexto mínimo (core concepts) em todas as disciplinas de Fisiologia? Qualquer pessoa pode ensinar Fisiologia?

- Quem ensina, deve ser uma escolha de quem coordena suportado pelo que é necessário para ensinar a Fisiologia de acordo com as necessidades do ciclo de estudos. Pode haver necessidade de recrutar alguém mais especializado. O coordenador da UC deve ter uma visão mais transversal.

- Há *core concepts* que devem estar nas UCs, transversais a todas as UCs de Fisiologia, mas cada curso tem nuances. Esses *core concepts* não têm (nem podem) tornar a Fisiologia ensinada num curso de Medicina, igual à Fisiologia ensinada em Nutrição ou em Biomédica.

- "Somos professores universitários, mas ninguém nos ensinou a ser professores universitários." "De alguma forma, alguém lhes reconheceu mérito numa determinada área." As competências que adquirimos são adquiridas em contexto de trabalho, exceto se tivermos ido alguma formação (por vezes facultativa). Isso significa que transmitimos os conhecimentos que adquirimos na investigação, junto dos mestres. Ao mesmo tempo, consoante as necessidades dos coordenadores das UCs, tem de haver alguma flexibilidade para o docente aprender novas matérias que não sejam da sua especialização, o que leva a que não haja a definição de um perfil fixo para docente de Fisiologia.

- "Um professor que faz investigação é muito melhor professor, um investigador que dá aulas é muito melhor investigador." "Um professor que faz investigação fala com outra propriedade daquilo que ele descobre e verifica do que um professor que apenas leu num livro. Um investigador que dá aulas, a capacidade de transmitir conhecimento é ela própria uma sistematização do seu conhecimento, transformando-o também num melhor investigador."

Notas sobre o debate:

Desta mesa redonda sobre o futuro do ensino da Fisiologia em Portugal, alguns dados trazem ressonâncias de investigações anteriores. Por exemplo, considerar a Fisiologia como uma ciência integradora, isto é, que permite aos alunos adquirirem conhecimento e formas de pensar que implicam a integração de conhecimentos de áreas diversas, como é o caso da biologia molecular (disciplina que tem estado mais em foco, por ser aquela que está mais vocacionada para a descoberta dos mecanismos por trás de qualquer fenómeno). Além desta perspetiva integradora, já encontrada noutras discussões sobre o tópico, a ideia da Fisiologia trazer uma 4ª dimensão à análise dos fenómenos (o Tempo), foi também uma ideia inovadora que pode ser um contributo importante para o desenho de futuros currículos para novas UCs.

Importante realçar que a Fisiologia, com esta vertente integradora, é vista como pedra basilar nos cursos da área da biomédica. Várias ameaças a esse papel foram identificadas, entre elas: a sobreposição temas de UCs no mesmo ciclo de estudos, o ensino da Fisiologia no 1º ano dos ciclos de estudos (quando os alunos ainda não têm a maturidade suficiente para o pensamento integrador e sistémico característico do estudo da Fisiologia), a expectativa dos alunos para ter conhecimento com aplicabilidade prática imediata e a natureza dinâmica e cada vez mais acelerada da evolução do conhecimento. Para estas ameaças, encaradas como desafios, os participantes aventaram algumas soluções nomeadamente: identificar os conceitos que os estudantes necessitam adquirir para serem bem sucedidos na prossecução dos estudos de outras disciplinas; revisitar esses conceitos periodicamente, reunindo os docentes das diversas disciplinais envolvidas para atualização e modificação dos currículos quando necessário; identificação de um conjunto de *core concepts*, transversais às cadeiras de Fisiologia dos diversos cursos, salvaguardando o espaço para as diferenças e nuances entre as diferentes áreas cientificas; ensino com base em componentes de Activity Based Learning, como simuladores, casos clínicos, Problem base learning, etc; trazer especialistas de determinadas áreas do conhecimento para dar aulas sobre o assunto, enquadradas no tema da Fisiologia.

Relativamente à relação com a investigação, entende-se que a Fisiologia é uma ferramenta para melhor entender a investigação que é feita, sobretudo de base molecular. Já as competências de investigação de biologia molecular são vistas como fundamentais para os novos investigadores que têm necessariamente de se preocupar com os mecanismos por trás dos fenómenos que querem descrever. Isso leva a que muitas pessoas não publiquem em revistas de Fisiologia, mas sim na área onde investigam, o que leva à perda gradual de importância das revistas da área da Fisiologia para estes investigadores. Já sobre a relação da investigação com o ensino, foi considerado que os professores de fisiologia não têm necessariamente de ser fisiologistas. O que é necessário é que o coordenador dessas UCs tenham uma visão transversal dos conteúdos que são ensinados e que recrutem alguém mais especializado quando necessário. A ligação do ensino com a investigação é vista como positiva, contribuindo muitas vezes para aquisição de competências pedagógicas dos investigadores assim como com a flexibilidade necessária para aprender e ensinar um novo tema numa área distinta daquela em que se especializaram, enquanto o contributo das competências de investigação se sentem sobretudo na capacidade de sistematizar conhecimento, transmitindo desta forma o conhecimento e a forma de pensar em fisiologia de uma forma mais concreta aos alunos dos diferentes cursos.

ANALYSIS OF THE SPFIS DEBATE 14/11/2023

This debate was conducted in Portuguese. This text is a translation.

The questions raised for discussion are presented, followed by a summary of the participants replies.

QUESTION: Does the subject "Physiology" still have a reason to exist at a time of great specialisation? If it has a future, what future do you think it could have? What are the reasons for the recurring concern about the future of the discipline?

- Physiology is an integrative science, which integrates knowledge from other areas (cell biology, molecular biology), giving it a rationale. The key to the importance of physiology is the integration of knowledge from different scientific areas.

- Physiology takes us into a fourth dimension, which is time. In other words, the same mechanism can have a certain behaviour in one cycle and a completely different behaviour in another phase of the same cycle. It gives us the ability to understand, rather than know, the mechanisms.

- The consequence of this integration is that the tools are very cross-cutting between scientific areas. The physiologist has the ability to look at everything in an integrated way. And that's the great challenge for teaching, giving students the ability to look at everything in an integrated way. However, nowadays in teaching there is a great tendency to "compartmentalise" information, which makes teaching physiology more challenging.

- The main threat comes from overlapping subjects. There is no standardisation of what is taught in Physiology in the different syllabuses.

- There is no cause for concern, but there are some challenges. The challenge is to adjust the curricula according to the specific needs of each course. What's important is that students retain it for the rest of the course and for the profession, so it's necessary to adapt the curricula to what students need throughout the course. One strategy is to align them with the needs of the more advanced courses.

- A few years ago, anyone who didn't know molecular biology wouldn't do research, but that's no longer the case today, as the integrative nature of physiology has been realised.

- When the Anatomy and Physiology subjects were initially separated in some institutions, there was a need on the part of the teachers of these UCs to integrate practical teaching between the various subjects.

- One challenge is that Physiology courses appear too early in some programmes (1st year), because students coming from secondary school are not prepared for the way of thinking in Physiology.

- Having specialists from certain areas (other than the course area) give practical Physiology classes where that specialism may be relevant (e.g. a nutritionist giving a class on the Physiology of the Bedridden Patient in a Nursing course) is seen as an added value.

- Physiology is a staple of health and biomedical engineering courses. It doesn't necessarily have to start by giving students immediate examples of applicability. This need is a threat that stems from students having an expectation of immediacy, which is a consequence of the "Google" generation, the need that is instilled in students to need to know the practical applicability of knowledge quickly. And there is an effort on the part of some universities (e.g. NMS, FMUP) to meet this need by bringing clinical cases, PBL, some with simulators, into the classroom. This direct link to practice helps to hold the student's attention and helps to teach the fundamentals of physiology. One problem that arises from this need is finding the ideal tools to motivate students (potential of the new AI tools - ChatGPT and so on).

- The other curricular units, not having much time, can repeat some of the Physiology concepts. Redundancy is fine, and can even be very positive and desirable.

- Another challenge is the dynamic evolution of knowledge. Evolution is very rapid, and we have to be able to absorb this knowledge in order to offer it to students. Curricula probably need to be adapted more frequently to reflect these changes and adapt to students' needs.

