Applied Medical Informatics
Original Research Vol. 44, No. 2 /2022, pp: 57-72

First Semester of Online Medical Education During the Coronavirus Disease 2019 Pandemic: A Single University Experience

Valeriu-Mihai BUT [1], Dinu BOLUNDUȚ [2,*], Sorana D. BOLBOACĂ [1], and Adriana Elena BULBOACĂ [3]

[1] Department of Medical Informatics and Biostatistics, Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca, Louis Pasteur Str., no. 6, 400349 Cluj-Napoca, Romania; but.valeriumihai@elearn.umfcluj.ro, sbolboaca@umfcluj.ro
[2] Faculty of Medicine, Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca, Louis Pasteur Str., no. 4, 400349 Cluj-Napoca, Romania; bolundut_dinu@elearn.umfcluj.ro
[3] Department of Pathophysiology, Iuliu Haţieganu University of Medicine and Pharmacy, Victor Babeş Str., no. 2-4, 400012 Cluj-Napoca, Romania; adriana.bulboaca@umfcluj.ro
E-mails: but.valeriumihai@elearn.umfcluj.ro; (*) bolundut_dinu@elearn.umfcluj.ro; sbolboaca@umfcluj.ro; adriana.bulboaca@umfcluj.ro

* Author to whom correspondence should be addressed;

Received: June 3, 2022/Accepted: June 30, 2022/ Published online: June 30, 2022

Abstract
Our study evaluated the medical student's attitude toward online medical training implementation during COVID-19 lockdown in a single university. A questionnaire was developed and distributed to the undergraduate students at the Faculty of Medicine, Iuliu Haţieganu University of Medicine and Pharmacy, Romania. Following a cross-sectional design, the study was carried out from May 20th to August 20th 2020. We studied the differences between the responses of Medicine students (Medicine) and other specializations (OtherS), respectively between three groups according to the year of the study (freshman - Fr first year, sophomores - So intermediate years, and seniors - Se last year of study). The Medicine students' attitude towards online professional education was significantly different than OherS (students with other specialties than Medicine) concerning 6 out of 11 questions (P-values < 0.018). Similar, significant differences were observed on 7/11 questions when comparing Fr, So, Se (P-values < 0.015), but only 4/7 differences were similar to Medicine vs. OtherS. The participants agreed that online education helped continue the academic year in the context of COVID-19 pandemic, but the medical skills development has suffered. Our study showed that students' needs, as well as their perceptions, are different both between specializations (Medicine vs. OtherS) as well as years of study (Fr, So, and Se).

Keywords: Medical education; e-learning; Online learning; Coronavirus Disease 2019 (COVID-19)

Introduction

Learning employing digital methods (digital learning, d-learning; as e-learning - "*the learning supported by digital electronic tools and media*" and m-learning - "*e-learning using mobile devices and wireless transmission*") [1] has innovated teaching in general, and also the medical education. Computer-based clinical scenarios, also known as virtual patients, is a d-learning method reported in the scientific literature in the early "70s [2,3] and proved helpful in promoting reasoning skills [4] compared to no

intervention, but with limited performances compared to traditional instructions [5]. E-learning methods in medical education include all the electronic techniques involved in the teaching process, such as electronic books, interactive atlases, the internet, virtual patient, online classes, webinars, and online synchronous workshops [6,7]. E-learning uses several ways to deliver the information, such as graphics, animations, interactive diagrams, and audio or video recordings, which can help medical students to improve their skills [8]. Multimedia materials allow replaying of content several times, while traditional learning methods do not [9]. Mixed learning combines e-learning technology and traditional education, and thus, lectures or demonstrations can be completed by an online tutorial, video, PowerPoint presentation, or practice with a virtual patient [10].

The COVID-19 (Coronavirus Disease 2019) was first reported in Wuhan, China, on 19 December 2019 [11], and many countries lockdown to minimize the spread of the disease and thus constrained medical universities to adapt. Survey studies, either national or local, and cross-sectional studies (including mixed-method surveys) [12] or interviews [13] were conducted to evaluate the online medical teaching during COVID-19 pandemic. Universities adapted learning during lockdown differently, as live tutorials via online platforms, supplementing the learning platform resources, introducing questions banks [14], pre-recorded video or presentations [15,] or a mixture of synchronous and asynchronous methods [16,17]. Universities used different platforms such as Blackboard, Zoom [18], e-Teaching, and Learning System [15], Microsoft Teams [19], Google Meet [20], Skype [21], Google classroom or YouTube platforms [22]. The main effects of COVID-19 on medical education from the undergraduate students' perspective were lack of enjoyment or engagement [14,23], disruption of medical skills development [24-26], comfort [27], higher flexibility, and lower costs (e.g., traveling, daily expenses) [14,28], technological barriers (e.g., poor internet connection or technical problems with the IT equipment [14, 29, 30]), or family distraction [14]. The flexibility and the benefit of remote learning may be considered for future medical curricula [12].

Our study evaluated the medical students' attitude toward online medical training implementation during COVID-19 lockdown in a single university. Our first hypothesis was that no differences exist between Medicine students and OtherS (including Nursing, or Radiology and Medical Imaging or Physio-Kinesiotherapy, and Rehabilitation) students regarding the implementation of e-learning methods during COVID-19 pandemic. The second hypothesis was that the perception of online education was the same regardless of the year of the study (*freshmans* - first year of the study, *sophomores* - intermediate years of the study, and *seniors* - students in the last year of the study).

Material and Method

The study was conducted in accordance with the Declaration of Helsinki and approved prior to data collection by the Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca Ethics Committee (approval no. 191/18 May 2020).

Study Design and Participants

A cross-sectional analytical study was conducted. The eligible participants were students at the Faculty of Medicine, Romanian section, Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca. The Faculty of Medicine has four undergraduate study programs: Medicine (6 years, 360 European system of transferable credits - ECTS), Nursing (4 years university studies, 240 ECTS), Radiology, and Medical Imaging Nursing (3 years university studies, 180 ECTS), and Physio-Kinesiotherapy and Rehabilitation (3 years university studies, 180 ECTS).

