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The Impact of Anatomy Computer-assisted Learning Training and Computer Literacy on Medical Students' Performance

Ana Cristina Pedrosa Beleza Carvalho

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Autor:
Ana Cristina Pedrosa Beleza Carvalho
cristinapbcarvalho@gmail.com

Orientador:
Ana Margarida Pinheiro Povo
Professora Auxiliar Convidada, Instituto Ciências Biomédicas Abel Salazar, Universidade do Porto
Assistente Hospitalar, Serviço de Cirurgia, Centro Hospitalar Universitário do Porto

Co-Orientador:
Bruno Tiago dos Santos Guimarães
Colaborador Externo, Faculdade de Medicina, Universidade do Porto
Interno de Formação Específica, Serviço de Medicina Física e Reabilitação, Centro Hospitalar Entre Douro e Vouga.

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Orientadora: Professora Doutora Ana Margarida Pinheiro Povo

Co-orientador: Professor Doutor Bruno Tiago dos Santos Guimarães

Aluna: Ana Cristina Pedrosa Beleza Carvalho

The Impact of Anatomy Computer-assisted Learning Training and Computer Literacy on Medical Students' Performance

Ana Cristina Carvalho,[1] Raquel Santos, [1] Stanislav Tsisar,[1] Diogo Ferreira, [1] Maria Amélia Ferreira[2], Bruno Guimarães,[1,2,3,4,*] and Ana Povo[5,6]

[1] Department of Surgery and Physiology, Faculty of Medicine, University of Porto, Porto, Portugal.

[2] Department of Public Health, Forensic Sciences and Medical Education, Faculty of Medicine, University of Porto, Porto, Portugal.

[3] Cardiovascular Research Center. Faculty of Medicine, University of Porto, Porto, Portugal.

[4] Physical and Rehabilitation Medicine Department, Centro Hospitalar de Entre o Douro e Vouga, Santa Maria da Feira, Portugal.

[5] Surgery Department, Instituto de Ciências Biomédicas Abel Salazar, University of Porto, Porto, Portugal.

[6] Ambulatory General Surgery Department, Centro Hospitalar Universitário do Porto, Porto, Portugal.

Running Title: Impact of anatomy CAL on academic performance

*Correspondence to: Dr. Bruno Guimarães, Department of Surgery and Physiology, Faculty of Medicine, University of Porto, 4200-319, Porto, Portugal. E-mail: btsguimaraes@med.up.pt.

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Resumo

O ensino de anatomia enfrenta desafios crescentes. Este contexto favorece a introdução de novas abordagens pedagógicas baseadas na *computer-assisted learning* (CAL). Esta abordagem fornece informações sobre os perfis de aprendizagem dos estudantes e características que estão correlacionados com a aquisição de conhecimento anatómico. O objetivo deste estudo é perceber a influência do estudo de anatomia através de CAL na performance académica, e caracterizar a literacia computacional e uso de computador dos estudantes. Um total de 671 estudantes de medicina frequentando as disciplinas de Anatomia musculo-esquelética (MA) e cardiovascular (CA), foram colocados em um de três grupos (grupo MA, grupo CA, grupo MA+CA). O uso do computador e *internet* com objetivos pedagógicos foi ubíquo entre os estudantes participantes, mas estes apresentaram atitudes positivas perante *e-learning*, considerando que a *computer-assisted learning* favorece o processo de aprendizagem. A performance académica na disciplina Anatomia musculo-esquelética nos grupos MA ($r = 0.761$, $p<0.001$) e MA+CA ($r = 0.786$, $p < 0.001$), e na disciplina anatomia cardiovascular nos grupos CA ($r = 0.670$, $p < 0.001$) e MA+CA ($r = 0.772$, $p < 0.001$), mostrou uma grande correlação positiva com o número de sessões de treino CAL. Múltiplos modelos de regressão linear foram realizados, considerando a performance académica, quer em anatomia musculosquelética, quer em anatomia cardiovascular, como variável dependente. Foi observada uma associação entre a quantidade de treino CAL e a performance académica. Estes resultados sugerem que o treino CAL em anatomia tem um efeito positivo dose-dependente na performance académica em anatomia. Perceber os perfis de aprendizagem dos estudantes, características individuais e experiência académica, contribui para a otimização do processo de aprendizagem.

Palavras-chave: educação médica; educação pré-graduada; perfis de aprendizagem; performance académica em anatomia; *computer-assisted learning; computer-assisted training;* análise de aprendizagem

Abstract

Anatomy education is facing increasing challenges. This context is contributing to the introduction of new pedagogical approaches based on computer-assisted learning (CAL). This approach provides insight into students' learning profiles and features that are correlated with anatomy knowledge acquisition. The objective of this study was to understand the influence of anatomy CAL training on academic performance as well as to characterize the students' computer literacy and computer usage. A total of 671 medical students attending Musculoskeletal (MA) and Cardiovascular Anatomy (CA) courses were allocated to one of three groups (MA Group, CA Group, MA + CA Group). The use of computer and internet for pedagogical purposes was ubiquitous among the study participants, while the students presented positive attitudes towards e-learning, considering that CAL favors learning process. Musculoskeletal and Cardiovascular Anatomy academic performance in both MA Group ($r = 0.761$, $p < 0.001$) and MA+CA Group ($r = 0.786$, $p < 0.001$) and in both CA Group ($r = 0.670$, $p < 0.001$) and MA+CA Group ($r = 0.772$, $p < 0.001$) respectively, showed a large positive correlation with the number of CAL training sessions. Multiple linear regression models were done considering either Musculoskeletal or Cardiovascular Anatomy academic performance as dependent variable. An association between Anatomy academic performance and the amount of CAL training was observed. The results suggest that CAL training in Anatomy has positive dose-dependent effect on Anatomy academic performance. Understanding students' learning profiles, individual features and academic background both contribute to the optimization of the learning process.

Key words: medical education; undergraduate education; learning profiles; anatomy academic performance; computer-assisted learning; computer-assisted training; learning analytics.

Lista de abreviaturas

CA - Cardiovascular Anatomy

CAL – Computer-assisted learning

CBA - Computer based assessment

CT - Computed tomography

FMUP - Faculty of Medicine, University of Porto

MA - Musculoskeletal Anatomy

MCQ - Multiple choice questions

MRI - Magnetic resonance imaging

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Introduction

Technology is becoming a part of modern Medicine, influencing the medical practice, research and learning process [1-4] . As consequence, Medical Education has been adapting and introducing technology in its processes.

The role of technology in Medical Education: the Case of Anatomy

The introduction of technology serving pedagogical purposes in Medical Education was favored by the medical curriculum reforms [5-7]. In this scenario, traditional core medical fields have been experiencing new challenges, such as the decrease in the curricular time devoted to teaching and insufficient logistical resources [8-12]. Anatomy, a traditional core basic science in Medical Curriculum, is a paradigmatic example of the influence of technology in its teaching approach. Indeed, besides the aforementioned challenges, the technological development in human body visualization promoted in clinical practice (namely by the collection of images using magnetic resonance imaging (MRI), computed tomography (CT), ultrasound and the introduction of laparoscopic and endoscopic procedures in the diagnostic/therapeutic medical and surgical approaches) heavily impacted Anatomy's current pedagogical perspective [12-14].

At pedagogical level, among others, technology promoted the implementation of intelligent tutoring systems, learning management systems and simulation systems [15-17]. In a broader sense, the stated pedagogical approaches can be characterized as computer-assisted learning (CAL) – teaching/learning methodologies supported by computerized platforms which enhance students learning experience [18, 19] and computer based assessment (CBA) – assessment of students' knowledge through computerized simulation environments [20-23]. CAL approaches have been associated with the enhancement of problem solving skills [11, 24], independent and flexible learning [11] and reduction of the logistics and costs associated with traditional learning methods [25]. Also, CBA platforms have been gathering students' satisfaction, without compromising their performance when compared with traditional assessment methods [9, 21]. Furthermore, both CAL and CBA platforms allow the easy incorporation of medical imaging, endoscopic and laparoscopic films, promoting a more clinically oriented perspective about the human body anatomy [11, 26].

In parallel, CAL and CBA provide the framework to better understand learners and their learning process [27]. In fact, every action or step during the learning process leaves a trace or footprint. This information can be easily gathered by CAL and CBA according to the Learning Analytics' principles. Learning Analytics advocates the measurement,

collection, analysis, and reporting of data about learners and their contexts, in order to understand and optimize the learning process so as to enhance/personalize the learning experience [28, 29].