- The challenges that are identified are an opportunity to revisit the concepts and identify those that are the core concepts that should be part of the curriculum of a general Physiology CU.

- At the end of each academic year, it could be important for there to be a "conversation" between the teachers of each cycle of studies about what will/should be taught in the Physiology and Anatomy courses so that students are better prepared when they get to the more specific and advanced courses.

- Functional Anatomy can work, but it needs previous foundations.

The role of Physiology is clearly in teaching, not only pure knowledge, but also how to articulate it. Is there research in Physiology, or is there research in different areas that are then integrated into what can be called Physiology research? Is the ultimate goal of Physiology research to publish integrative reviews, or are we still looking to publish articles in the different basic scientific areas?

- In research, there is a need to look for the mechanism, just like in other areas. The difference is that in Physiology there's also a need to look for "what that thing is for", almost innately for those doing research in Physiology.

- Molecular biology tools can help identify the mechanism, and when integrated, can help understand how it works.

- There may be many researchers who don't realise that they are doing research in Physiology. Physiology is there, but as a tool. There is a bias in research because people are either studying a pathology and so they publish in that area. There isn't much room to publish in Physiology journals.

Should there be a minimum context (core concepts) in all Physiology subjects? Can anyone teach Physiology?

- Who teaches should be the choice of the coordinator supported by what is needed to teach Physiology according to the needs of the cycle of studies. There may be a need to recruit someone more specialised. The UC coordinator should have a more transversal vision.

- There are *core concepts* that should be in the courses, transversal to all Physiology courses, but each course has its own nuances. These *core concepts do* not (and cannot) make the Physiology taught in a Medicine course the same as the Physiology taught in Nutrition or Biomedicine.

- "We're university professors, but nobody taught us how to be university professors." "Somehow, someone recognised their merit in a certain area." The skills we acquire are learnt in a work context, unless we have attended (sometimes optional) training. This means that we pass on the knowledge we've acquired in research to our masters. At the same time, depending on the needs of the course coordinators, there has to be some flexibility for the lecturer to learn new subjects that are not part of their specialisation, which means that there is no fixed profile for a physiology lecturer.

- "A teacher who does research is a much better teacher, a researcher who teaches is a much better researcher." "A teacher who carries out research speaks with greater ownership of what he discovers and verifies than a teacher who has only read in a book. A researcher who teaches, the ability to pass on knowledge is itself a systematisation of his knowledge, making him a better researcher too."

Notes on the debate:
From this round table on the future of physiology teaching in Portugal, some of the data resonates with previous research. For example, considering Physiology as an integrative science, that is, one that allows students to acquire knowledge and ways of thinking that involve integrating knowledge from different areas, as is the case with molecular biology (a discipline that has been more in focus, as it is more geared towards discovering the mechanisms behind any phenomenon). In addition to this integrative perspective, already found in other discussions on the topic, the idea of Physiology bringing a 4th dimension to the analysis of phenomena (Time), was also an innovative idea that could be an important contribution to the design of future curricula for new UCs.

It is important to emphasise that Physiology, with its integrative approach, is seen as a cornerstone of biomedical courses. Several threats to this role were identified, among them: the overlapping themes of UCs in the same study cycle, the teaching of Physiology in the first year of study cycles (when students are not yet mature enough for the integrative and systemic thinking characteristic of the study of Physiology), the expectation of students to have knowledge with immediate practical applicability and the dynamic and increasingly accelerated nature of the evolution of knowledge. To these threats, seen as challenges, the participants came up with a few solutions, namely: identifying the concepts that students need to acquire in order to be successful in pursuing studies in other disciplines; revisiting these concepts periodically, bringing together teachers from the various disciplines involved to update and modify curricula when necessary; identifying a set of *core concepts that are* transversal to the Physiology subjects of the various courses, safeguarding space for the differences and nuances between the different scientific areas; teaching based on Activity Based Learning components, such as simulators, clinical cases, Problem Based Learning, etc; bringing in specialists from certain areas of knowledge to give classes on the subject, within the framework of the Physiology theme.

Regarding the relationship with research, it is understood that Physiology is a tool for better understanding the research that is being carried out, especially on a molecular basis. Molecular biology research skills, on the other hand, are seen as fundamental for new researchers who necessarily have to worry about the mechanisms behind the phenomena they want to describe. This means that many people don't publish in physiology journals, but rather in the area they are researching, which leads to a gradual loss of importance of physiology journals for these researchers. As for the relationship between research and teaching, it was considered that physiology professors don't necessarily have to be physiologists. What is needed is for the coordinator of these UCs to have a transversal vision of the content being taught and to recruit someone more specialised when necessary. The link between teaching and research is seen as positive, often contributing to the acquisition of researchers' pedagogical skills as well as the flexibility needed to learn and teach a new subject in an area other than the one in which they specialise, while the contribution of research skills is felt above all in the ability to systematise knowledge, thus transmitting knowledge and the way of thinking about physiology in a more concrete way to the students of the different courses.

Artificial Intelligence in Education: Reflections and Implications

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Introduction

Artificial Intelligence (AI) has created turmoil in many areas of society, with education being no exception. In particular, with the advent of generative AI, learners and educators now have transformative resources readily at hand that create unprecedented opportunities but also raise significant challenges. Let us start by taking a step back: in a broader sense, education is arguably as old as human civilizations. Beyond, but also within, traditional classroom teaching, technology has historically been a facilitator of novel educational practices[1], and education technology (EdTech) is currently a field in itself.

With the rise of audiovisual media and telecommunications from the 1920s to the 1960s, learners were no longer bound to a physical location or to direct real-time interaction with educators, by being able to access educational content remotely and/or in a pre-recorded format [1]. Later, the semicondutor industry enabled greater efficiency in classroom tasks that would otherwise be resource intensive, freeing time that learners and educators could use to pursue more nuclear and complex educational objectives [2]. Around 1970, handheld calculators started allowing quick mathematical computations, and the democratization of personal computing in the 1980s skyrocketed these capabilities, with access to increasingly higher processing power and convenient tools (e.g., word processors and spreeadsheets).

More recently, educational practices and learning opportunities have been forever transformed by the World Wide Web and derived technologies. Since the 1990s, learners and educators have been able to share and access content on an unprecedented scale [3]. Whereas, previously, knowledge beyond the classroom was largely circumscribed to physical media (e.g., books, class notes, files on local computers), combined with the worldwide dissemination of mobile devices (i.e., smartphones and tablets, of which there are now over 7 billion) that followed in the 21st century, the Internet has enabled educational resources to become instantly available to almost anyone, anywhere, and from a plethora of sources.

The landscape of digital tools as of the 2020s is further contributing to augmenting and extending the classroom, enabling more engaging experiences, in line with the latest trends in project-based learning, flipped classrooms, and related methodologies. These include mobile devices used as laboratory/classroom equipment, cloud-based services, and the Internet of Things (IoT) [4], but are quickly expanding to encompass also emerging technologies such as *virtual and augmented reality* (VR and AR).

Overall, each leap forward in EdTech has led to advantages in three main pillars: (1) access to educational resources; (2) process efficiency; and (3) personalization. In light of these pillars, and considering how educational practices have historically interwoven with technology, AI is yet another stepping stone, albeit a very important one, in the EdTech evolutionary path.

Emerging Uses of AI in Education

There are currently thousands of useful AI tools available for learners and educators[2]; the most salient application domains can be classified as (a) language; (b) audiovisual; (c) development; and (d) learning.

[1] https://www.simplek12.com/just-for-fun/evolution-of-edtech-infographic

[2] https://medium.com/brains-to-ventures/5-ways-to-think-about-investing-in-generative-ai-in-2023-and-beyond-41eda2770a6b

Concerning language (a), existing tools are primarily used for copywriting, proofreading, and text generation. For example, Grammarly[3] has seamless integration with desktop, mobile, and web apps, enabling on-the-fly spellchecking, grammar checking, and even content generation. ChatGPT[4] took the world by storm [5], by bringing *large language models* (LLMs) to the masses; it and Google's Gemini have grown to become go-to tools for copywriting (i.e., improving texts based upon a preliminary draft provided by the user), in addition to their advanced prompt-based content generation capabilities. These relate mainly to EdTech pillars (1) and (2) mentioned in Section 1.