The first case of infection with the new coronavirus in Romania was confirmed on February 26, 2020. The emergency state was initially declared on March 16, 2020 for 30 days and extended until May 15, 2020 [31]. A national lockdown was implemented during this period [32]. On March 3, 2020 the teaching activities (lectures, seminars, and practical activities) were moved online at the Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca. The platform used was Microsoft Teams. All teachers and enrolled students received a Microsoft Teams account during the first week of online activities. Instructions on logging in and installing the Microsoft Teams desktop were sent

via e-mails. Short online sessions were organized to instruct the teachers and students to use the platform. All lectures, seminars, and practical activities were synchronously given as scheduled at the beginning of the semester via the Microsoft Teams online platform. Teachers and students used personal devices (e.g., laptops, smartphones, tablets, desktops, etc.) to participate in didactical activities, while in exceptional cases, financial support was given to students for buying a tablet or a laptop

Survey Instrument

A twenty items questionnaire divided into three sections was developed and used in this study. The first section (Section A) consists of eleven items referring to online medical education (Table 1) in the Faculty of Medicine during the second semester of the 2019-2020 academic year (the lockdown period). The second section (Section B) contains four questions aiming to evaluate the technical aspects of the implementation of e-learning. The third section (Section C) collected five items from socio-demographic data. We constructed the questions dedicated to online medical education evaluation using a 5-points Likert scale.

Table 1. Components and items of the questionnaire

QID	Question
Section A: Online Medical Education	
A01	To continue your academic year, do you consider it was important for our University to apply e-learning methods during the COVID-19 pandemic?
A02	Do you consider the adopted e-learning method was effective for the educational process?
A03	By applying e-learning methods, do you consider that the learning process suffered during the COVID-19 pandemic?
A04	Did you encounter difficulties in the process of assimilating theoretical knowledge?
A05	Did you encounter difficulties in the process of developing practical skills?
A06	The information received during the practical activities / courses on the Teams platform came in addition to the recommended teaching materials? (course materials, manuals, handbooks, etc.)
A07	The practical activities carried out on the Teams platform were interactive?
A08	Did you receive projects/tests/quizzes to verify the level of understanding of the subject studied this semester?
A09	Do you consider that by applying e-learning methods, mobility has been reduced, thus saving time and considerably reducing exposure to the SARS-CoV-2 virus?
A10	Do you consider beneficial the pre-existence of a platform designed to support the educational process in the context of emergencies?
A11	Do you consider that an e-learning platform can be used in medical education? (e.g., consultations, scientific student activities, or optional courses)
Section B: Resources	
B01	What type of device did you use while using the Teams platform?
B02	What other sources of e-learning did you use during this period?
B03	How often have you encountered technical difficulties accessing courses / practical activities conducted on the University's online platform?
B04	What was the source of the technical problems? (If you have faced any of them)
Section C: Demographic data	
C01	What is your gender?
C02	How old are you?
C03	Which of these describes best the general area where you live?
C04	Which study program do you follow?
C05	Year of study

The questionnaire contained questions on personal opinion using a 5-point scale (1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree), "closed" questions giving a choice of answers, and multiple-choice questions. The questions for which the Likert scale was used are from A01-A07, and A09-A11. For questions A03, A04, and A05 the Likert scale was reversed prior to statistical analysis

From May 20, 2020 to August 20, 2020, the questionnaire was distributed via internet to the students of the Faculty of Medicine from Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca. The survey was written in the Romanian language and promoted on Facebook student groups using a convenient sampling method. The student representatives (administrators of groups) were asked to give access to the group to distribute the survey. Thirty-four student groups of all students of the Faculty of Medicine, Romanian section, summing 2,926 students, without overlap, were used to invite the students to participate. An invitation for joining the study was posted once on each group, and the link to the Google Forms version of our survey was provided. The participants were informed at the beginning of the survey about the purpose of the study, the data collection procedure, and anonymity while respecting the General Data Protection Regulation (GDPR) legal framework.

Statistical Analysis

The internal consistency of the used instrument was evaluated using the ten items from section A (A08 was excluded because the response was dichotomial). A Cronbach alpha score higher or equal to 0.9 indicates excellent consistency, a value from 0.7 to 0.9 indicates good consistency, and a value from 0.6 to 0.7 indicates acceptable consistency [33]. The sample was divided into two groups according to the study program, Medicine and the OtherS (other specialties) containing Nursing, Radiology and Medical Imaging, and Physio-Kinesiotherapy and Rehabilitation students to test the first hypothesis.

The sample was divided according to the year of study into three groups to test the second hypothesis: ***freshman (Fr)*** – students in the first year of study, ***sophomore (So)*** – students in the intermediate years of study (years from II to IV for *Medicine*, II and III for *Nursing* and II for *Radiology and Medical Imaging* and *Physio-Kinesiotherapy and Rehabilitation*) and ***senior (Se)*** – students in the last year of study (VI for *Medicine*, IV for *Nursing* and III for *Radiology and Medical Imaging,* and *Physio-Kinesiotherapy and Rehabilitation*).

Numbers and percentages were reported for qualitative variables. The Chi-squared test was used to test the differences between groups whenever the expected frequencies' assumptions were achieved. Otherwise, Fisher's exact test was used. Post-hoc analysis in the contingency table was done first by constructing multiple derived contingency tables for comparison of three groups and comparing two-by-two groups and second by evaluation of adjusted residuals using the Chi-squared test at a significance level corrected by Bonferroni method. The distribution of age variable was tested with the Kolmogorov-Smirnov test for each group and a P-value < 0.05 indicated a distribution away from the theoretical normal distribution. The age variable was reported as median and (Q1 to Q3) range, where Q1 is the first quartile and Q3 is the third quartile. The comparison between the two groups was made with Mann–Whitney test.

The results were statistically processed using SPSS software (v. 27.0 trial version, Armonk, NY, USA). The significance level of 5% was used to compare two groups (first hypothesis). The differences between the three groups (second hypothesis) were considered statistically significant for P-values lower than 0.017.

Results

The internal consistency conducted on ten items from section A retrieved a Cronbach's Alpha equal to 0.840 (95% CI = [0.819 to 0.856], P-value < 0.001), showing a good consistency. The Cronbach Alpha on the latent variable that measures the belief in learning effectiveness (A2-A5, Table 1) is 0.765 (95% CI = [0.733 to 0.793] , P-value < 0.001).

Medicine vs. Nursing, or Radiology and Medical Imaging or Physio-Kinesiotherapy and Rehabilitation

As expected, the respondents from the Medicine group were older, and the women were more frequent among the respondents from the OtherS group (see Table 2).