The impact of Computer-assisted learning in learners' performance

As previous mention, the pedagogical context favored the implementation of new complementary pedagogical approaches, as CAL [9, 30]. More recently, the focus has been on evaluating, not only students' preferences and attitudes towards the new pedagogical approaches, but the effectiveness of CAL in contribution for the learning process [31-33].

Studies in different academic fields of knowledge have evaluated the impact of CAL in students' academic performance. When combined with face-to-face teaching, some studies showed that CAL is associated with an improved retention of contents [34, 35], better attitudes towards the subject matter, increase in students' satisfaction, and better achievements on exams [34-36]. In Anatomy field, some studies showed that students who used CAL or web-based resources more frequently, obtained better performances on exams compared with students that had never accessed these resources [36-38]. Furthermore, in Neuroanatomy, Arantes *et al.* [39] found that CAL training contributed to improve academic performance, while learners expressed positive attitudes towards these tools.

Nevertheless, some studies didn't show positive evidence regarding the impact of CAL training in academic performance, neither in other pedagogical fields [40], nor in Anatomy [41-43].

How to favor the adoption of CAL: the importance of the perception and skills correlated with computer literacy

Despite CAL being regarded as a positive complementary pedagogical approach to traditional learning approach [44-48], the lack of computer literacy impacts students' perception on CAL. Indeed, students with poor computer skills have shown a trend toward considering that e-learning isn't more than the distribution of notes through the internet, revealing the absence of students' knowledge on the potential of CAL [44]. This perception changes as students acquire computer skills [44, 49]. Indeed, the previous experience with computers and e-learning has a big effect on students' perceptions regarding computer-assisted learning [48].

In overview, computer literacy is the collection of skills relating to the use of information and communication technology [50] and it also involves knowledge related to basic operating systems functions and skills necessary to perform tasks in word processing, databases, spreadsheets, generic data management and communication applications as well as search strategies [51]. In that sense, to improve the adherence to CAL and CBA medical courses have been increasingly concerned with the improvement of students' computer literacy [47, 51-53].

Anatomy Courses at the Faculty of Medicine, University of Porto

Anatomy education in the Faculty of Medicine, University of Porto (FMUP) is distributed throughout the first two years of the medical curriculum. Anatomy courses are integrated with Physiology and Histology courses.

Since the Medical curricular reform in 2013, Anatomy courses at FMUP suffered a significant reduction in their contact hours, from 309 to 180.5 hours [9]. Hence, cadaveric dissection was abandoned in favor of cadaveric prosection, a less time-consuming teaching strategy. Additionally, it is estimated that over the last 20 years, Portuguese medical schools registered a 397% increase in students' enrolment [54], further contributing to these logistical restrains.

The current curriculum organization of Anatomy courses in FMUP integrates the Musculoskeletal Anatomy course and Neuroanatomy course, respectively in the first and second semesters of the first year. In the second year, students take the Cardiovascular Anatomy and Endocrine/Reproductive Anatomy courses in the first semester. Digestive system Anatomy, Respiratory/Urinary Anatomy and Integrative Anatomy courses are taken in the second semester.

Each course is composed by theoretical and practical lessons. The Musculoskeletal Anatomy course lasts for 9 weeks while the Cardiovascular Anatomy course takes 14 weeks. . The total contact hours in Musculoskeletal Anatomy is 46.5 hours, *versus* 24 hours in Cardiovascular Anatomy. Theoretical focus is placed on the general Anatomy principles, the correlations and the functionalities of anatomical structures and other relevant Anatomy clinical information. Practical lessons take place in the anatomical theatre and are based on cadaveric material prosection. The Musculoskeletal Anatomy course incorporates 4 one-hour long theoretical sessions and 17 practical exercises, each 2.5 hours long. This course focuses on the human bones, muscles and joints - except for the bones and muscles of the head that are object of study in Neuroanatomy - the general principles of movement, the superficial Anatomy and clinical knowledge regarding the musculoskeletal system. The Cardiovascular Anatomy

course includes two theoretical sessions (1 hour long), and 11 practical exercises, each 2 hours long. This course focuses on the heart and arterial/venous blood vessels' anatomy and correlations, as well as anatomy clinical knowledge related with the cardiovascular system.

By the end of the courses, students are subjected to the final assessment, which is composed by theoretical and practical examinations. The practical assessment is based on a short-answer steeplechase examination, in which a sequence of pin-pointed cadaveric anatomical structures is presented, for the purpose of students correctly identifying the pointed anatomical structure.

In order to address the challenges created by the anatomy courses reform in FMUP, a CBA platform (VIMU) was implement with the intent to reduce the logistical burdens associated with the assessment process [9, 55]. Based on the previous experiences, VIMU was adapted into a CAL platform to function as a training resource for the practical examinations of both the Musculoskeletal Anatomy and the Cardiovascular Anatomy courses.

In this context, a study was conducted to evaluate the impact of the training with the CAL platform on the anatomy academic performance of medical students. Indeed, the present study aims to assess the potential dose-dependent effect between students' academic performance and frequency of training with the CAL platform. Additionally, we intended to characterize the students' computer literacy and computer usage, while correlating that with students' adherence to the training session.

Material and Methods

This experimental protocol was approved by the Commission of Ethics for Health of Centro Hospitalar São João/Faculty of Medicine, University of Porto. Written informed consent was obtained from all participants.

Recruitment of Participants

This study took place in Faculty of Medicine, University of Porto. The participants consisted of 304 medical students enrolling the MA course (MA Group), the 241 medical students enrolling the CA course (CA Group) and the 126 medical students enrolling the both MA + CA courses, reflecting students that didn't obtain approval in MA course (MA + CA Group) (total number of 671 students) were contacted in person, by e-mail or cell phone to participate in the study. Of the original pool, 611 students (288 MA students, 217 CA students and 106 MA + CA students) responded and voluntary agreed to participate in the study. They were provided with informed consent forms.

Sample characterization

Information about all the participating students was collected to characterize the population in this study and thus to relate this information with their computer literacy. It was gathered information about the selected students that covered several parameters, such as, personal features (gender and age); admission to Medicine school (admission entry grade and type of enrolling program, which in this case was divided in the usual 1) undergraduate medical program and 2) Other – including the graduate medical program and foreigner students' program). Also, it was collected student's final steeplechase grade for the academic year during which the study was conducted (respectively Current Musculoskeletal Anatomy Course and Current Cardiovascular Anatomy Course). In addition, the performance in previous Anatomy related courses steeplechase examinations was also collected (Previous Musculoskeletal Anatomy Course for the CA Group and Previous Neuroanatomy Course for both the CA Group and MA + CA Group).

Software Description - VIMU

In this study we used a training platform called VIMU, which is an e-learning online platform. It was raised in Porto, Portugal, 2012, under the jurisdiction of FMUP's

Department of Public Health, Forensic Science and Medical Education (at the time of creation it was the Department of Medical Education). VIMU was created with the aim to function as a training tool for CAL of Anatomy. This platform simulates theoretical pen-and-paper tests (multiple-choice questions (MCQ)) and practical steeplechase tests [9].

VIMU has several modules. For the purposes of this study, we use the *Virtual Quiz* module which simulates the steeplechase. It displays a series of stations, each containing two main 2D images of cadaveric anatomical, with one pinpointed anatomic structure per image. Bearing in mind that the original cadaveric anatomical structures have volume (3D structures), each main 2D images displayed is accompanied by another one with an alternative spatial orientation to ensure that the 2D nature of the images does not impair the spatial orientation of the depicted structure. Students have sixty seconds to complete each station (i.e. to type both answers through the keyboard). When the time limit elapses, the software automatically presents them with the following station.

Immediately after completing the steeplechase examination, students are provided with a review of their examinations in the *Results and Review* module. In this module, students access the obtained grade (in a scale of 0 to 20) and are able to review each individual question contemplating the correct answer. In addition to providing feedback to the student, this platform has the capacity of granting teachers access to information about students' performance. Indeed, in the *Backoffice* module, teaching staff besides creating the questions and examinations, can access to the information about the examinations designed (e.g. percentage of correct and incorrect answers as well as the percentage of unanswered questions; examinations' difficulty, discrimination and reliability indexes; students' grade distribution) and for each question (e.g. percentage of right answers/wrong answers/absence of answer as well as difficulty and discrimination indexes).

Study Design

The students that accepted to participate in the study were invited for a mandatory preparatory session. In this session, they learned the functionality of VIMU platform, and students' computer literacy and attitudes towards computer-based learning were also accessed through the completion of the evaluation questionnaire "*Computer-based learning*" [48].