Regarding audiovisual (b), AI is being increasingly used to overcome copyright limitations and to streamline content creation, which relates primarily with EdTech pillar (2). Learners and educators often struggle with copyrights when producing content, especially images; tools such as Midjourney[5] or Dall-E[6] pioneered the ability to create original images from text-based prompts. Figure 1 illustrates an example of an image generated using the former Microsoft Bing image generator (now known as Image Creator from Microsoft Designer). AI-powered content creation already extends also to the audio and video domains; tools such as Google Vertex AI Studio[7] can be used to create speech from text, while Sora[8] can create engaging videos from user prompts. Technology in this domain goes as far as to enable realistic narrative footage (e.g. Synthesia[9]).

Development (c), on the other hand, is quite encompassing, ranging from AI-assisted production of educational materials to even more specialized activities (e.g., creating computer code). Microsoft Copilot is a comprehensive cross-application assistant that can competently assist in co-creation; a powerful example is the integration with PowerPoint[10], which can be used to draft presentations in aspects as simple as the table of contents or as sophisticated as the whole slide deck. GitHub Copilot[11] is an example of an assistant that can program in most mainstream languages. In terms of the main EdTech pillars described in Section 1, these tools contribute mainly to pillars (2) and (3).

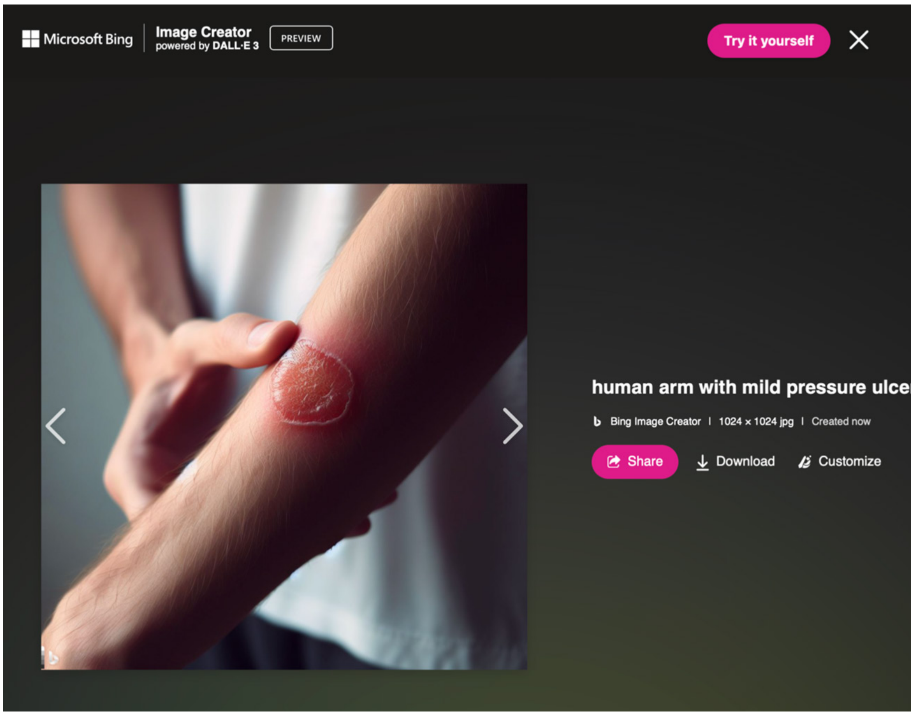

Figure 1. Illustration of a pressure ulcer created with AI.

[3] https://www.grammarly.com/
[4] https://chat.openai.com/
[5] https://www.midjourney.com/home
[6] https://openai.com/dall-e-3
[7] https://console.cloud.google.com/vertex-ai/generative
[8] https://openai.com/sora
[9] https://share.synthesia.io/76bc39eb-0872-42b6-b99b-013fcd2af4ee
[10] https://support.microsoft.com/en-us/copilot-powerpoint
[11] https://visualstudio.microsoft.com/github-copilot/

Lastly, AI is an invaluable tool to support, and even revolutionize, the learning process, namely in what concerns studying, assessment (in particular self-assessment), tutoring, and counseling, which is in line with all the EdTech pillars described in Section 1. Tools like the Jasper Text Summarizer[12] are increasingly used to summarize research papers, assisting personalized learning paths more efficiently. Assessment and proctoring, both self-passed and in a more formal educational setting, are also on the rise; although sufficiently consolidated tools are, arguably, still lacking, Gradescope[13] is a representative example of an AI-assisted grading tool. One of the currently most widespread uses of AI in education is in counseling (or as a "study buddy") [6]; LLMs and the chatbots on which they are based, such as ChatGPT, can effectively act as an always-on, always-available, never-tired, tutor, virtually trained with much more knowledge (both in terms of breadth and depth) than their human counterparts. As another example, Khanmigo[14] is a chatbot built on GPT-4, designed to help users with math, science, humanities, and coding. Figure 2 shows an example of a 12-lead electrocardiography (ECG) strip, alongside part of the response of ChatGPT to the prompt "Analyze this", enabling a learner to start grasping the basics of ECG interpretation.

Implications of AI in Education

Despite its relative recency, AI has already become a colossal force in EdTech, requiring an immediate paradigm shift. A critical aspect is the in-class assessment; in particular, written essays have historically been an essential graded component in many courses, and even more so in theses and dissertations. Due to the increasing sophistication of modern LLMs, we are approaching a scenario where the majority of written content will be either largely AI-assisted or fully produced by AI [5, 7]. This is even more alarming when considering the lack of effective tools to detect AI-generated content, if this is at all possible. As a result, educators should equate the extent to which more concise written essays (possibly in-class) and/or other written media more rooted in creative thinking (e.g. poster or slide presentations) can more effectively drive learners to achieve the educational objectives as well as assess the effectiveness of the educational process.

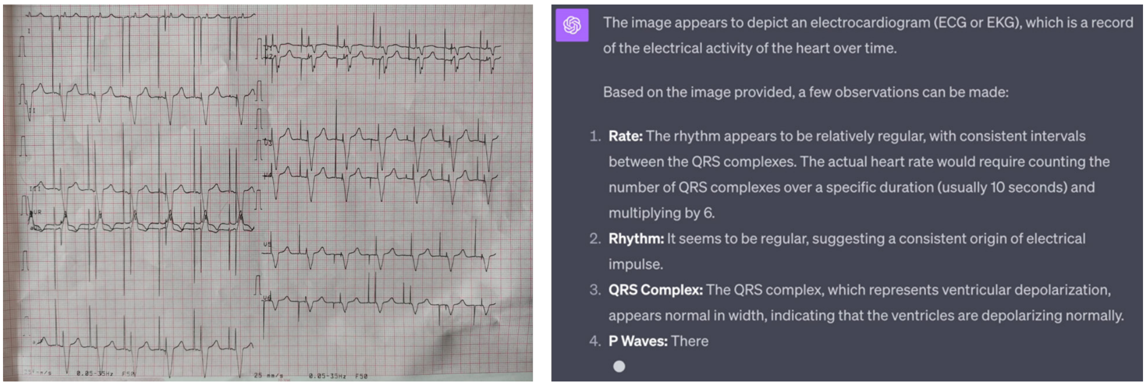

Figure 2. Electrocardiography (ECG) strip (left) and part of a GPT-4 response (right) to the prompt "Analyze this".

Similarly, didactic learning needs to be further reinforced with critical thinking and experiential learning, to promote learner engagement. It is expected that AI will gradually outperform humans in most systematic and analytical tasks; education is no exception. However, the real (physical, biological, social, …) world is inherently interactive, and, to a large extent, learning about it requires hands-on experience and experiments. This adds to the significance of "learning by doing" approaches, especially when dealing with topics that require interacting with the physical world. This type of learning may be AI-assisted but is currently not easily mediated by AI alone. Figure 3 illustrates a hands-on project developed in the scope of a bio-instrumentation course in which project-based learning was introduced to foster hard skills development in learners.