Table 2. Medicine vs. OtherS.

Characteristic	All (n=635)	Group		Stats. (P-value)
		Medicine(n=467)	OtherS (n=168)	
Gender, female [a]	465 (73.2)	321 (68.7)	144 (85.7)	18.2 (< 0.001)
Age, years [b]	21 (20 to 23)	22 (20 to 24)	21 (20 to 22)	3.6 (< 0.001)
Origins, rural [a]	113 (17.8)	60 (12.8)	53 (31.5)	29.5 (< 0.001)
Year of study				n/a
I	134 (21.1)	94 (20.1)	40 (23.8)	
II	165 (26.0)	91 (19.5)	74 (44.0)	
III	118 (18.6)	81 (17.3)	37 (22.0)	
IV	86 (13.5)	69 (14.8)	17 (10.1)	
V	66 (10.4)	66 (14.1)		
VI	60 (10.4)	66 (14.1)		

[a] Chi-squared test; [b] Mann–Whitney test; Stats = statistics of the test; n/a = not available.

More students in the OtherS group were in the first two years of the study (67.9%) as compared to the first three years of respondents from Medicine (57.0%), the difference being statistically significant ($\chi^2 = 6.1$, P-value = 0.014).

Seven out of 11 investigated statements regarding online medical education were perceived significantly differently by the Medicine students than those from the OtherS group (Table 3).

Table 3. Online education perception: Medicine vs. OtherS. Data are reported as absolute and relative (in the round brackets) frequencies (%).

Question	All (n=635)	Group		χ^2 (P-value)
		Medicine (n=467)	OtherS (n=168)	
A01				31.5 (<0.001)
Strongly Disagree	28 (4.4)	15 (3.2)	13 (7.7)	
Disagree	29 (4.6)	14 (3.0)	15 (8.9)	
Neutral	87 (13.7)	53 (11.3)	34 (20.2)	
Agree	144 (22.7)	105 (22.5)	39 (23.2)	
Strongly Agree	347 (54.6)	280 (60.0)*	67 (39.9) *	
A02				7.0 (0.134)
Strongly Disagree	66 (10.4)	41 (8.8)	25 (14.9)	
Disagree	93 (14.6)	66 (14.1)	27 (16.1)	
Neutral	174 (27.4)	136 (29.1)	38 (22.6)	
Agree	209 (32.9)	153 (32.8)	56 (33.3)	
Strongly Agree	93 (14.6)	71 (15.2)	22 (13.1)	
A03				8.1 (0.090)
Strongly Disagree	24 (3.8)	21 (4.5)	3 (1.8)	
Disagree	59 (9.3)	50 (10.7)	9 (5.4)	
Neutral	108 (17.0)	81 (17.3)	27 (16.1)	
Agree	172 (27.1)	124 (26.6)	48 (28.6)	
Strongly Agree	272 (42.8)	191 (40.9)	81 (48.2)	
A04				14.3 (0.007)
Strongly Disagree	72 (11.3)	62 (13.3)	10 (6.0)	
Disagree	123 (19.4)	96 (20.6)	27 (16.1)	
Neutral	152 (23.9)	103 (22.1)	49 (29.2)	
Agree	173 (27.2)	131 (28.1)	42 (25.0)	
Strongly Agree	115 (18.1)	75 (16.1)	40 (23.8)	
A05				3.3 (0.502)
Strongly Disagree	8 (1.3)	4 (0.9)	4 (2.4)	
Disagree	31 (4.9)	22 (4.7)	9 (5.4)	
Neutral	53 (8.3)	42 (9.0)	11 (6.5)	
Agree	135 (21.3)	98 (21.0)	37 (22.0)	
Strongly Agree	408 (64.3)	301 (64.5)	107 (63.7)	

Question	All (n=635)	Group		χ^2 (P-value)
		Medicine (n=467)	OtherS (n=168)	
A06				16.1 (0.003)
Strongly Disagree	26 (4.1)	18 (3.9)	8 (4.8)	
Disagree	74 (11.7)	49 (10.5)	25 (14.9)	
Neutral	188 (29.6)	123 (26.3)	65 (38.7)	
Agree	225 (35.4)	177 (37.9)	48 (28.6)	
Strongly Agree	122 (19.2)	100 (21.4)	22 (13.1)	
A07				11.9 (0.018)
Strongly Disagree	58 (9.1)	35 (7.5)	23 (13.7)	
Disagree	108 (17.0)	85 (18.2)	23 (13.7)	
Neutral	224 (35.3)	168 (36.0)	56 (33.3)	
Agree	183 (28.8)	127 (27.2)	56 (33.3)	
Strongly Agree	65 (9.8)	52 (11.1)	10 (6.0)	
A08, Yes	498 (78.4)	369 (79.0)	129 (76.8)	0.4 (0.547)
A09				15.0 (0.005)
Strongly Disagree	15 (2.4)	9 (1.9)	6 (3.6)	
Disagree	21 (3.3)	14 (3.0)	7 (4.2)	
Neutral	49 (7.7)	29 (6.2)	20 (11.9)	
Agree	132 (20.8)	88 (18.8)	44 (26.2)	
Strongly Agree	418 (65.8)	327 (70.0)	91 (54.2)	
A10				25.3 (<0.001)
Strongly Disagree	16 (2.5)	9 (1.9)	7 (4.2)	
Disagree	20 (3.1)	12 (2.6)	8 (4.8)	
Neutral	57 (9.0)	32 (6.9)	25 (14.9)	
Agree	143 (22.5)	95 (20.3)	48 (28.6)	
Strongly Agree	399 (62.8)	319 (68.3)	80 (47.6)	
A11				18.6 (0.001)
Strongly Disagree	49 (7.7)	34 (7.3)	15 (8.9)	
Disagree	64 (10.1)	42 (9.0)	22 (13.1)	
Neutral	100 (15.7)	61 (13.1)	39 (23.2)	
Agree	152 (23.9)	111 (23.8)	41 (24.4)	
Strongly Agree	270 (42.5)	219 (46.9)	51 (30.4)	

*P-values based on adjusted residuals < 0.001 (Bonferroni correction 0.05/10 = 0.005 considered statistically significant)

Regardless of the specialty, half of the students used two devices to connect to the online classes, in most cases, a laptop and a smartphone (Table 4).