After the preparatory session, students were proposed to complete online training through VIMU's *Virtual Quiz* module, between the period of 3 weeks comprised between the end of the academic semester and the beginning of final assessment period.

Each training session consisted in a steeplechase examination that respects a blueprint of topics covering all the essential outcomes of the Musculoskeletal and Cardiovascular Anatomy courses and vetted by the teaching staff. The construction of the steeplechase examinations was based on a question bank created by the teaching staff. The content incorporated was based on the cadaveric material used in Musculoskeletal and Cardiovascular Anatomy classes. Photographs of cadaveric material were collected with high-resolution cameras (in different perspectives) and then treated in image editor software (to introduce pin-pointed anatomical structures). Two members of teaching staff, based on the previous defined blueprint, independently selected from the collected images the ones to be incorporated in the question-bank that supported the training sessions. If consent was not reached, the opinion of a third teaching staff member was used. Each question was composed by two 2D images of the same anatomical structure in different spatial orientations, to facilitate the contextualization.

Each Musculoskeletal Anatomy and Cardiovascular Anatomy training steeplechase examination comprised 10 stations, with a total of 20 anatomic structures digitally pinpointed on photographs of cadaveric material. There were provided 15 training sessions for Musculoskeletal Anatomy course and 12 training sessions for Cardiovascular Anatomy course. The sessions were gradually available, with an average of one sessions per day, during 24 hours at VIMU platform, which students accessed through an individual account. The training session were merely formative nature, and thus they were not mandatory -students weren't penalized if they did not completed the purposed training session. The adherence to the training sessions was evaluated and defined in two variables: Musculoskeletal Anatomy Training Sessions and Cardiovascular Anatomy Training Sessions.

After the training period, anatomy courses assessment performance was analyzed.

The schematics of the study design is represented in figure 1.

Computer-based Learning **Questionnaire**

Students' computer literacy and demographic was assessed through the *Computer-based learning* questionnaire (in appendix) [48]. An adapted short-version of this questionnaire was applied. It was constituted by 3 groups, designed to collect information about: attitudes and previous experiences with e-learning; computer usage and access to a computer and internet.

To evaluate attitudes towards e-learning, the students were to indicate their degree of agreement with each statement about the importance of computer and communication

technologies (ICT) in Medical Education, on an 8-point likert type scale, ranging from 1 (completely disagree) to 8 (completely agree). These statements contained items such as “E-learning should be nothing more than the distribution of notes over the Internet” and “Web-based learning programs are able to replace lectures”. Previous contact with e-learning was evaluated through a multiple-choice question, in which students had to indicate the different e-learning programs they had already contacted with. There was also a question with similar items where students have to selected which of the learning support programs they considered most useful, based on their experiences. Some of the programs were “forums for communicating with other students”, “learning management systems”, “quizzes” and “simulations”, among others.

In order to assess computer usage and access to a computer and internet students indicated the frequency (daily, several times a week, several times a month, less often or never) in which they used the computer for some tasks, like “Organize appointments, tasks, and notes”, “Create spread sheets or perform calculations”, “send emails”, among others.

Students’ private computer infrastructure and their internet access were also evaluated, in multiple-choice questions.

Statistical Analysis

All data analyses were undertaken using the Statistical Package for Social Sciences (SPSS®), version 22.0 for Windows (IBM Corp., Armonk, NY). Statistical significance was determined at the level of $p < 0.05$.

The characteristics of the population in study were assessed by categorical variables as gender, type of enrolling program and anatomy courses approval status, described in terms of absolute and relative frequencies. Also, characteristics of the population in study were assessed by continuous variables as age, grade in anatomy courses among approved students, the number Musculoskeletal Anatomy Training Sessions and Cardiovascular Anatomy Training Sessions, described in terms of mean and standard deviation.

Computer literacy features were described in relative frequencies. The agreement with the use of CAL in Anatomy was described in terms of mean and standard deviation. The agreement with the use of CAL was then compared between MA Group, CA Group and MA+CA Group. Differences among the experimental groups, regarding attitudes towards e-learning were evaluated with the use of an analysis of variance (ANOVA), followed by the independent sample t-test, when findings with the ANOVA model were significant. Cohen’s d examined the effect size of the agreement with the use of CAL

difference between groups, using the mean scores and standard deviations of both groups [56]. For the purpose of interpretation, the effect size's cut offs were considered as defined by Cohen (1988) and Sawilowsky [56, 57].

The Anatomy academic performance scores obtained were described in terms of mean and standard deviation. Pearson's correlation coefficient (r) was used to assess the correlation between the anatomy academic performance score and the number of Musculoskeletal Anatomy Training Sessions and Cardiovascular Anatomy Training Sessions performed. In addition, anatomy academic performance score was correlated with the classifications in the previous academic years' anatomy courses, as well as the students' age and admission grades. Cohen's standard [58] was used to evaluate the correlation coefficients to determine the strength of the relationship, or the effect size. In this case, correlation coefficients between 0.10 and 0.29 represent a small association, coefficients between 0.30 and 0.49 represent a medium association, and coefficients of 0.50 and above represent a large association or relationship [58]. The association between the anatomy academic performance and students' gender, and the type of enrolling program was assessed through independent sample t-test. Cohen's d examined the effect size of the anatomy academic performance using the mean scores and standard deviations each group [56]. Cohen's d examined the effect size of the anatomy academic performance, using the mean scores and standard deviations, of each group [56]. For the purpose of interpretation, the effect size's cut offs were considered as defined by Cohen (1988) and Sawilowsky [56, 57].

Multiple linear regressions were used to identify the variables associated with anatomy academic performance score (dependent variable). The covariates used the model were: the number of Musculoskeletal Anatomy Training Sessions and Cardiovascular Anatomy Training Sessions performed, the students' age, gender, admission grades and the type of enrolling program, and for the cases of the CA and the MA + CA Group the classifications in the anatomy courses of previous academic years.

The adjusted regression model showed that an increase in one unit of each of the variables included in the model is associated with an increase of (correspondent to B value) units of the anatomy academic performance.

Results

Characteristics of participants

The 611 students that participated in both pre-training and post-training sessions were distributed in the MA Group (288 students), CA Group (217 students) and MA + CA Group (106 students). All the groups were constituted mainly by females [MA Group N = 188 (65.3%), CA Group N = 131 (60.4%), MA + CA Group N = 80 (75.5%)]. The mean age of the participants was 20.8 ± 4.35 (range of 18 to 40 year-old) for the MA Group, 21.2 ± 3.43 (range of 19 to 42 year-old) for the CA Group, and 21.6 ± 3.73 (range of 19 to 39 year-old) for the MA + CA Group, as shown in Table I.

The mean admission grade was 18.48 ± 1.00 (MA Group), 18.62 ± 1.02 (CA Group), and 18.52 ± 0.88 (MA + CA Group). The number of students admitted under the undergraduate medical program was 237 (82.3%) for the MA Group, 180 (82.9%) for the CA Group, and 89 (84.0%) for the MA + CA Group, as presented in Table I.

In Anatomy courses in previous academic years, the number of approved students in the previous Neuroanatomy course was 178 (82.0%), with a mean grade within approved students of 13.8 ± 2.30 for the CA Group and 51 (48.1%), with a mean grade within approved students of 11.5 ± 1.57 for the MA + CA Group. Furthermore, the number of approved students in the previous Musculoskeletal Anatomy course was 147 (67.7%), with a mean grade within approved students of 12.6 ± 2.22 for the CA Group, as shown in Table I.

The number of approved students in the current Musculoskeletal Anatomy course was 124 (43.1%), with a mean grade within approved students of 12.2 ± 2.03 for the MA Group and 58 (54.7%), with a mean grade within approved students of 12.7 ± 1.62 for the MA + CA Group. Additionally, the number of approved students in the current Cardiovascular Anatomy course was 201 (92.6%), with a mean grade within approved students of 15.4 ± 2.47 for the CA Group and 83 (78.3%), with a mean grade within approved students of 13.9 ± 2.50 for the MA + CA Group, as presented in Table I.

Computer literacy characterization

As expected, the results showed that all the students had access to a computer with Internet access in all the MA Group (100%) and in CA Group (100%) and in the MA+CA Group (100%). Moreover, in all groups, the majority of the students used computers with less than five years (that corresponds to the general life span of the

personal computer [59]) - MA Group (87,4%) and in CA Group (81,5%) and in the MA+CA Group (88,4%).