[1] https://www.jasper.ai/tools/text-summarizer
https://www.gradescope.com/
https://www.khanmigo.ai/

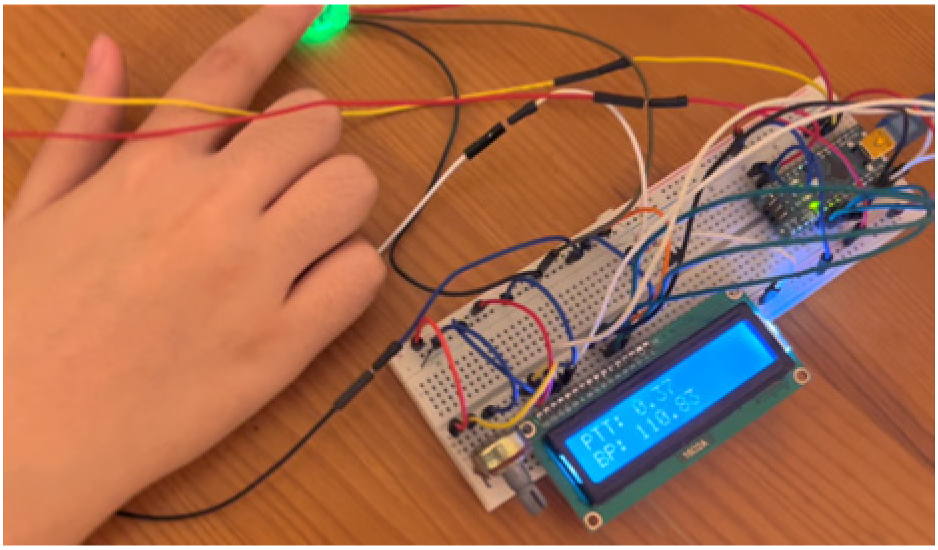

Figure 3. Experimental *blood pressure* (BP) monitor based on *pulse transit time* (PTT) developed as a final project in a bio-instrumentation course.

Although harder to implement, another strategy to deal with the potential negative effects of AI in educational practices is the development of specific materials that are unknown to mainstream AI systems. One example is the P3 educational CPU, used at IST as a learning tool for computer engineering students [8], which builds upon the basic principles of computer architectures but implements them in a custom simulator programmed with a variant of the Assembly language (P3 Assembly). Another example is ScientISST[15] [4], a set of hardware and software resources to support educational activities in biomedical engineering, developed at IT in collaboration with IST and used at the IST Department of Bioengineering. These approaches force learners to really deepen their knowledge of the topics covered in the courses.

Discussion

The impact of AI in education is an unavoidable reality, which needs to be actively embraced by learners and educators. Attempts to block or prohibit its use will be, at best, ineffective, at worst, it will result in a loss of competitiveness comparatively to peers with more open and progressive approaches. Also, such negative reactions are likely to have to be abandoned at some point in time (as shown by the recent events in Italy[16]).

As with any technology (namely EdTech), AI does not come without its risks. With the level of sophistication of already existing tools, it becomes much harder to determine whether certain educational outcomes are originally produced by learners or fabricated by AI-assisted tools. Due to the ease of access and use of such tools, it is also unclear whether learners will use these tools to effectively enhance their learning processes (e.g., to deepen their knowledge) versus using them simply as an aid to maximize academic success (i.e., grades), relaying learning to a lower plane. Furthermore, we are now faced with a reality in which learners may tend to have more trust in AI than in their human educators, despite the inherent and well-documented tendency of AI systems to "hallucinate" [9]. Arguably, the highest risk of AI is the gradual loss of critical thinking. For the first time in EdTech history, we are presented with a technology that may contribute to procrastination, memory loss, and academic performance decrease [10].

Whenever suitable, educators should use AI-based tools to enrich and streamline the educational resource creation process. Learners should be encouraged to use AI consciously and responsibly, e.g., as study support and/or work assistance tools. Educators should ensure that learners are guided towards the use of AI tools

[15] https://www.scientisst.com/

[16] https://www.bbc.com/news/technology-65139406

in a productive manner, including to improve the quality of their work (e.g., writing), to select and distill educational content, and for ideation. Grade assessment also needs to be fundamentally reconsidered in light of the current and expected future capabilities of AI. Traditional methods should be complemented with more dynamic components that promote direct interaction between the learner and the educator, including oral evaluation, project-based learning, and hands-on activities.

Despite the risks and difficult adaptation process, AI has the potential to significantly improve efficiency and provide more personalized learning paths. For learners, this paradigm shift can result in the enhancement of their talents and capabilities, while for educators it can free the necessary bandwidth to devote to the most noble parts of their profession: engaging with students and stimulating their curiosity and desire to learn.

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Integrating Metacognition in Physiology Education

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Abstract

Metacognition, the awareness and understanding of one's thought processes, empowers individuals to self-assess, monitor their learning, and improve through self-regulation. This study highlights the significance of metacognition in the teaching and learning of human physiology, advocating for its integration in the pedagogical strategy. We conducted a proof-of-concept study for such integration, which included two key phases: A survey on a priori student's study strategies and weekly formative tests, supplemented by counselling on active study techniques. Students' metacognitive growth was assessed through self-score predictions and adaptive study strategies, while incentives were provided for accurate exam score predictions. Data analysis showed a considerable advancement in students' metacognitive abilities over time. Machine learning with formative tests data predicted student performance with remarkable accuracy, offering the potential for early intervention. To promote physiological skills, however, one must ensure authentic assessment methods. In summary, this study emphasizes the value of metacognition in the educational process and provides a structured framework to nurture this cognitive ability in the context of human physiology education. Integrating metacognitive development in the pedagogical strategy, should improve the overall educational experience and empower students for lifelong learning.

Keywords: metacognition; self-assessment; active study; machine learning

Introduction

Human physiology is a fundamental curricular unit in health sciences courses and provides a critical foundation for understanding diseases and treatments, namely in other curricular units such as pharmacology, pathophysiology, and pharmacotherapy. Pharmaceutical sciences students are typically expected to immediately recognize propranolol in a multiple choice of beta-adrenergic receptor antagonists (BRA). But can they integrate human physiology to predict the effects of BRA on the cardiovascular system? Can they perform or interpret pharmacological assays that quantify BRA effects? Are they aware of their real level of knowledge, or under the delusion that recognizing drug names (e.g., associative memory of the suffix -olol) is a skill that solves real-world pharmacology problems? The ability to self-assess, and become aware of the real level of knowledge, is one of several fundamental metacognitive skills that are necessary to enhance academic learning and emotional intelligence. Given the widespread access to information, metacognitive skills are arguably more valuable than simple associative memory and should thus be fostered in students (Medina et al. 2017, Rivers et al. 2020).

Metacognition, the awareness and understanding of one's thought processes, is essential in education. This cognitive ability empowers students to develop metacognitive skills such as the self-assessment of current knowledge, the self-monitoring of the learning process, and the self-regulation of active study strategies that allows continuous improvement. Naturally, metacognitive skills also apply to educators, namely to how they plan, conduct, and manage their pedagogical strategy of teaching and assessment in interaction with students. Focusing on students, the learning of human physiology provides ample opportunity for cognitive development. To understand the mechanisms of human body function, one should go beyond simple associative memory, and establish a dynamic mental network of cause-effect relationships. Establishing such mental network requires metacognitive skills. Our objective was to explicitly integrate metacognitive development in the physiological education strategy. Namely, to implement a learning environment that fosters the development of metacognitive skills, including an assessment strategy that values the demonstration of such skills. This short paper reports our initial findings, presented to the Portuguese Physiology and Pharmacology societies.