Table 4. Devices used to connect to online classes: Medicine vs. OtherS.

Characteristic	All (n=635)	Group		χ^2 (P-value)
		Medicine (n=467)	OtherS (n=168)	
Type of the device				
Laptop	572 (90.1)	435 (93.1)	137 (81.5)	18.6 (< 0.001)
Smartphone	431 (67.9)	308 (66.0)	123 (73.2)	3.0 (0.084)
Tablet	65 (10.2)	55 (11.8)	10 (6.0)	4.6 (0.033)
Computer	54 (8.5)	43 (9.2)	11 (6.5)	1.1 (0.289)
TV	9 (1.4)	7 (1.5)	2 (1.2)	0.0 (> 0.999)
Difficulties using the platform				23.5 (< 0.001)
rarely	139 (21.9)	116 (24.8)	23 (13.7)	
rare	234 (36.9)	179 (38.3)	55 (32.7)	
sometimes	137 (21.6)	99 (21.2)	38 (22.6)	
frequently	90 (14.2)	56 (12.0)	34 (20.2)	
very often	35 (5.5)	17 (3.6)	18 (10.7)	

Data are expressed as no. (%). Comparison between groups was made with Chi-squared test excepting TV (TeleVision) when the Fisher exact test was used. n/a = not applicable.

Among the most common technical problems during the online teaching activity were unstable internet connection, interruption of the energy source of the devices, incorrect classification of students in virtual groups not corresponding to the schedule, errors in the operation of the Teams platform, failure of the devices used by students.

The top five resources used by students were YouTube (542, 85.1%), PubMed (342, 53.7%), Osmosis (210, 33.0%), Medscape (179, 28.1%) and Amboss (89, 14.0%) closely followed by Dr.Najeeb (81, 12.7%) (Figure 1).

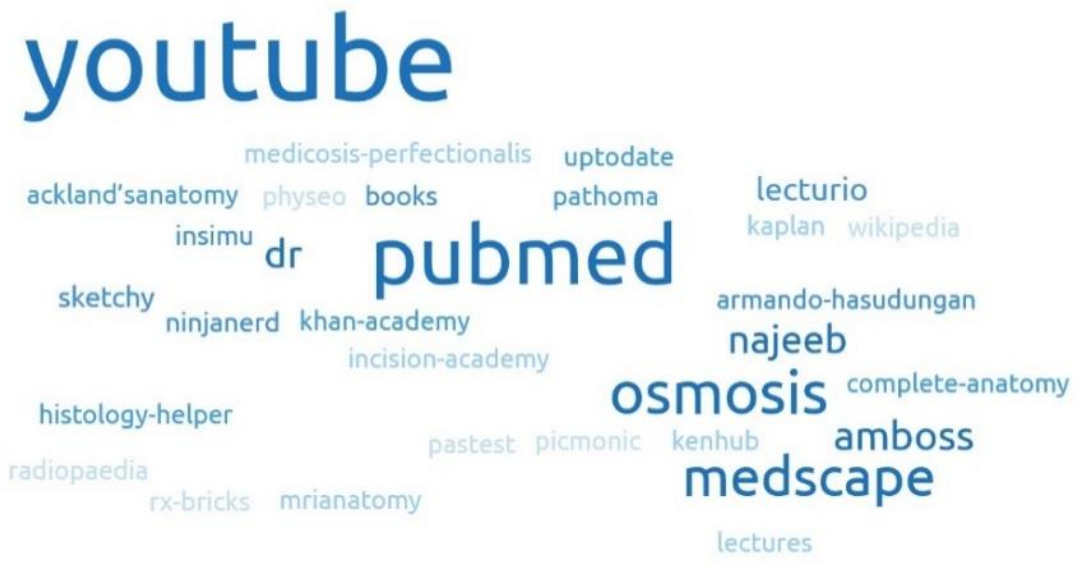

Figure 1. Students consulted educational resources as support to their medical training (the biggest letter the most frequently used by the respondents).

The free resources (Figure 1) listed by respondents were: PubMed (database with access to scientific literature, abstract, and full-text of articled deposited in PubMed), Medscape (information for physicians and healthcare professionals, registration is needed), Armando Hasudungan ("biology and medicine videos"; drawings are available for a fee), Histology Helper (YouTube movie collection with histology images), Khan Academy (not exclusively medicine and university students), MRIAnatomy (documented Magnetic Resonance Images), Radiopaedia (free radiology resource), WHO-World Health Organization (WHO), Wikipedia (general resource), YouTube (general resource). Resources that require payment of fees: Amboss ("a digital medical resource fundend by doctors, for doctors"), Dr. Najeeb (medical lectures), Ninja Nerd ("learning platform for medicine and science"), InSimu ("interactive virtual patient simulator platform to enhance clinical training of health care students and professionals", limited access for free to practice clinical reasoning but a month fee is required to manage learning performances and progress), Osmosis (a learning resource developed by students at Johns Hopkins U.S.A.), Complete Anatomy (an Elsevier educational resource – 3D anatomy platform), Incision Academy (resource dedicated to learning Operation Room skills), KenHub (platform to learn anatomy), Kaplan (a platform that assist student to prepare for exams not exclusively medicine or healthcare professionals), Medicosis Perfectionalis (medical content channel; pay for lecture), Rx-Bricks (assisted medical learning), Sketchy (visual learning material), UpToDate (a resource developed by Wolters Kluwer as support towards evidence-based clinical decision support), Pathoma (learning resource for pathology), PHYSEO (video resource preclinical and clinical curriculum), Picmonic (learning medicine by pictures), Lecturio (resource for medical and nursing students, for different medical examens with resources for students and teachers).

Freshman, Sophomore, and Senior

The senior (Se) respondents were most frequently from rural areas (Table 5), but the differences did not reach the significance threshold. Seven out of 11 questions showed differences in online medical training perceptions among the three groups (Table 5).

The use of devices among freshman, sophomore, and senior groups for online education was similar (Table 6). Significant differences were observed between groups regarding the use of Amboss (more frequent used by the sophomore), Medscape (more frequent used by the seniors), Osmosis (more frequent used by the sophomore), PubMed (more frequent used by the seniors), and YouTube (more frequent used by the freshman).

Table 5. Demographics and perceptions of online medical training: differences between freshman, sophomore and senior undergraduate students.