The average age that students started using computer for the first time was 7.43 ± 0.142 (range of 2 to 16 year-old) for the MA Group, 7.73 ± 0.162 (range of 3 to 17 year-old) for the CA Group, and 7.76 ± 0.246 (range of 3 to 16 year-old) for the MA+CA Group. Furthermore, the majority of students uses computer for learning purposes. In fact, at least once *per* month, the majority of students: search on the internet for relevant webpages – MA Group (93,5%) and in CA Group (98,6%) and in the MA+CA Group (99,0%), download notes or similar items from the Internet – MA Group (78,5%) and in CA Group (93,5%) and in the MA+CA Group (92,3%). Despite not as frequently, a significant percentage of students, on a monthly basis, accessed the learning management system – MA Group (31,1%) and in CA Group (39,6%) and in the MA+CA Group (51,0%), or the use of CAL programs – MA Group (31,6%) and in CA Group (50,7%) and in the MA+CA Group (56,7%).

Generally, the animations or videos – MA Group (15,6%), CA Group (19,8%) and MA+CA Group (22,6%) - computerized simulation assessment environments system – MA Group (16,7%), CA Group (12,0%) and MA+CA Group (21,7%) - and online quizzes system – MA Group (18,1%), CA Group (26,7%) and MA+CA Group (20,8%) - were identified as the most useful CAL pedagogical resources.

The level of agreement towards the use of CAL (Group III of the questionnaire) only showed differences in question 2 (MA: 3.26 ± 1.673 vs. CA: 3.85 ± 1.752 vs. MA+CA: 4.00 ± 1.740; $p < 0.001$), namely between MA Group and both other groups (MA: 3.26 ± 1.673 vs. CA: 3.85 ± 1.752; $p < 0.001$, Cohen's $d = 0.346$) (MA: 3.26 ± 1.673 vs. MA+CA: 4.00 ± 1.740; $p = 0.001$, Cohen's $d = 0.434$), as showed in figure 2. No statistically significant differences were found between the group for the other questions: Q1 (MA: 5.58 ± 1.496 vs. CA: 5.42 ± 1.375 vs. MA+CA: 5.60 ± 1.452; $p = 0.421$), Q3 (MA: 2.12 ± 1.420 vs. CA: 2.27 ± 1.341 vs. MA+CA: 1.95 ± 1.272; $p = 0.131$), Q4 (MA: 6.77 ± 1.445 vs. CA: 6.48 ± 1.407 vs. MA+CA: 6.55 ± 1.600; $p = 0.079$), Q5 (MA: 3.12 ± 1.704 vs. CA: 2.64 ± 1.452 vs. MA+CA: 2.92 ± 1.728; $p = 0.152$) and Q6 (MA: 3.90 ± 1.980 vs. CA: 3.78 ± 1.864 vs. MA+CA: 4.33 ± 2.102; $p = 0.060$), as showed in figure 2.

Correlation between CAL and performance in Anatomy courses

The Musculoskeletal Anatomy academic performance in the MA Group showed a large positive correlation with the number of Musculoskeletal Training sessions ($r = 0.761$, $p < 0.001$), a small positive correlation with the Admission Grade ($r = 0.194$, $p = 0.003$) and a small negative correlation with students' age ($r = -0.136$, $p = 0.025$). Similarly,

Musculoskeletal Anatomy academic performance in the MA + CA Group showed a large positive correlation with the amount of Musculoskeletal Training sessions ($r = 0.786$, $p < 0.001$). Also, the female students in MA + CA Group showed better Musculoskeletal Anatomy academic performance (10.92 ± 3.32 vs. 8.95 ± 4.09) with a medium effect size ($p = 0.028$; Cohen's $d = 0.528$), as presented in Table II.

The Cardiovascular Anatomy academic performance in the MA Group showed a large positive correlation with the number of Cardiovascular Training sessions ($r = 0.670$, $p < 0.001$), a medium positive correlation with the previous Neuroanatomy academic performance ($r = 0.439$, $p < 0.001$) and a small positive correlation Musculoskeletal academic performance ($r = 0.294$, $p < 0.001$). Also, the male students in CA Group showed better Cardiovascular Anatomy academic performance (15.47 ± 3.04 vs. 14.48 ± 3.20) with a medium effect size ($p = 0.028$; Cohen's $d = 0.325$). Similarly, Cardiovascular Anatomy academic performance in the MA + CA Group showed a large positive correlation with the amount of Musculoskeletal Training sessions ($r = 0.772$, $p < 0.001$) and a medium positive correlation with the previous Neuroanatomy academic performance ($r = 0.442$, $p < 0.001$), as presented in Table III.

Multiple Linear Regression Models

For both MA group and MA + CA group, the multiple linear regression models showed that the Musculoskeletal Anatomy academic performance was significantly associated with the number of Musculoskeletal Anatomy Training Sessions ($p < 0.001$). In both groups, the other variables didn't appear to be significantly related with Musculoskeletal Anatomy academic performance. The presented model explained for almost 60% of the variation of the Musculoskeletal Anatomy academic performance in either MA Group and MA + CA Group, as shown in Table IV.

Similar trend was observed for both CA Group and MA + CA Group regarding Cardiovascular Anatomy academic performance. Indeed, for these groups the multiple linear regression models showed that the Cardiovascular Anatomy academic performance was significantly associated with the number of Cardiovascular Anatomy Training Sessions ($p < 0.001$). Also, in both cases, Cardiovascular Anatomy academic performance was significantly associated with previous Neuroanatomy academic performance (CA Group: $B = 0.259$, $p<0.001$; MA + CA Group: $B = 0.393$, $p = 0.001$). In the case of the CA Group, Cardiovascular Anatomy academic performance was also significantly associated with students' gender ($B = 0.755$, $p = 0.006$). The other variables didn't appear to be related with the performance in the Cardiovascular Anatomy academic performance. The presented model explained for more than 50% and 60% of the variation

of the Cardiovascular Anatomy academic performance in CA Group and MA + CA Group respectively, as shown in Table V.

Discussion

Understanding the influence of students' profiles and features in the learning process is essential for modern education [60, 61]. Indeed, these principles are on the basis of the Learning Analytics [28, 62]. Learning Analytics advocates the collection, measurement and analysis of the growing quantity of data regarding not only students' performance, but also their cognitive profiles and background [29, 62]. Ultimately, its goal is to interpret students' learning progression, and how to contribute to the optimization and personalization of the learning process [62].

In the current anatomy education context, different studies revealed the influence that the training with CAL has on Anatomy academic performance [36-38]. Nevertheless, to the authors' knowledge, despite few attempts, no study quantified the impact that the training with CAL in Anatomy has in comparison with other features that might affect the academic performance outcome. Contemplating this information is very relevant, not only to implement, but also to evaluate the pedagogical interventions. In this sense, the present study supports that the use of CAL platforms in Anatomy for training purposes contributes to the improvement of anatomy academic performance. Moreover, it suggests that training with the CAL platforms has a direct dose-dependent influence on students' anatomy academic performance, presenting likewise a larger influence than other features of students' background.

Students' Computer Literacy and Perspectives

As expected, all the students reported to have access to both computer and Internet. As a matter of fact, computerized resources are becoming ubiquitous among the newest generation of medical students, and particularly in Anatomy field [9, 10, 13]. This context underlines a huge opportunity to the implementation of e-learning systems in anatomy education, particularly in FMUP, due to the recent challenges imposed by the reforms in medical curriculum, the reduction in teaching time, and also the increase in the number of students in Portuguese medical schools.

In this regard, it is relevant to analyze students' computer literacy, since it is being described as an important factor influencing their attitudes towards new learning environments [63, 64]. The found results suggest that students' computer literacy wasn't the limiting factor for the implementation and consequent use of the CAL platform in Anatomy. This observation was similar to other studies - in fact, some studies have shown that students are able to adopt new technologies in their learning quite easily, even if they are not familiar with these educational technologies [36, 65].

On other hand, as previously described [66-68], it is relevant to assess students' perceptions towards CAL in Anatomy, in order to guarantee a successful implementation of these pedagogical approaches [63].

In line with the findings described in other reports regarding anatomy field, the results showed that students presented positive attitudes towards e-learning, considering that it favors their learning process [49, 66, 67, 69]. Moreover, the overall acceptance towards CAL was independent of the course in analysis, in line with the findings described in other reports regarding Anatomy field.

Variables that correlate with Anatomy academic performance

In the analyzed groups, the main correlation observed was between Anatomy academic performance and the correspondent training sessions attended. Indeed, this result reflects the importance of the amount of training over the other examined features like age, gender or enrollment background, and even Anatomy academic background. These results are in agreement with the literature [34-36]. These findings support that subsequent pedagogical interventions with CAL in the Anatomy field should consider the amount of training as the main concern, in order to achieve an improvement in Anatomy academic performance.