Methods

Students registered in the Physiology unit of the Integrated Master in Pharmaceutical Sciences from the University of Porto (2021/2022, n = 175) were invited to self-assess their interest in learning physiology and their learning strategies, including average time invested in autonomous study on a weekly basis. This self-assessment was conducted via a survey (Survey-1) in the learning management system (Moodle), where students selected answers corresponding to a gradation of low-to-high investment (automatically converted to low-to-high scores). Students were also invited to perform voluntary formative tests on a weekly basis (via Moodle; average test duration 15 min) where, after answering all questions and before seeing their actual score, they had the option to reflect on their performance in the test and register their prediction of their score (metacognitive self-monitoring and self-assessment). Then, each students had access to their own true individual score, and to the global average scores (individual student scores remained anonymous). This way they could monitor the accuracy of their absolute score predictions, their relative position to the average of a particular test, and how that evolved over time. Students received weekly teacher feedback on their tests and counselling on active study techniques, which assisted the self-regulation of their learning strategy. In the summative exam (via Moodle; mandatory to obtain unit approval), the accuracy of student score prediction was valued as bonus (this provided an incentive for training and improving the accuracy of self-assessments). Students were then surveyed (Survey-2, via Moodle) on their perception of the benefits of voluntary formative tests, and their study adaptations according to counselling (metacognitive self-regulation). Data collected from Moodle were anonymized and analysed with the R language for statistics, including machine learning to identify population patterns and to predict exam scores (based on how often student self-assessed on formative tests and their actual scores). The question database in Moodle was built so that questions varied between formative tests (across physiology chapters/systems), and there was a random allocation of twin questions (similar topic and difficulty but different correct answers). This ensured that higher scores were not a function of memorizing answers keys (as these changed with random and twin questions), thus increasing the reliability of the non-proctored formative tests and decreasing the risk of fraud in the proctored summative tests.

Results and Discussion

Analysis of Survey-1 data showed that students' self-assessment of their levels of motivation for learning, interest in science/physiology, initiatives towards learning, as well as the regularity, volume, diversity, and activity of study strategies were highly inter-related (internal consistency: IC = 86%; n = 144). Unsupervised machine learning (hierarchical clustering) on data from Survey-1 showed that the student population organized into three main clusters, mainly explained by the self-reported levels of interest in physiology and volume of study. The three clusters were coded green (high-interest-high-study), red (low-interest-low-study), and blue (high-interest-low-study) (Figure 1A). When comparing the respective distribution of scores in the summative exam, the high-study green cluster displayed a significantly higher average score that the low-study red and blue clusters (Figure 1B). While theoretically it is unsurprising that higher study associates with higher average scores, it is useful for the purpose of metacognitive growth to demonstrate this association to students with their own data. Moreover, there were two informative observations: first – a substantial proportion of the self-reported high-study cluster scored lower than average of the low-study clusters (Figure 1B, green fill vs. blue and red lines); second – self-reported high-interest without high-study did not suffice for higher scores (Figure 1B, proximity of blue and red, both with lower average than green).

The incongruent association between high-interest and low-study in the blue cluster suggests incomplete self-regulation to achieve the necessary study for knowledge acquisition. Self-regulation requires monitoring, so the next step was to investigate how student monitored their learning in formative tests, and how that translated into the accuracy of their predictions of scores.

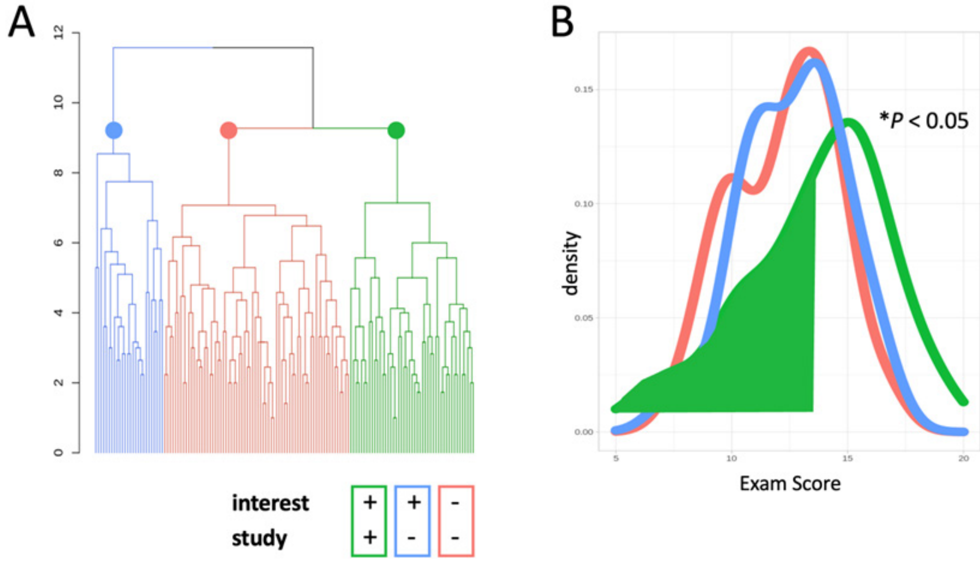


Figure 1. Student clusters and their association with exam scores. (A) Hierarchical clustering performed on Survey-1 data. (B) Density plot of exam scores for each of the 3 main clusters: green (high-interest-high-study), red (low-interest-low-study), and blue (high-interest-low-study); *P < 0.05, One-way ANOVA.

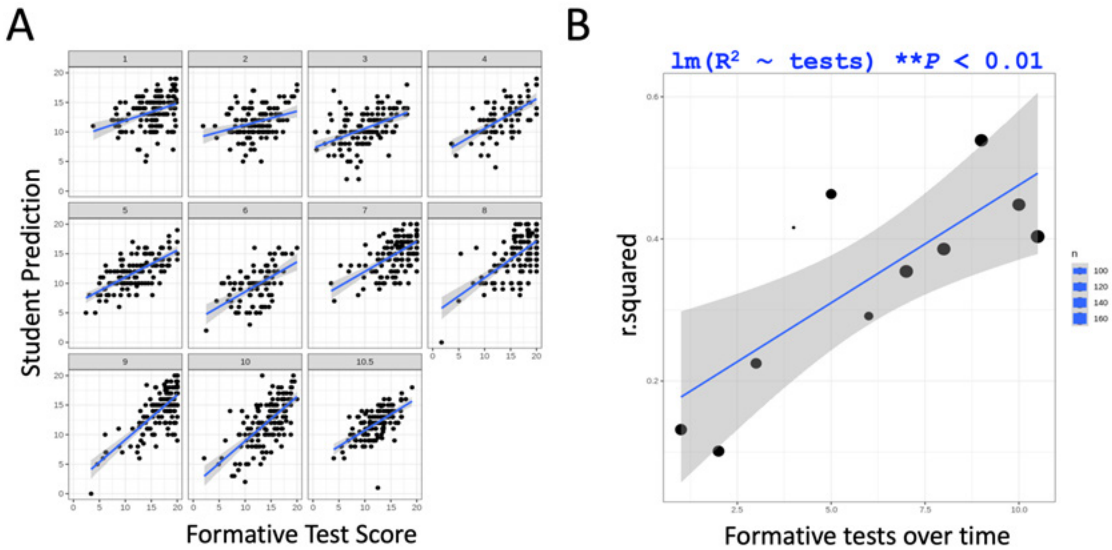
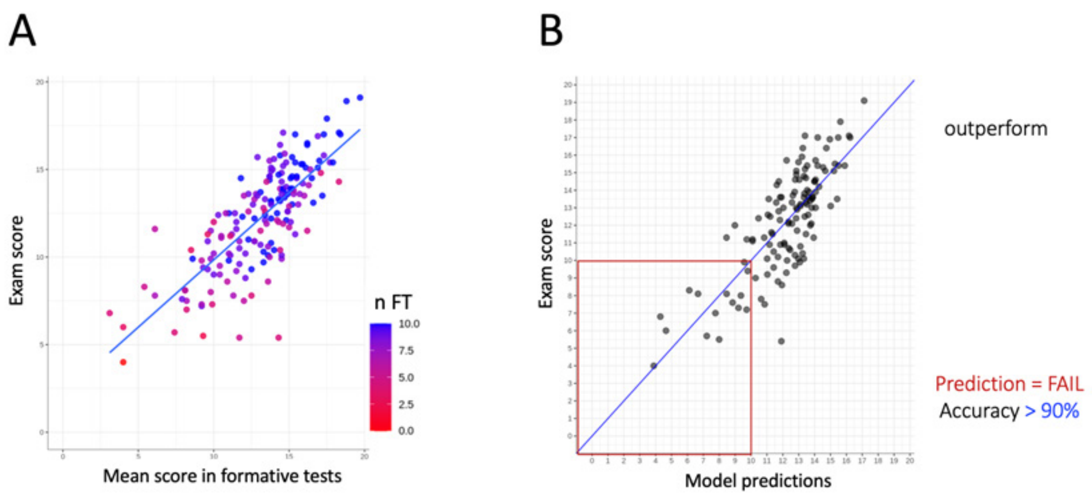


Figure 2. Evolution of correlations between student score predictions and reality. (A) Score prediction vs. reality correlations in individual formative tests. (B) Increasing metacognitive ability to predict scores accurately (higher correlation R^2) over time.