	Freshman (n=134)	Sophomore (n=399)	Senior (n=102)	χ^2 (P-value)
Demographics				
Gender, female	95 (70.9)	284 (71.4)	85 (83.3)	6.3 (0.042)
Origins, rural	26 (19.4)	62 (15.5)	25 (24.5)	4.8 (0.092)
Online education perception				
A01			#	18.8 (0.016)
Strongly Disagree	7 (5.2)	19 (4.8)	2 (2.0)	
Disagree	9 (6.7)	15 (3.8)	5 (4.9)	
Neutral	27 (20.1)	50 (12.5)	10 (9.8)	
Agree	34 (25.4)	94 (23.6)	16 (15.7)	
Strongly Agree	57 (42.5)[a11]	221 (55.4)[a12]	69 (67.6)[a13]	
A02		**	#	24.1 (0.002)
Strongly Disagree	18 (13.4)	43 (10.8)	5 (4.9)	
Disagree	20 (14.9)	59 (14.8)	14 (13.7)	
Neutral	48 (35.8)	109 (27.3)	17 (16.7)	
Agree	36 (26.9)	131 (32.8)	42 (41.2)	
Strongly Agree	12 (9.0)	57 (14.3)	24 (23.5)	
A03				9.8 (0.279)
Strongly Disagree	6 (4.5)	15 (3.8)	3 (2.9)	
Disagree	7 (5.2)	41 (10.3)	11 (10.8)	
Neutral	19 (14.2)	68 (17.0)	21 (20.6)	
Agree	35 (26.1)	104 (26.1)	33 (32.4)	
Strongly Agree	67 (50.0)	171 (42.9)	34 (33.3)	
A04		**	#	38.4 (< 0.001)
Strongly Disagree	10 (7.5)	41 (10.3)	21 (20.6)	
Disagree	17 (12.7)	83 (20.8)	23 (22.5)	
Neutral	31 (23.1)	56 (21.6)	35 (34.3)	
Agree	51 (38.1)	107 (26.8)	15 (14.7)	
Strongly Agree	25 (18.7)	82 (20.6)	8 (7.8)	
A05			#	19.1 (0.014)
Strongly Disagree	1 (0.7)	3 (3.9)	4 (3.9)	
Disagree	5 (3.7)	19 (4.8)	7 (6.9)	
Neutral	4 (3.0)	38 (9.5)	11 (10.8)	
Agree	37 (27.6)	75 (18.8)	23 (22.5)	
Strongly Agree	87 (64.9)	264 (66.2)	57 (55.9)	
A06				11.0 (0.201)
Strongly Disagree	7 (5.2)	17 (4.3)	2 (2.0)	
Disagree	13 (9.7)	51 (12.8)	10 (9.8)	
Neutral	45 (33.6)	108 (27.1)	35 (34.3)	
Agree	46 (34.3)	151 (37.8)	28 (27.5)	
Strongly Agree	23 (17.2)	72 (18.0)	27 (26.5)	

	Freshman (n=134)	Sophomore (n=399)	Senior (n=102)	χ^2 (P-value)
A07				11.3 (0.184)
Strongly Disagree	17 (12.7)	34 (8.5)	7 (6.9)	
Disagree	24 (17.9)	68 (17.0)	16 (15.7)	
Neutral	55 (41.0)	135 (33.8)	34 (33.3)	
Agree	29 (21.6)	124 (31.1)	30 (29.4)	
Strongly Agree	9 (6.7)	38 (9.5)	15 (14.7)	
A08, yes	127 (94.8) *	307 (76.9) **	64 (62.7) #	36.5 (< 0.001)
A09	*		#	30.0 (< 0.001)
Strongly Disagree	2 (1.5)	12 (3.0)	1 (1.0)	
Disagree	7 (5.2)	13 (3.3)	1 (1.0)	
Neutral	23 (17.2)	23 (5.8)	3 (2.9)	
Agree	28 (20.9)	85 (21.3)	19 (18.6)	
Strongly Agree	74 (55.2)	266 (66.7)	78 (76.5)	
A10				11.1 (0.194)
Strongly Disagree	7 (5.2)	9 (2.3)	0 (0.0)	
Disagree	3 (2.2)	14 (3.5)	3 (2.9)	
Neutral	14 (10.4)	32 (8.0)	11 (10.8)	
Agree	34 (25.4)	91 (22.8)	18 (17.6)	
Strongly Agree	76 (56.7)	253 (63.4)	70 (68.6)	
A11	*		#	39.5 (< 0.001)
Strongly Disagree	19 (14.2)	21 (5.3)	9 (8.8)	
Disagree	18 (13.4)	42 (10.5)	4 (3.9)	
Neutral	29 (21.6)	59 (14.8)	12 (11.8)	
Agree	36 (26.9)	98 (24.6)	18 (17.6)	
Strongly Agree	32 (23.9)	179 (44.9)	59 (57.8)	

Data are expressed as no. (%). X^2 is the statistics of the Chi-squared test; * P-values<0.001 for comparisons between Freshman and Sophomore; ** P-values<0.013 Sophomore vs. Senior; # P-values<0.005 Freshman vs. Senior; P-values ^{a11} 0.0015; ^{a12} 0.6249 ^{a13} 0.00399 (corrected significance level 0.0033)

Table 6. Devices and e-learning resources: comparisons between freshman, sophomore and senior.

	Freshman (n=134)	Sophomore (n=399)	Senior (n=102)	χ^2 (P-value)
Devices				
Laptop	120 (89.6)	359 (90.0)	93 (91.2)	0.2 (0.912)
Smartphone	85 (63.4)	270 (67.7)	76 (74.5)	3.3 (0.194)
Tablet	19 (14.2)	38 (9.5)	8 (7.8)	3.1 (0.210)
Computer	10 (7.5)	38 (9.5)	6 (5.9)	1.6 (0.445)
TV	2 (1.5)	5 (1.3)	2 (2.0)	0.3 (0.862)
E-learning sources				
Amboss	4 (3.0)*	69 (17.3)	16 (15.7) #	17.3 (< 0.001)
Medscape	21 (15.7) *	112 (28.1) **	46 (45.1) #	24. 8 (< 0.001)
Osmosis	27 (20.1) *	155 (38.8)	28 (27.5)	17.6 (0.0002)
PubMed	51 (38.1) *	220 (55.1) **	71 (69.6) #	23.9 (< 0.001)
YouTube	120 (89.6)	348 (87.2) **	74 (72.5) #	16.4 (< 0.001)
Dr.Najeeb	17 (12.7)	58 (14.5)	11 (10.8)	1.1 (0.582)
Lecturio	6 (4.5)	27 (6.8)	5 (4.9)	1.2 (0.552)
Difficulties				2.5 (0.960)
rarely	27 (20.1)	89 (22.3)	23 (22.5)	
rare	50 (37.3)	144 (36.1)	40 (39.2)	
sometimes	29 (21.6)	85 (21.3)	23 (22.5)	
frequently	21 (15.7)	56 (14.0)	13 (12.7)	
very often	7 (5.2)	25 (6.3)	3 (2.9)	