Also, the previous Anatomy courses academic performances, namely Neuroanatomy course performance, were positively correlated with the evaluated Anatomy academic performance, which is similar to what was observed in other study [70], reflecting the importance that the previous academic performance background has on predicting the performance outcome, namely in Anatomy cases.

The remaining analyzed variables haven't showed to be consistently correlated with academic performance across all groups. Therefore, even if punctual correlations between Anatomy academic performance and features as gender, age, and previous academic background (admission grade and enrolling program) might be found, they don't seem to condition the academic performance in the same extent as the CAL training. These results come in line with the observed in a previous study from this group, which showed that the improvement in spatial abilities, a fundament skill to Anatomy learning [71], was mostly correlated with Anatomy CAL training, while the other variables, didn't show to have influence [55].

Dose-dependent effect of Anatomy CAL training sessions in the spatial abilities

The multiple linear regressions models supported the previous observations. As a matter of fact, CAL training sessions were positively associated with the Anatomy academic performance in all groups. Likewise, previous academic performance in other anatomy courses (in the case Neuroanatomy course) showed positive association with the Cardiovascular Anatomy academic performance. However, this observation wasn't consistent, since Musculoskeletal Anatomy academic performance in MA+CA Group didn't show the same association. Similar findings were observed regarding gender: in the case of the CA Group, it showed association with Anatomy academic performance, while this association wasn't found neither in MA Group or in MA + CA Group.

The sustainability of the coefficient of determination (R-squared) across the different models and the expressive percentage of the response variable variation that is explained in the presented models (between 50 and 65%), supports the use of these models and the variables in analysis for measuring the factors that impact Anatomy academic performance.

The presented models emphasize the role that the CAL training sessions have on Anatomy academic performance. Furthermore, for each group, the models gave a sense of a dose-dependent effect between the number of training sessions performed and improvement in academic performance. Indeed, each Musculoskeletal Anatomy CAL training session attended reflected an enhancement of 0.789 for the MA Group and 0.687 for the MA + CA Group in Musculoskeletal Anatomy academic performance, while each Cardiovascular Anatomy CAL training session attended reflected an enhancement of 0.569 for the CA Group and of 0.793 for the MA + CA Group in Cardiovascular anatomy academic performance. Hence, the results support that interventions aiming to improve Anatomy academic performance should be implemented in the field of anatomy through CAL, and that the amount of training is the best predictor of the level of improvement.

Limitations of this study

It should be taken in consideration that the evaluation of computer literacy and perspectives towards CAL and the relationship between learning Anatomy and these skills, could have been conducted with other questionnaires, different than the one adapted. Also, with the evolution and ubiquitination of technology, it is relevant to reflect on the best approach to measure computer literacy and perspectives in general towards CAL, namely if the used approached is outdated. However, the significant adhesion to the conducted pedagogical initiative, confirmed by the significant attendance to the CAL

training session, supports the general observations that the studied population possesses the required computer literacy and positive perspectives towards the CAL purposed.

In the present study design, it was challenging to control the confounding factors that might influence Anatomy academic performance, such as students' learning commitment and motivation, as well as the amount of training and study completed by the students, besides the performed in the CAL platform. Among the possible confounding factors is the previous Anatomy knowledge, reflected by the performance in previous Anatomy courses [72]. To address this issue, the incorporation of the students' Anatomy courses performances in the multiple linear regression models was conducted. These models showed that the association between previous Anatomy courses performance and the current Anatomy academic performance isn't always present. Despite the fact that we could not exclude this effect, the impact in the observed anatomy performance appeared to be lesser than the impact of the training with CAL.

Furthermore, the study design didn't incorporate a traditional control group. This decision was taken because of ethical concerns regarding the availability of a pedagogical tool that might have contributed to improve the Anatomy knowledge, as well as the voluntary nature of students' participation in the study.

Conclusion

An evaluation of the impact that CAL in Anatomy has on medical students' academic performance was performed. The collected data demonstrates that the use of the CAL in Anatomy improved the Anatomy academic performance and that this improvement was dose-dependent, i.e. the amount of training through CAL was related with a larger improvement of the Anatomy academic performance. Furthermore, the presented level of computer literacy and perspectives towards CAL among the assessed population supports the implementation of this pedagogical solution for Anatomy teaching approach.

The role that CAL is adopting in Anatomy learning and assessment is undeniable. In addition, the increasing use of CAL enables the collection of, otherwise lost, data. This information once analyzed and processed, according to the Learning Analytics' principles, will contribute to the optimization and personalization of the learning process.

Thus, by raising awareness to the importance of students' learning profiles, as well as to the importance of measuring the impact that individual features and academic background have on the academic performance, the authors hope that further studies keep evaluating the factors that impact the knowledge acquisition in Anatomy education, and the potential role that CAL might have on them.

References

1. Ekeland, A.G., A. Bowes, and S. Flottorp, *Effectiveness of telemedicine: a systematic review of reviews.* International journal of medical informatics, 2010. 79(11): p. 736-771.
2. Schulmeister, L. *Technology and the transformation of oncology care*. in *Seminars in Oncology Nursing*. 2016. Elsevier.
3. Evans, R., *Electronic health records: then, now, and in the future.* Yearbook of medical informatics, 2016. 25(S 01): p. S48-S61.
4. Lehoux, P., et al., *Medical innovation and the sustainability of health systems: A historical perspective on technological change in health.* Health Services Management Research, 2016. 29(4): p. 115-123.
5. Ward, J.P., et al., *Communication and information technology in medical education.* The Lancet, 2001. 357(9258): p. 792-796.
6. Guze, P.A., *Using technology to meet the challenges of medical education.* Transactions of the American Clinical and Climatological Association, 2015. 126: p. 260.
7. Trelease, R.B., *From chalkboard, slides, and paper to e-learning: How computing technologies have transformed anatomical sciences education.* Anatomical sciences education, 2016. 9(6): p. 583-602.
8. Drake, R.L., *A retrospective and prospective look at medical education in the United States: Trends shaping anatomical sciences education.* Journal of anatomy, 2014. 224(3): p. 256-260.
9. Guimarães, B., et al., *Rethinking Anatomy: How to Overcome Challenges of Medical Education's Evolution.* Acta medica portuguesa, 2017. 30(2): p. 134-140.
10. Sugand, K., P. Abrahams, and A. Khurana, *The anatomy of anatomy: a review for its modernization.* Anatomical sciences education, 2010. 3(2): p. 83-93.
11. Johnson, E.O., A.V. Charchanti, and T.G. Troupis, *Modernization of an anatomy class: From conceptualization to implementation. A case for integrated multimodal–multidisciplinary teaching.* Anatomical sciences education, 2012. 5(6): p. 354-366.
12. Leung, K.-k., et al., *Anatomy instruction in medical schools: connecting the past and the future.* Advances in Health Sciences Education, 2006. 11(2): p. 209-215.
13. Estai, M. and S. Bunt, *Best teaching practices in anatomy education: A critical review.* Annals of Anatomy-Anatomischer Anzeiger, 2016. 208: p. 151-157.
14. Lufler, R.S., et al., *Incorporating radiology into medical gross anatomy: Does the use of cadaver CT scans improve students' academic performance in anatomy?* Anatomical sciences education, 2010. 3(2): p. 56-63.
15. Lau, F. and J. Bates, *A review of e-learning practices for undergraduate medical education.* J Med Syst, 2004. 28(1): p. 71-87.
16. Legowski, E., et al., *Evaluation of an Intelligent Tutoring System in Pathology: Effects of External Representation on Performance Gains, Metacognition, and Acceptance.* Journal of the American Medical Informatics Association, 2007. 14(2): p. 182-190.
17. Rehder, R., et al., *The role of simulation in neurosurgery.* Child's Nervous System, 2016. 32(1): p. 43-54.
18. Devolder, A., J. van Braak, and J. Tondeur, *Supporting self-regulated learning in computer-based learning environments: systematic review of effects of scaffolding in the domain of science education.* Journal of Computer Assisted Learning, 2012. 28(6): p. 557-573.
19. Attardi, S.M., et al., *Mixed methods student evaluation of an online systemic human anatomy course with laboratory.* Anatomical sciences education, 2016. 9(3): p. 272-285.