The metacognitive ability of students to predict their score in formative tests started low in tests 1 and 2 ($R^2 = 0.13$ and 0.10 in linear regressions of prediction vs. reality), and then increased gradually until the observed maximum in test 9 ($R^2 = 0.54$) (Figure 2). Also, the first three tests had low internal consistency (IC = 44-52%), and then increased gradually to the observed maximum by test 9 (IC = 81%). This gradual increase over time in the internal consistency of tests is a likely proxy to increasing physiology knowledge in the student population: when knowledge is low, consistency is also low due to random answers ("guessing"); as student's physiology knowledge increases so does the internal consistency of the tests (Oliveira 2022). The exam displayed higher IC (88%) than the top IC in formative tests (81%), and a low standard error (5%): a likely combination of a higher number of questions and a higher average knowledge (typically, students intensify study closer to the exam). Unlike IC, the R^2 of the correlation between score prediction and reality in the exam ($R^2 = 0.40$) was not



Supervised Machine Learning: `score ~ mean_FT + n_FT; adj.R²=0.67, rmse=1.9`

Figure 3. Predicting exam scores with data from formative tests. (A) Correlation between mean scores in formative tests vs. exam, coloured by the number of tests performed (red-low to blue-high) (B) Supervised machine learning model predictions vs, actual exam score, highlight high accuracy for "fail" (<10:20) predictions, and outperforming for higher scores.

higher than the top R^2 in formative tests (0.54). Possibly because the exam had an additional sub-population of students that skipped the formative tests, perhaps due to procrastination (Oliveira 2020), and the lack of training in score prediction of that sub-population limited the R^2 value.

To next step was to test the idea that performance in formative tests may yield good predictions of outcomes in a summative exam. A supervised machine learning model trained with a random sample of 70% of the data on summative exam scores, including as predictors the number of formative tests taken by the students and their average score (n_FT and mean_FT in Figure 3 formula) yielded an adjusted R^2 of 0.67. Using the remaining 30% of data to test the trained model, it predicted exam scores with an error under 2 points on a scale from 0 to 20 points. Also, the model predicted failure in the exam (score under 10 out of 20 points) with 90% accuracy (Figure 3).

Taken together, data from formative tests over time evidence significant improvements in students' metacognitive ability to accurately self-assess, and when integrated into a machine learning model show a strong predictive ability for performance in a summative exam. These interpretations are supported by the fact that, over time, in formative tests and in the exam, students were exposed to randomly assigned questions on different physiology chapters, from a bank with multiple twin questions (same topic, similar difficulty, yet different answers). This random allocation of twin questions not only increases the reliability of the formative tests (voluntary, not proctored, and sequential, i.e., without free navigation), but also decreases risk of fraud in the summative exam (mandatory, proctored, free navigation in questions).

Lastly, analysis of Survey-2 responses, showed that most students consider that the availability of weekly formative tests was very useful (97%) and promoted: their motivation (90%); their regular study (74%); their use of active study techniques (80%); and improved their metacognitive skills (84%). Taken together, responses in Survey-2 support the occurrence of study adaptations as a function of self-assessment and self-monitoring, indicative of widespread metacognitive self-regulation in the student population,

Conclusion

This study provides evidence-based support for enhanced student metacognition by means of a strategy involving regular voluntary formative tests with incentives for accurate score predictions. Moreover, this study supports the concept that machine learning models can help characterize the starting student population, allowing adaptations of pedagogical strategies. Also, machine learning models can accurately predict student failure, enabling early counselling. To promote physiological skills, we emphasise the need for authentic assessment (measuring valuable physiological knowledge and skills). Integrating metacognitive development in the pedagogical strategy assists in empowering students for autonomous life-long learning and in the fostering of a continuous improvement mindset in future professional settings.

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Digital Table for physiology applications

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Disclaimer: This extended abstract, written by an affiliate of Anatomage Italy s.r.l, reports how a company's device has been used in the teaching process. This abstract is not intended as promotional material and it purely describes a specific application of the equipment, shown and described during the seminar "Learning and Teaching in Physiology," which took place in Porto on November 14th 2023

Abstract

Digital technologies are becoming more and more relevant in the education field: the segmented anatomy datasets and clinical case rendering of the Anatomage Table make it a powerful tool to be used in anatomy teaching. In this abstract, we analyze which content can be specifically exploited by the device's users to create lessons and curriculum material for physiology classes, as well as how it can be applied to physiology teaching applications.

Keywords: Education; Anatomy; Table; Digital

Introduction

Over the last decade, the educational field has undergone a huge innovation process: the introduction of digital technologies is becoming more and more relevant as these are becoming an important part of institutions' assets, and their incorporation has proved successful in assisting the progress of teaching and learning. The benefits of digital tools can vary between lower costs, more accessible resources, specialized content and better engagement. In this regard, more and more companies are providing different types of technologies to support institutions in improving their educational proposal: between these, Anatomage offers different digital solutions for anatomy teaching, allowing medical schools, teaching hospitals, colleges, and private companies to enhance their teaching experience.

In particular, in this abstract, we will see how the main product of the company, the Anatomage Table, can be used to support physiology teaching thanks to the segmented anatomy datasets coming from real-life bodies, together with a histology library that can be used to link the macroscopical anatomy and functionalities to the microscopical features of body tissues.

Methods

The TableEDU 9.0.3 software content has been used for a simple clinical case review. In particular: 1) the female Asian full-body dataset from the Visible Korean Human project [1] has been used to analyze the macroscopical anatomy of the shoulder joint region. 2) The Kinesiology Tool from the Functional Anatomy section of the software has been used to analyze joint motions, together with the main muscular structures and ligaments involved in shoulder movement. 3) A 3D volume render of a CT acquisition from a real shoulder dislocation case of the Table library has been used to analyze a real-life example of this type of injury.

Discussion

3.1 Basic Anatomy

As a first step, the male Asian full body has been used to create a 3D visualization of the shoulder joint, to introduce its main anatomical structures (Fig 1a): this customizable view, known as Preset in the Anatomage Table, allows users to have a clear representation of the anatomy of a specific body district, using it as a starting point for further analysis. In this case, a custom-created view is used to visualize the major bony structures of the shoulder, while different presets from the Table pre-made library are used to explore muscles and ligaments involved in joint stability and movement: they are annotated and highlighted with different colors for a clearer representation (Fig 1b). Moreover, additional information can be added with different Table tools, such as innervation and blood supply for a specific structure, to visualize connections between different systems (Fig 1c).