* P-values < 0.005 for comparisons between Freshman and Sophomore; ** P-values < 0.009 for comparisons between Sophomore and Senior; # P-values < 0.005 for comparisons between Freshman and Senior.

Discussion

In our study, medical students agreed that implementing e-learning was a reasonable alternative to traditional learning during COVID-19 lockdown. Our results showed several differences in students' opinions about the e-learning implementation, both between specialties and years of the study, reflecting the differences in perception of e-learning in medical education.

Due to the SARS-CoV-2 pandemic (COVID-19), most administrative, scientific, business, cultural, and education activities were made exclusively online. Most medical schools suspend traditional learning methods and shift to online medical training as a measure of protection for students' and teachers' health [12].

A delayed educational institutions' closure is less effective than preserving face-to-face training in preventing the infection spread during a pandemic [34]. Despite the epidemiological benefits of social distancing, remote learning leads to isolation that can affect the students' and teachers' mental health [35] and disrupt the development of medical skills [24-26]. Positive effects associated with online education include more learning time, fewer costs, and better exam results [36,37].

The medical students included in our study belongs to the millennials and Z generation, also known as "electronic natives" [38], so it is expected to have the technology skills needed for online learning [39].

A large majority of participants considered it was important for our University to adopt e-learning methods during the COVID-19 pandemic. In particular, final year students, called seniors (Se) and students of the Medicine section, strongly agreed with the importance of academic year continuity (Tables 3 – first hypothesis and 5 – second hypothesis, A01). A similar result has also been reported by Ahmed et al. [40], who highlighted that the continuation of teaching, even in the context of reduced clinical activities, allowed students to graduate and sit the final exams. Different opinions between freshman, sophomore, and senior could be explained by different exposure to medical training (freshman respondents entering in lockdown at the beginning of the studies) as well as different level of matuurization.

In our study, less than 50% of respondents agreed that e-learning was adequate for the educational process (Tables 3 – first hypothesis and 5 – second hypothesis, A02 agree or strongly agree), with a significantly higher percentage of *Seniors* than *Freshmans* and *Sophomore* (Table 5 – second hypothesis). According to McCoy et al. [41], students and teachers believe that all the existing technological tools can help the educational process by replacing the lack of face-to-face meetings. Providing effective education through online forms in a speedy transition represents a significant test for academic teachers, considering that not all types of technology can enhance learning [42]. However, academic staff should devote additional time and energy to developing e-learning materials with clear intended learning outcomes (ILOs) [43] to create the frame that can reduce students' anxiety regarding exams promotion [44]. However, this transition cannot occur overnight, it needs appropriate training and sufficient time to create and validate proper educational materials [45].

Because of the fast spread of SARS-CoV-2, faculties and students worldwide were forced to face sometimes (especially those who did not have an e-learning platform implemented before the COVID-19 pandemic) an entirely brand-new education system. Most of our survey participants declared that the learning process suffered during the COVID-19 pandemic (Table 3 – first hypothesis and 5 – second hypothesis – A03), even if educational activity continued online. However, disadvantages of e-learning, even in the pandemic context, need to be acknowledged, and disruption of medical skills development and low engagement [12,14, 28, 24-26] are the most important.

Regarding the process of assimilating theoretical knowledge, most of the first-year students agreed that they encountered difficulties, unlike sophomore and senior students (Table 5 – first hypothesis, A04). This expected result could be explained by the lack of academic experience that provokes difficulties in learning progress for freshman students, an effect previously reported in the scientific literature [17].

Our findings showed that most students, no matter their year of study or specialization, strongly agreed that they confronted obstacles regarding practical professional skills (Table 3 – first hypothesis and 5 – second hypothesis, A05). Several studies described the same missing element in the effectiveness of e-learning [30-32,**Error! Bookmark not defined.**,46]. It is well known that

technology cannot replace human interaction, the interactivity between medical professionals and patients represents a unique and important key in physicians' professional development [4]. Clinical skills are indispensable in a medical practitioner's career, and preclinical education is the foundation for a proficient medical staff [47]. The lack of training sessions in wards rotations can affect medical students' clinical confidence and during the COVID-19 pandemic, the current medical students lost several months of practical learning [48].

Interactivity is another ingredient of effectiveness in education, and our participants were neutral regarding this component during online education (Table 3 – first hypothesis and 5 – second hypothesis, A07). Previously reported results showed a low interaction during the remote classes and thus low individual motivation during the COVID-19 crisis [14,28,49,50]. However, online interaction during synchronous lectures helps students who often hesitate or who present a lack of confidence in face-to-face dialogue [51]. The online interactivity had technical support through student response systems (SRSs) along with audience response systems (ARSs, real-time multiple-choice questions) to encourage higher receptivity and implication during the educational process [52-54].

Students received projects and quizzes as instruments of knowledge assessment in a similar amount on *Medicine* as compared to other specializations, but more in preclinical years than clinical (Table 3 – first hypothesis and 5 – second hypothesis, A08). Scaffolding learning methods (e.g., quizzes or practical tests and synchronous e-learning) promote student-content, student-student, and student-instructor interactions. Thus, they encourage students to be more confident in their knowledge and prolific in their study [55].

Most of our participants considered beneficial the pre-existence of a platform designed to support the educational process in the context of emergencies (Table 3 – first hypothesis and 5 – second hypothesis, A10). Also, the students admitted that information received during the practical classes/courses on the Teams platform came in addition to the teaching materials such as manuals, course materials, or handbooks (Table 3 – first hypothesis and 5 – second hypothesis, A06). Universities should purchase adequate and professional gear for good technical support to allow appropriate digital learning [48] and provide sustainable logistic support [56].