20. Inuwa, I.M., et al., *Anatomy practical examinations: How does student performance on computerized evaluation compare with the traditional format?* Anatomical sciences education, 2012. 5(1): p. 27-32.
21. Meyer, A.J., et al., *Student performance on practical gross anatomy examinations is not affected by assessment modality.* Anatomical sciences education, 2016. 9(2): p. 111-120.
22. Guimarães, B., et al., *Performance equivalency between computer-based and traditional pen-and-paper assessment: A case study in clinical anatomy.* Anatomical sciences education, 2018. 11(2): p. 124-136.
23. Bloom, T.J., et al., *Perceptions and performance using computer-based testing: One institution's experience.* Curr Pharm Teach Learn, 2018. 10(2): p. 235-242.
24. Veneri, D., *The role and effectiveness of computer-assisted learning in physical therapy education: a systematic review.* Physiotherapy Theory and Practice, 2011. 27(4): p. 287-298.
25. Peine, A., K. Kabino, and C. Spreckelsen, *Self-directed learning can outperform direct instruction in the course of a modern German medical curriculum - results of a mixed methods trial.* BMC Med Educ, 2016. 16: p. 158.
26. Trelease, R.B. and A. Rosset, *Transforming clinical imaging data for virtual reality learning objects.* Anatomical sciences education, 2008. 1(2): p. 50-55.
27. Vaitsis, C., V. Hervatis, and N. Zary, *Introduction to Big Data in education and its contribution to the quality improvement processes*, in *Big Data on Real-World Applications*. 2016, IntechOpen.
28. Siemens, G., *Learning analytics: The emergence of a discipline.* American Behavioral Scientist, 2013. 57(10): p. 1380-1400.
29. Pinnell, C., G. Paulmani, and V. Kumar, *Curricular and learning analytics: a big data perspective*, in *Big Data and Learning Analytics in Higher Education*. 2017, Springer. p. 125-145.
30. Turney, B.W., *Anatomy in a modern medical curriculum.* The Annals of The Royal College of Surgeons of England, 2007. 89(2): p. 104-107.
31. Khasawneh, R., et al., *The effectiveness of e-learning in pediatric medical student education.* Medical education online, 2016. 21(1): p. 29516.
32. Rosenberg, H., M. Sander, and J. Posluns, *The effectiveness of computer-aided learning in teaching orthodontics: a review of the literature.* American journal of orthodontics and dentofacial orthopedics, 2005. 127(5): p. 599-605.
33. Walsh, C.M., et al., *Learning in the simulated setting: a comparison of expert-, peer-, and computer-assisted learning.* Academic Medicine, 2011. 86(10): p. S12-S16.
34. Tam, M., et al., *Is learning anatomy facilitated by computer-aided learning? A review of the literature.* Medical Teacher, 2009. 31(9): p. e393-e396.
35. Nicholson, D.T., et al., *Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model.* Medical education, 2006. 40(11): p. 1081-1087.
36. McNulty, J.A., B. Sonntag, and J.M. Sinacore, *Evaluation of computer-aided instruction in a gross anatomy course: A six-year study.* Anatomical sciences education, 2009. 2(1): p. 2-8.
37. Hallgren, R.C., et al., *An interactive, web-based tool for learning anatomic landmarks.* Academic Medicine, 2002. 77(3): p. 263-265.
38. Kish, G., S.A. Cook, and G. Kis, *Computer-assisted learning in anatomy at the International Medical School in Debrecen, Hungary: A preliminary report.* Anatomical sciences education, 2013. 6(1): p. 42-47.
39. Arantes, M., J. Arantes, and M. Ferreira, *Tools and resources for neuroanatomy education: a systematic review.* BMC medical education, 2018. 18(1): p. 94.

40. Garrison, D.R. and H. Kanuka, *Blended learning: Uncovering its transformative potential in higher education.* The internet and higher education, 2004. 7(2): p. 95-105.
41. Codd, A.M. and B. Choudhury, *Virtual reality anatomy: Is it comparable with traditional methods in the teaching of human forearm musculoskeletal anatomy?* Anatomical sciences education, 2011. 4(3): p. 119-125.
42. Khot, Z., et al., *The relative effectiveness of computer-based and traditional resources for education in anatomy.* Anatomical sciences education, 2013. 6(4): p. 211-215.
43. Preece, D., et al., *"Let's get physical": advantages of a physical model over 3D computer models and textbooks in learning imaging anatomy.* Anatomical sciences education, 2013. 6(4): p. 216-224.
44. Buabbas, A.J., H.M. Al-Shawaf, and A.A. Almajran, *Health Sciences Students' Self-Assessment of Information and Communication Technology Skills and Attitude Toward e-Learning.* JMIR Med Educ, 2016. 2(1): p. e9.
45. Moazami, F., et al., *Comparing two methods of education (virtual versus traditional) on learning of Iranian dental students: a post-test only design study.* BMC Med Educ, 2014. 14: p. 45.
46. Varghese, J., M. Faith, and M. Jacob, *Impact of e-resources on learning in biochemistry: first-year medical students' perceptions.* BMC Med Educ, 2012. 12: p. 21.
47. Dorup, J., *Experience and attitudes towards information technology among first-year medical students in Denmark: longitudinal questionnaire survey.* J Med Internet Res, 2004. 6(1): p. e10.
48. Link, T.M. and R. Marz, *Computer literacy and attitudes towards e-learning among first year medical students.* BMC Med Educ, 2006. 6: p. 34.
49. Bediang, G., et al., *Computer literacy and E-learning perception in Cameroon: the case of Yaounde Faculty of Medicine and Biomedical Sciences.* BMC Med Educ, 2013. 13: p. 57.
50. Poelmans, S., F. Truyen, and R. Deslé. *Perceived computer lireracy among different types of (under) graduate students: findings of a survey*. in *ICERI 2009*. 2009. IATED.
51. Robabi, H. and A. Arbabisarjou, *Computer literacy among students of Zahedan University of Medical Sciences.* Glob J Health Sci, 2015. 7(4): p. 136-42.
52. Ameh, N., T.S. Kene, and E.A. Ameh, *Computer knowledge amongst clinical year medical students in a resource poor setting.* African Health Sciences, 2008. 8(1): p. 40-43.
53. Ranasinghe, P., et al., *Computer literacy among first year medical students in a developing country: A cross sectional study.* BMC Research Notes, 2012. 5: p. 504-504.
54. Diogo, P.G., et al., *Study on portuguese medical schools' learning conditions: a national analysis on student satisfaction, student-tutor ratios and number of admissions.* Acta medica portuguesa, 2016. 29(5): p. 301-309.
55. Guimarães, B., et al., *The Role of Anatomy Computer-Assisted Learning on Spatial Abilities of Medical Students.* Anatomical sciences education, 2019. 12(2): p. 138-153.
56. Cohen, J., *Statistical power analysis for the behavioral sciences Lawrence Earlbaum Associates.* Hillsdale, NJ, 1988: p. 20 -26.
57. Sawilowsky, S.S., *New effect size rules of thumb.* Journal of Modern Applied Statistical Methods, 2009. 8(2): p. 597 -599.
58. Cohen, J., *A power primer.* Psychological bulletin, 1992. 112(1): p. 155.
59. Babbitt, C.W., et al., *Evolution of product lifespan and implications for environmental assessment and management: a case study of personal computers in higher education.* Environmental science & technology, 2009. 43(13): p. 5106-5112.

60. Mitchell, R., *The advancement of learning: Building the teaching commons.* The Review of Higher Education, 2006. 29(4): p. 539-540.
61. Chatti, M.A., et al., *Learning analytics: Challenges and future research directions.* eleed, 2014. 10(1).
62. Ferguson, R., *Learning analytics: drivers, developments and challenges.* International Journal of Technology Enhanced Learning, 2012. 4(5/6): p. 304-317.
63. Deutsch, T., et al., *Implementing computer-based assessment–A web-based mock examination changes attitudes.* Computers & Education, 2012. 58(4): p. 1068-1075.
64. Terzis, V. and A.A. Economides, *The acceptance and use of computer based assessment.* Computers & Education, 2011. 56(4): p. 1032-1044.
65. Ng, W., *Can we teach digital natives digital literacy?* Computers & education, 2012. 59(3): p. 1065-1078.
66. Buzzetto-More, N., *Student perceptions of various e-learning components.* Interdisciplinary Journal of E-Learning and Learning Objects, 2008. 4(1): p. 113-135.
67. Mcdowall, T. and B. Jackling, *The impact of computer-assisted learning on academic grades: An assessment of students' perceptions.* Accounting Education: an international journal, 2006. 15(4): p. 377-389.
68. Aşkar, P., H. Yavuz, and M. Köksal, *Students' perceptions of computer assisted instruction environment and their attitudes towards computer assisted learning.* Educational Research, 1992. 34(2): p. 133-139.
69. Liaw, S.-S., *Investigating students' perceived satisfaction, behavioral intention, and effectiveness of e-learning: A case study of the Blackboard system.* Computers & education, 2008. 51(2): p. 864-873.
70. Sturges, D., et al., *Academic performance in human anatomy and physiology classes: a 2-yr study of academic motivation and grade expectation.* Adv Physiol Educ, 2016. 40(1): p. 26-31.
71. Guillot, A., et al., *Relationship between spatial abilities, mental rotation and functional anatomy learning.* Advances in Health Sciences Education, 2007. 12(4): p. 491-507.
72. Gross, M.M., M.C. Wright, and O.S. Anderson, *Effects of image-based and text-based active learning exercises on student examination performance in a musculoskeletal anatomy course.* Anatomical sciences education, 2017. 10(5): p. 444-455.