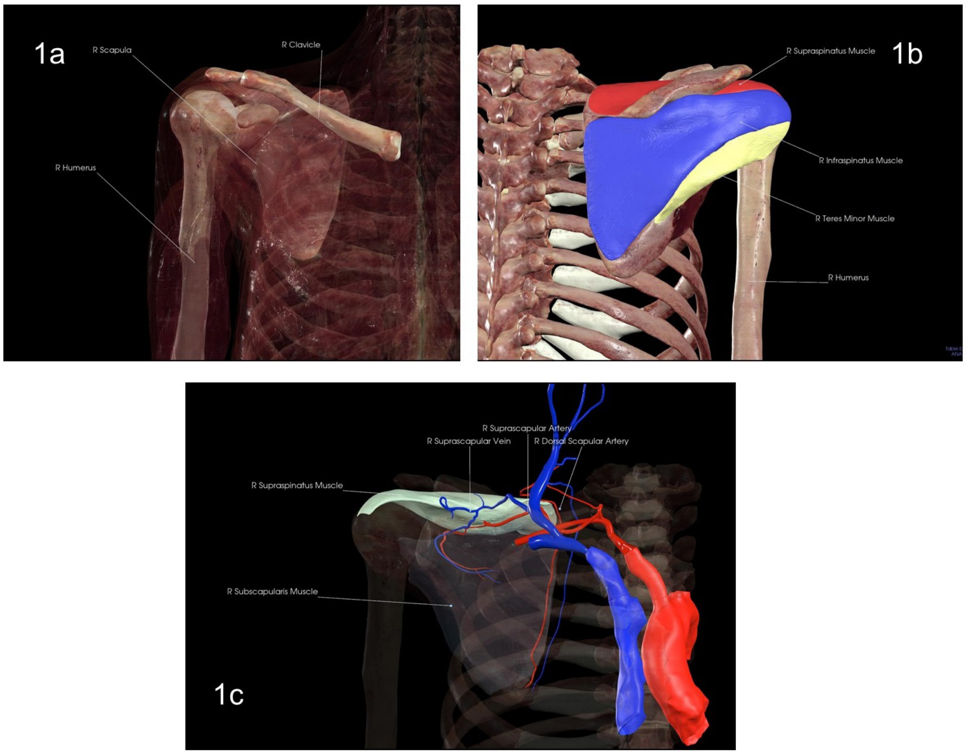

Figure 1. Basic anatomy of the shoulder joint. Anatomage Inc. - Anatomage TableEDU

The 3D rendering of the cadaver data is from the Anatomage Table.

3.2 Kinesiology

The second step consisted of an evaluation of the joint's movement trough the Kinesiology tool in the Functional Anatomy section of the software. This tool allows real-time visualization of the shoulder's main movements, offering a 3D simulation of muscles and ligaments deformation: this has been used to analyze which muscular structures are activated during a specific action (Fig 2), allowing a further understanding of the joint structure.

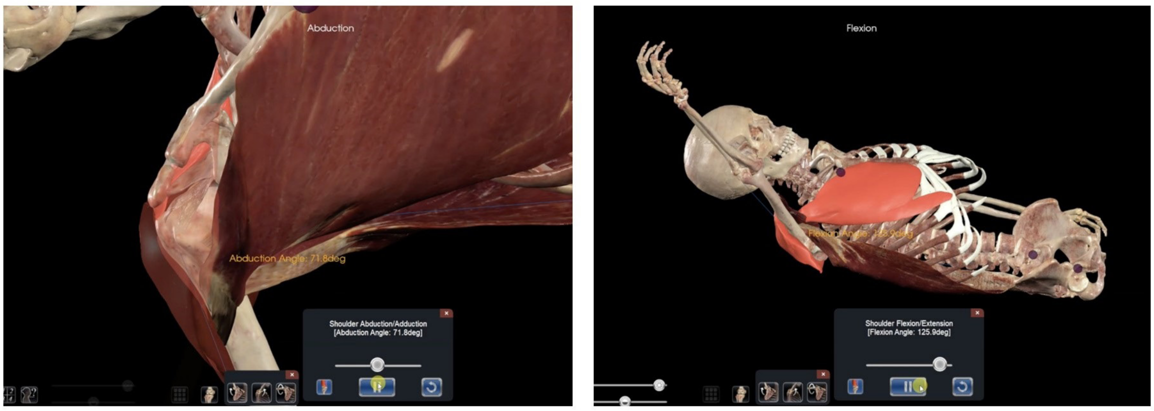

Figure 2. Kinesiology of shoulder joint. Anatomage Inc. - Anatomage Table EDU. The image shown is from the Anatomage Table.

3.3 CT scan visualization

The third step was the 3D visualization of a CT scan using the Case Library section of the Table: in the scan, an anterior shoulder dislocation is visible (Fig 3) and it has been used as a comparison with the normal anatomy to understand and evaluate possible structures damages and, consequently, symptoms caused by the trauma.

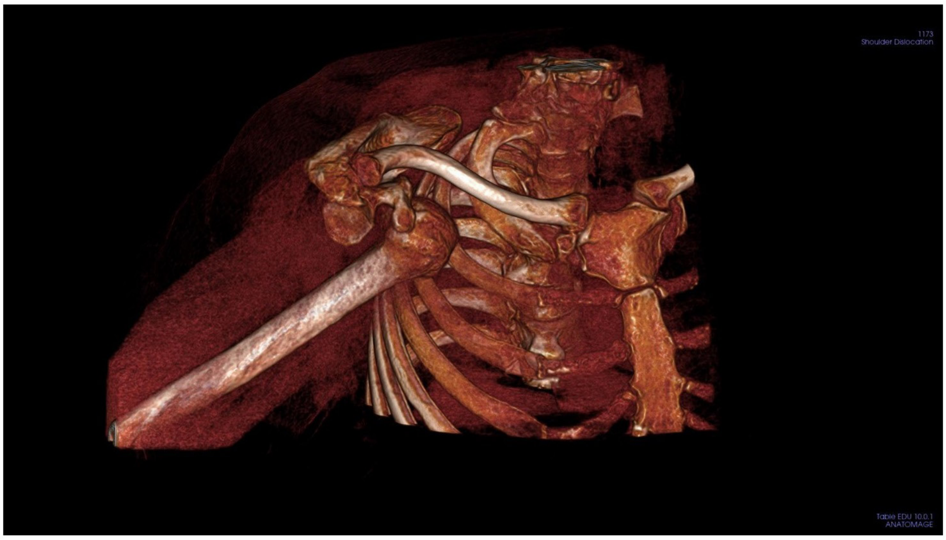

Figure 3. 3D render of a shoulder CT scan, anterior dislocation is visible. Anatomage Inc. - Anatomage Table EDU.

The image is sourced from Università degli Studi di Catania and Fondazione Mediterranea "G.B. Morgagni" and visualized with the Anatomage Table.

3.4 Nervous structures damages

The final step of this case analysis was to visualize, using the already made presets from the software, possible damages to relevant upper limb nervous structures caused by the dislocation. Using these presets (Fig 4a) it was possible to explore which nerves are more likely to be compromised according to symptoms of the patient.Moreover, it was possible to analyze the microscopical structure of the peripheral nervous system thanks to high-resolution histology scans: some of these scans, coming from TableEDU 9.0.3 Histology library, contain segmented relevant structures with annotations that support the analysis of the specimen. Consequently, a more in-depth comprehension of how damages could have affected upper limbs nerves was carried out, with the visualization of peripheral nerves structure, components and functionality (Fig 4b).

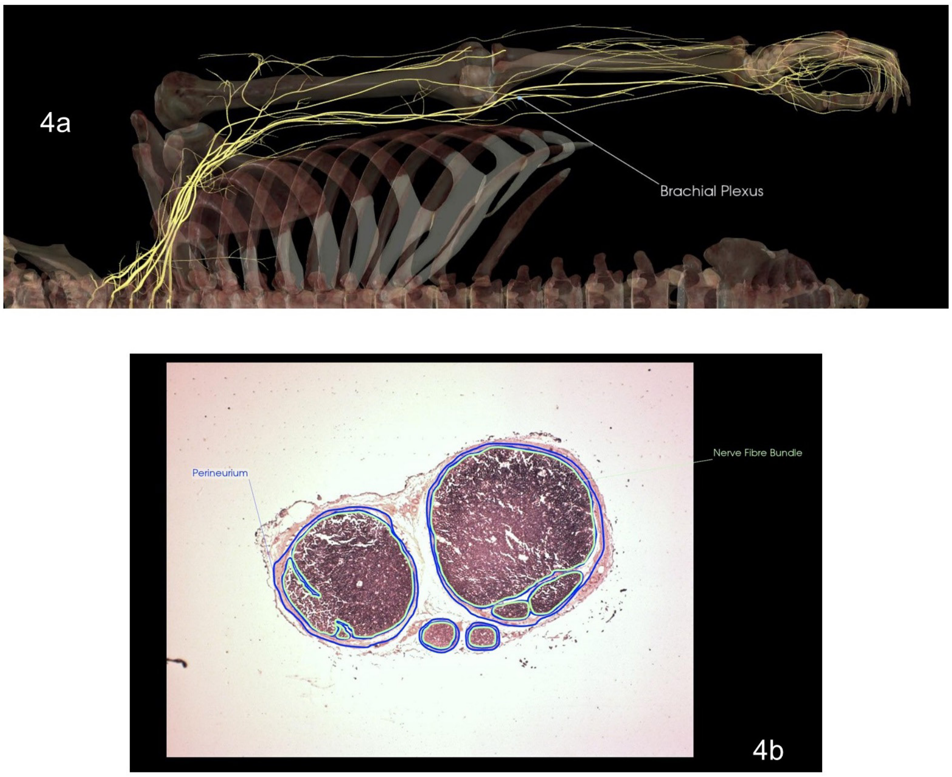

Figure 4. 4a) Brachial plexus and relevant upper limb nerves highlighted. 4b) Histology scan of a peripheral nerve, with perineum and nerve fiber bundle marked. Anatomage Inc. - Anatomage Table EDU. The image is sourced Institute for Anatomy and Embryology, University Medical Center Goettingen, Germany, visualized with the Anatomage Table.