In our study, most students, especially from medicine specialization (first hypothesis), *sophomore* and *senior* students (second hypothesis), agreed that e-learning could be used in continuing medical education (Table 3 and 5, A11). Optional courses delivered using e-learning tools could also be reliable in medical education. Furthermore, the use of technology could increase learning outcomes as demonstrated in ophthalmology (computer-assisted learning) [57] or effectiveness in teaching anatomy [58]. Friedl et al. [59] reported no differences in knowledge acquisition when multimedia was compared to traditional education. In contrast, other studies reported online education as a learning method that improves skills and medical knowledge, which greatly impacted students' satisfaction and motivation [60,61]. Undoubtedly, online continuing medical education programs (CME) such as webinars, conferences, and even workshops proved appropriate solutions during COVID-19 outbreaks [62].

During the outbreak of COVID-19, e-learning was recognized as a "full-time" form of education [63] and has been important for achieving SARS-CoV-2 infection clinical management [64]. The COVID-19 pandemic has determined a complete transfer of traditional methods to e-learning methods in medical science methods, mainly as synchronous (real-time) activities rather than asynchronous (no real-time, pre-recorded materials that assure more flexibility [65]). We expected to see more frequent implementations of virtual elements such as virtual patients, artificial intelligence for adaptive learning, virtual reality (VR), and augmented reality (AR) in future educational strategies [66]. These instruments could provide accurate education methods that fit the student's needs, extensive study tools, and personalized feedback [67]. Coupled with physical components, virtual educational approaches offer a new range of blended learning called extended reality (XR) [68].

This is the first study that reports the impact of COVID-19 on online medical teaching in Romania using a short-survey that includes mostly closed questions to reduce the nonresponse errors and results' diversity. Another strength of our study is the homogenous representation of respondents according to the year of study across preclinical and clinical years. However, the study was conducted in only one University, and several limitations must be highlighted. First, almost 94% of the target

population was reached, but only nearly 22% of the available population participated in our survey. The response rate in our study is lower than the mean response rate of 53% reported after the evaluation of 1014 surveys [69]. The technology burnout considering that students used technology more hours than before the COVID-19 pandemic and mental health burdens [17] could explain the low participation rate. The participation was voluntary without any constraints, and since we reached a low response rate, we could expect the non-participants to have a different opinion. Thus, the generalizability of the reported results to the targeted medical student's population is not recommended. Second, our survey was administered only to the Romanian section students, so the results reflect the Romanian participants students' views and not the English and/or French sections, Medicine specialization at the "Iuliu Haţieganu" University of Medicine and Pharmacy Cluj-Napoca. Due to heterogeneous cultural variety among students from English and French sections, a different view on this particular population is expected, and it would be interesting to compare the views in the same University. Third, the students were asked to share the educational resources they use in learning medicine, but we only classified them according to the type of access and not their content. An evaluated list with resources given by the teachers could standardize the supplementary learning resources but will not necessarily fit each student's needs and training technique. Fourth, we did not evaluate the types of online teaching provided because the variety was large, and the comparison is not necessarily appropriate (different tools could be appropriate for one discipline but not for other disciplines).

Conclusion

In our findings, the participants agreed that e-learning was a powerful tool that helped academic education during the pandemic, but the acquirement of practical skills has suffered. Thus, online learning methods must be considered an alternative to traditional education, including in crisis situations. However, to guarantee the effectiveness of e-learning for undergraduate medical students, educational innovations should be rigorously and regularly evaluated. Our study showed that students' needs, as well as their perceptions, differ both between specializations as well as years of study.

List of abbreviations

OtherS =other specialties
Fr= freshman
So=sophomore
Se= senior
SARS-CoV-2= Severe acute respiratory syndrome coronavirus 2
COVID-19= Coronavirus disease 2019

Ethical Issues

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca Ethics Committee (approval no. 191/18 May 2020).

The following informed consent sentence was included in the survey: "No personal data are collected in this survey. By filling in the survey, you are consenting to participation and inclusion in our research of your responses".

Conflict of Interest

The authors declare no conflict of interest.

Authors' Contributions

Conceptualization, V.M.B., D.B. and A.E.B.; methodology, V.M.B., D.B., A.E.B. and S.D.B.; validation, D.B. and S.D.B.; formal analysis, D.B. and S.D.B.; investigation, V.M.B, D.B.; resources, V.M.B. and D.B.; data curation, S.D.B.; writing—original draft preparation, V.M.B. and D.B.; writing—review and editing, S.D.B.; visualization, S.D.B.; supervision, A.E.B.; project administration, V.M.B.; funding acquisition, A.E.B. All authors have read and agreed to the published version of the manuscript.