Figures

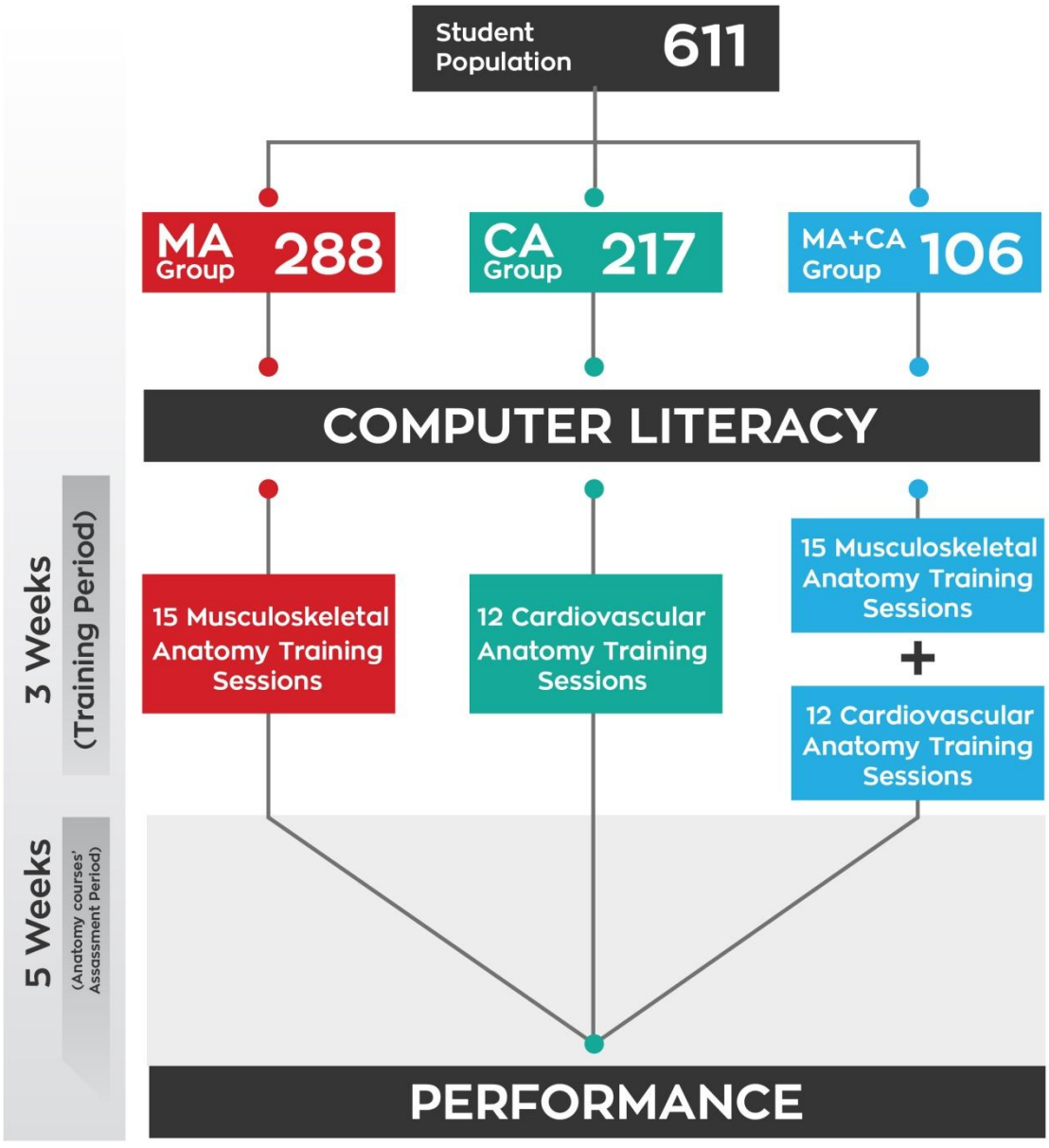


Figure 1 – Study design

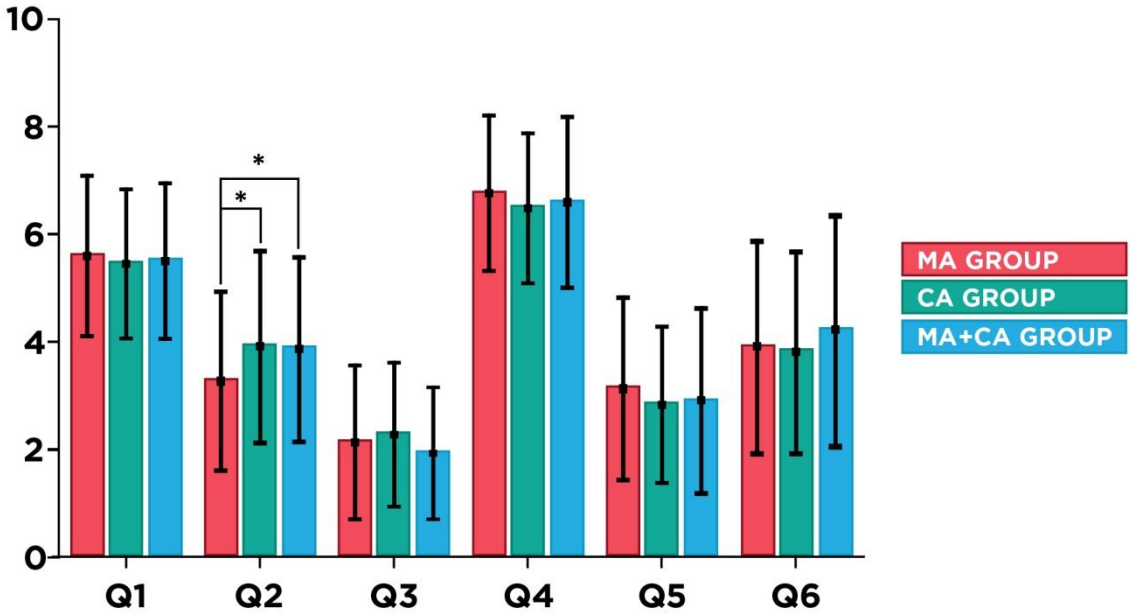


Figure 2 - The level of agreement towards the use of CAL in MA, CA and MA + CA Groups. Agreement is presented in mean scores. Error bars represent ± standard deviation; * P < 0.05; MA – Musculoskeletal anatomy, CA – Cardiovascular anatomy.

Tables

Table I - Characteristics of participants (MA Group, CA Group and MA+CA Group).

Variable	MA Group (N = 288)		CA Group (N = 217)		MA+CA Group (N = 106)	
Female Gender, N (%)	188	(65.3)	131	(60.4)	80	(75.5)
Age in years, mean (SD)	20.8	(4.35)	21.2	(3.43)	21.6	(3.73)
Enrolling Program						
Undergraduate, N (%)	237	(82.3)	180	(82.9)	89	(84.0)
Graduate, N (%)	51	(17.7)	37	(17.1)	17	(16.0)
Admission Grade, mean (SD)	18.48	(9.99)	18.62	(10.17)	18.52	(8.80)
Current Musculoskeletal Anatomy Course						
Approved, N (%)	124	(43.1)	-		58	(54.7)
Grade (within approved), mean (SD)	12.2	(2.03)	-		12.7	(1.62)
Current Cardiovascular Anatomy Course						
Approved, N (%)	-		201	(92.6)	83	(78.3)
Grade (within approved), mean (SD)	-		15.4	(2.47)	13.9	(2.50)
Previous Neuroanatomy Course						
Approved, N (%)	-		178	(82.0)	51	(48.1)
Grade (within approved), mean (SD)	-		13.8	(2.30)	11.5	(1.57)
Previous Musculoskeletal Anatomy Course						
Approved, N (%)	-		147	(67.7)	-	
Grade (within approved), mean (SD)	-		12.6	(2.22)	-	
Musculoskeletal Anatomy Training Sessions, mean (SD)	10.6	(3.85)	-		8.8	(4.75)
Cardiovascular Anatomy Training Sessions, mean (SD)	-		9.2	(3.56)	7.4	(3.62)

N - number of students.
SD - standard deviation.
MA - musculoskeletal anatomy course
CA - cardiovascular anatomy course
[a] - Admission grades vary between 9.5 and 20 in Portuguese higher education.