Conclusion

Thanks to the several types of data contained in the TableEDU 9.0.3 software it was possible to perform a simple review of a clinical case, that can be used as a starting point to perform a more detailed analysis of the physiology of different structures and systems of the human body. This could let the Table be used as a support tool in main physiology courses, allowing users to create their own material by combining together different types of content from the device libraries. Moreover, teaching sessions can be enhanced, once a didactic baseline has been created, by integrating information coming from other sources (such as different courses or topics).

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High structure course design to improve student engagement and learning

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What is high structure course design?

There have been many calls in recent decades to improve undergraduate STEM education by using evidence-based practices and course design principles [1, 2]. Active learning, which is a teaching style wherein students are engaged in the learning process during class using activities, group problem solving, case studies, and personal response systems, among many other ways, has been shown to improve student performance in STEM courses [3]. However, what happens before and after class are equally important and well-designed pre-class and after-class activities can help students develop strong metacognitive skills and study skills.

High structure course design (Figure 1) aims to build on active learning through the pre- and after-class components of a course. In this model, which is built on scaffolding [4], students are guided through the learning process via pre-class content acquisition and formative assessment, in-class active learning, and after-class review and formative and/or summative assessment. This course design experience begins with backward design where course-level and lesson-level learning objectives are well-articulated so that students know what they need to able to do in terms of demonstrating conceptual knowledge and skill development and all downstream assessments and learning activities are tied to these objectives [5].

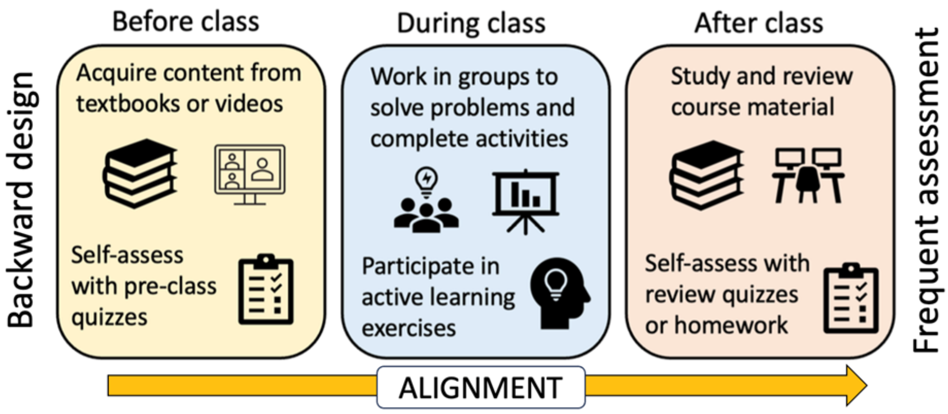
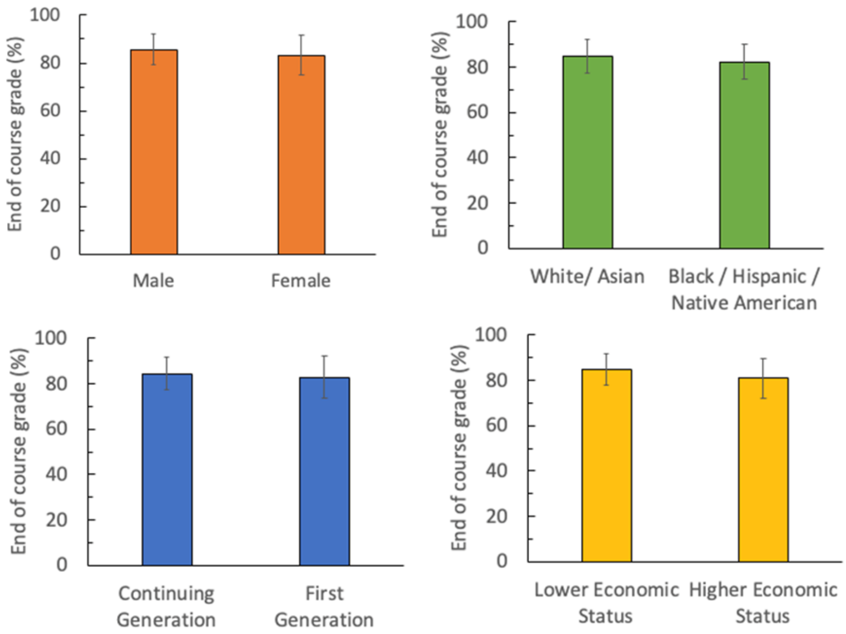


Figure 1. Overview of high structure course design

What are the benefits of teaching with high structure?

There are a myriad of benefits that come from high structure course design. First, students perform better on exams and thus learning increases [6-8]. Second, using high structure course design results in reduced or closed performance gaps between student groups including those based on gender, ethnicity, college generation status, and economic status [7, 9-11]. Indeed, data from the author's own high structure human anatomy and physiology course demonstrate no gaps in these demographic categories (Figure 2). Third, students feel more belonging in that they feel better connected to their local community and university and that they make more friends [12]. Fourth, students are able to use the many practice opportunities in a high structure course to frequently self-assess their learning and develop their metacognition and study skills. Last, by moving some basic content pre-class and asking students to be accountable for it, time is freed up in class for instructors to use higher-level examples, introduce real-world case studies, and have students work through more in-depth active learning activities.

Figure 2. Performance data of three semesters of a high structure human anatomy and physiology course at the Colorado School of Mines (n = 102). No gaps exist based on these four student demographic groups



How can instructors adopt high structure course design principles?

Interested instructors can work on adding high structure course design features to an existing course or build a high structure course from scratch. Below are some guiding tips to consider when doing so.

• Be transparent – Let students know why you are using high structure course design and share the data with them to showcase how it is beneficial.

• Be aligned – make sure all of your pre-class, in-class, and after-class activities and assessments are not only tied to your learning objectives, but also that they are tied to each other in that the in-class component builds on what happens pre-class and the after-class component builds on what happens in both pre-class and in-class.

• Find your niche – Not all high structure courses are identical. Design your course the way that will work for you and your students, but be sure to include engaging pre-class, in-class, and after-class components.

• Don't reinvent the wheel – There are many web resources from disciplinary societies or more general teaching databases that you can rely on to find activities, assessments, and problems for students to work on. Don't forget to also use whatever resources come from your textbook publisher as well as colleagues who teach similar courses. General artificial intelligence can also be quite helpful for brainstorming ideas!

• Start small (and short!) – When first trying to add high structure components it might be best to add one piece at a time and build up over several semesters so as to be able to balance your course design with your other duties. In addition, when adding active learning, first try short, one minute or less activities (for example, just have your students chat with each other about the problem at hand!) before moving on to more-involved strategies and techniques.

Conclusion

No matter what type of discipline you teach in, high structure course design can be a useful addition to your teaching toolbox so as to simultaneous increase student engagement and student learning. There is a time commitment to adding high structure components on both the instructor side and student side, but the benefits outweigh the costs as not only do all students do better with high structure but students who have historically struggled in STEM do disproportionately better. Make use of your colleagues and get feedback as you introduce high structure course design so as to ensure a smooth course design and teaching experience. Good luck!

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