Table II - Correlation coefficients between Musculoskeletal Anatomy academic performance and the other variables in analysis, per group (MA Group and MA + CA Group).

Association model variables	Anatomy Academic Performance			
	MA Group (N = 288)		**MA + CA group** (N = 106)	
	Association	*P*-value	Association	*P*-value
Musculoskeletal Anatomy Training Sessions (number of sessions)	0.761	<0.001	0.786	<0.001
Previous Neuroanatomy Course (mean grade)	-		0.186	0.099
Gender[a]	-		-	
Female	9.22 (± 3.24)	0.980	10.92 (± 3.32)	0.028
Male	9.21 (± 3.67)		8.95 (± 4.09)	
Age (years)	-0.136	0.025	-0.021	0.862
Admission Grade (mean grade)[b]	0.194	0.003	0.106	0.327
Enrolling Program[a]	-		-	
Undergraduate	9.55 (± 3.24)	<0.001	10.69 (± 3.42)	0.188
Other	7.61 (± 3.67)		9.38 (± 4.24)	

N = number of students
MA - musculoskeletal anatomy course
CA - cardiovascular anatomy course
[a] - Independent t-test, all the other variables are Pearson's coefficient.
[b] - Admission grades vary between 9.5 and 20 in Portuguese higher education.

Table III - Correlation coefficients between Cardiovascular Anatomy academic performance and the other variables in analysis, per group (CA Group and MA + CA Group).

Association model variables	Anatomy Academic Performance			
	CA Group (N = 217)		**MA + CA group** (N = 106)	
	Association	*P*-value	Association	*P*-value
Cardiovascular Anatomy Training sessions (number of sessions)	0.670	<0.001	0.772	<0.001
Previous Musculoskeletal Anatomy Course (mean grade)	0.294	<0.001	-	
Previous Neuroanatomy Course (mean grade)	0.439	<0.001	0.442	<0.001
Gender[a]	-		-	
Female	14.48 (± 3.20)	0.026	12.28 (± 3.65)	0.405
Male	15.47 (± 3.04)		13.00 (± 4.25)	
Age (years)	-0.076	0.269	-0.141	0.158
Admission Grade (mean grade)[b]	-0.024	0.724	0.150	0.162
Enrolling Program[a]	-		-	
Undergraduate	15.02 (± 3.23)	0.516	12.63 (± 3.55)	0.277
Other	14.19 (± 2.79)		11.43 (± 5.20)	

N = number of students
MA - musculoskeletal anatomy course
CA - cardiovascular anatomy course
[a] - Independent t-test, all the other variables are Pearson's coefficient.
[b] - Admission grades vary between 9.5 and 20 in Portuguese higher education.

Table IV - Multiple linear regression models for Musculoskeletal Anatomy academic performance in the MA group and in the MA + CA group.

Regression model variables	MA Group				MA+CA Group			
	R^2= 0.581 / R_a^2 = 0.573				R^2 = 0.628 / R_a^2 = 0.597			
	B	95% CI		*P*	B	95% CI		P
Musculoskeletal Anatomy Training Sessions (number of sessions)	0.789	0.703	0.875	< 0.001	0.687	0.550	0.824	<0.001
Previous Neuroanatomy Course (mean grade)	-	-	-	-	0.170	-0.058	0.399	0.142
Gender [male/female]	0.076	-0.481	0.633	0.789	-0.899	-2.069	0.270	0.130
Age (years)	-0.013	-0.147	0.122	0.855	-0.050	-0.398	0.297	0.773
Admission Grade (mean grade)[a]	-0.002	-0.005	0.002	0.350	0.024	-0.126	0.173	0.754
Enrolling Program [Undergraduate/Other]	0.046	-0.487	0.579	0.866	0.065	-1.307	1.437	0.925

MA - musculoskeletal anatomy course
CA - cardiovascular anatomy course
[a] - Admission grades vary between 9.5 and 20 in Portuguese higher education.
P - *P*-value

Table V - Multiple linear regression models for Cardiovascular Anatomy academic performance in the MA group and in the MA + CA group.

Regression model variables	CA Group				MA+CA Group			
	R^2 = 0.538 / R_a^2 = 0.522				R^2 = 0.644 / R_a^2 = 0.619			
	B	95% CI		P	B	95% CI		P
Cardiovascular Anatomy Training Sessions (number of sessions)	0.569	0.472	0.666	<0.001	0.793	0.637	0.948	<0.001
Previous Musculoskeletal Anatomy Course (mean grade)	0.098	-0.018	0.214	0.096	-	-	-	-
Previous Neuroanatomy Course (mean grade)	0.259	0.144	0.374	<0.001	0.393	0.173	0.612	0.001
Gender [male/female]	0.755	0.146	1.363	0.006	0.655	-0.448	1.757	0.241
Age (years)	0.008	-0.142	0.159	0.914	-0.159	-0.513	0.196	0.377
Admission Grade (mean grade)[a]	0.001	-0.003	0.003	0.855	-0.047	-0.172	0.078	0.456
Enrolling Program [Undergraduate/Other]	0.095	-0.305	0.496	0.639	0.100	-1.279	1.480	0.885

MA - musculoskeletal anatomy course
CA - cardiovascular anatomy course
[a] - Admission grades vary between 9.5 and 20 in Portuguese higher education.
P - *P*-value

Appendix

Adapted version of *Computer-based learning* questionnaire

I. Access to a computer and internet

A. At which age did you use a computer for the first time (PC, Mac or something similar)?

B. Do you have ready access to a computer you can use for learning?

1. Yes, my own computer
2. Yes, a computer shared by a family or in an apartment
3. Yes, in a public computer facility (e.g. at the university)
4. No

C. Does this computer have Internet access?

1. Yes, modem (telephone line)
2. Yes, ISDN or similar
3. Yes, cable/ADSL or another type of broad-band Internet access
4. Yes, LAN (e.g. in public computer rooms at the university)
5. No
6. Not applicable (e.g. because no computer available)

D. If you possess a computer of your own, how old (production date) is it?

Less than 1 year

1. 1 to 2 years
2. 2 to 3 years
3. 3 to 4 years
4. 4 to 5 years
5. 5 to 6 years
6. 6 to 7 years
7. 7 to 8 years
8. 8 to 9 years
9. 9 to 10 years
10. More than 10 years

II. Computer usage

How often do you use a computer for learning?

A. To search the Internet for relevant webpages.

1. at least weekly
2. at least monthly
3. about once a term
4. less often
5. never

B. To download notes or similar items (with a known Internet address).

1. at least weekly

2. at least monthly
3. about once a term
4. less often
5. never

C. To use a learning management system for a course (other than the medical university's study guide).

1. at least weekly
2. at least monthly
3. about once a term
4. less often
5. never

D. To use computer- or web-based learning programs (CD-ROMs, webpages or similar).

1. at least weekly
2. at least monthly
3. about once a term
4. less often
5. never

E. Which of these types do you consider the most useful for learning?

1. Image repositories (usually containing little explanatory text)
2. Hypertexts (e.g. web-based textbooks)
3. Simulations (e.g. patient or laboratory simulations)
4. Quizzes (e.g. question repositories with assessment)
5. Animations (e.g. computer animations which offer some user interaction)
6. Encyclopedias (e.g. Online-Pschyrembel)
7. Forums for communicating with other students
8. Learning management systems (portals for hosting web-based courses)

III. Attitudes and previous experiences with e-learning

A. What do you think about the following statements? How far do you agree or disagree? (1 to 8 liker scale)

1. Computer or Web-based training should play a more important role.
2. Web-based learning programs are able to replace lectures.
3. In medical teaching, there is no need for the use of Web-based programs.
4. Computer Web-based training should be made available to supplement lectures and exercises.
5. E-Learning should be nothing more than the distribution of notes over the Internet.
6. I find it awkward to speak out in the classroom, which is why I often refrain from doing so. I would find it easier to participate in a discussion in an online-forum.