References

1. Basak SK, Wotto M, Belanger P. E-learning, M-learning and D-learning: Conceptual definition and comparative analysis. E-Learning and Digital Media 2018;15(4):191-216. doi: 10.1177/2042753018785180
2. Harless WG, Drennon GG, Marxer JJ, Root JA, Miller GE. CASE: a Computer-Aided Simulation of the Clinical Encounter. J Med Educ. 1971;46(5):443-448.
3. Herrick MC, A new approach to computer assisted instruction in health science education. Ala J Med Sci 1970;7(2):172-174.
4. Cook DA, Triola MM. Virtual patients: a critical literature review andproposed next steps. Medical Education 2009;43:303-311. doi:10.1111/j.1365-2923.2008.03286.x
5. Cook DA, Erwin PJ, Triola MM. Computerized Virtual Patients in Health Professions Education: A Systematic Review and Meta-Analysis. Academic Medicine 2010;85(10):1589-1602. doi: 10.1097/ACM.0b013e3181edfe13
6. Kim S. The Future of e-Learning in Medical Education: Current Trend and Future Opportunity. J Educ Eval Health Prof. 2006;3:3. doi: 10.3352/jeehp.2006.3.3
7. Vaona A, Banzi R, Kwag KH, Rigon G, Cereda D, Pecoraro V, et al. E-learning for health professionals. Cochrane Database Syst Rev 2018;1(1):CD011736. doi: 10.1002/14651858.CD011736.pub2
8. Clark RC, Mayer RE. E-learning and the science of instruction: proven guidelines for consumers and designers of multimedia learning [Internet]. Wiley; 2016. Available from: https://www.wiley.com/en-hus/e+Learning+and+the+Science+of+Instruction%3A+Proven+Guidelines+for+Consumers+and+Designers+of+Multimedia+Learning%2C+4th+Edition-p-9781119158660 (accessed on 18 April 2021).
9. Ward JP, Gordon J, Field MJ, Lehmann HP. Communication and information technology in medical education. Lancet 2001;357:792-796.
10. Masie E. Blended learning: the magic is in the mix. In: Rossett A (ed). The ASTD E-Learning Handbook. New York: McGraw-Hill 2002, pp. 58-63.
11. Pollard CA, Morran MP, Nestor-Kalinoski AL. The COVID-19 pandemic: a global health crisis. Physiol Genomics 2020;52(11):549-557. doi:10.1152/physiolgenomics.00089.2020
12. Connolly, N.; Abdalla, M.E. Impact of COVID-19 on medical education in different income countries: a scoping review of the literature. Med Educ Online 2022;27(1):2040192. doi:10.1080/10872981.2022.2040192
13. Rotar-Pavlic D, Erzar A, Ustar B, Maksuti A. Medical students' perception of distance-based education during the COVID-19 pandemic in Slovenia: A qualitative study. International Journal of Educational Research Open 2022;3:100-135. doi:10.1016/j.ijedro.2022.100135
14. Dost S, Hossain A, Shehab M, Abdelwahed A, Al-Nusair L. Perceptions of medical students towards online teaching during the COVID-19 pandemic: a national cross-sectional survey of 2721 UK medical students. BMJ Open 2020;10(11):e042378. doi: 10.1136/bmjopen-2020-042378

15. Kim JW, Myung SJ, Yoon HB, Moon SH, Ryu H, Yim JJ. How medical education survives and evolves during COVID-19: Our experience and future direction. PLoS One. 2020;15(12):e0243958. doi:10.1371/journal.pone.0243958
16. Motte-Signoret E, Labbé A, Benoist G, Linglart A, Gajdos V, Lapillonne A. Perception of medical education by learners and teachers during the COVID-19 pandemic: a cross-sectional survey of online teaching. Med Educ Online 2021;26(1):1919042. doi:10.1080/10872981.2021.1919042
17. Shahrvini B, Baxter SL, Coffey CS, MacDonald BV, Lander L. Pre-clinical remote undergraduate medical education during the COVID-19 pandemic: a survey study. BMC Med Educ 2021;21:13. doi:10.1186/s12909-020-02445-2
18. Elzainy A, El Sadik A, Al Abdulmonem W. Experience of e-learning and online assessment during the COVID-19 pandemic at the college of medicine, Qassim University. J Taibah Univ Med Sci 2020;15(6):456-462. doi:10.1016/j.jtumed.2020.09.005
19. Torda, A. How COVID-19 has pushed us into a medical education revolution. Intern Med J 2020;50(9):1150-1153. doi: 10.1111/imj.14882
20. Liu CH, You-Hsien Lin H. The impact of COVID-19 on medical education: Experiences from one medical university in Taiwan. J Formos Med Assoc 2021;120(9):1782-1784. doi: 10.1016/j.jfma.2021.02.016
21. Thomas A, Shenoy, MT, Shenoy KT, Suresh Kumar S, Sidheeque A, Khovidh C, et al. Survey Among Medical Students During COVID-19 Lockdown: The Online Class Dilemma. International Journal of Medical Students 2020;8(2):102-106. doi:10.5195/ijms.2020.571
22. Rafi A, Varghese P, Kuttichira P. Concerns and confidences expressed by teaching staff about the shift of medical education to online mode in South India during the COVID 19 pandemic. J Ideas Health 2020;3(Special2):272–275.
23. Vatier C, Carrié A, Renaud MC, Simon-Tillaux N, Hertig A, Jéru I. Lessons from the impact of COVID-19 on medical educational continuity and practices. Adv Physiol Educ 2021;45(2):390-398. Doi:10.1152/advan.00243.2020
24. Harries AJ, Lee C, Jones L, Rodriguez RM, Davis JA, Boysen-Osborn M, et al. Effects of the COVID-19 pandemic on medical students: a multicenter quantitative study. BMC Med Educ 2021;21:14. doi:10.1186/s12909-020-02462-1
25. Alsoufi A, Alsuyihili A, Msherghi A, Elhadi A, Atiyah H, Ashini A, et al. Impact of the COVID-19 pandemic on medical education: Medical students' knowledge, attitudes, and practices regarding electronic learning. PLoS One 2020;15(11):e0242905. doi:10.1371/journal.pone.0242905
26. Abbasi MS, Ahmed N, Sajjad B, Alshahrani A, Saeed S, Sarfaraz S, et al. E-Learning perception and satisfaction among health sciences students amid the COVID-19 pandemic. Work 2020;67(3):549-556. doi:10.3233/WOR-203308
27. Bączek M, Zagańczyk-Bączek M, Szpringer M, Jaroszyński A, Wożakowska-Kapłon B. PhD Students' perception of online learning during the COVID-19 pandemic. Medicine 2021;100(7):e24821. doi: 10.1097/MD.0000000000024821
28. Daroedono E, Siagian FE, Alfarabi M, Cing JM, Arodes ES, Sirait RH, et al. The impact of COVID-19 on medical education: our students perception on the practice of long distance learning. International Journal of Community Medicine and Public Health 2020;7(7):2790-2796. doi: 10.18203/2394-6040.ijcmph20202545
29. Baticulon RE, Sy JJ, Alberto NRI, Baron MBC, Mabulay REC, Rizada LGT, et al. Barriers to online learning in the time of COVID-19: a national survey of medical students in the Philippines. Med Sci Educator 2021;31(2):615-626. doi:10.1007/s40670-021-01231-z
30. Almomani EY, Qablan AM, Atrooz FY, Almomany AM, Hajjo RM, Almomani HY. The Influence of Coronavirus Diseases 2019 (COVID-19) Pandemic and the Quarantine Practices on University Students' Beliefs About the Online Learning Experience in Jordan. Front Public Health 2021;8:595874. doi: 10.3389/fpubh.2020.595874
31. The Emergency State on Romanian Territory. Available online: https://www.presidency.ro/ro/media/decret-semnat-de-presedintele-romaniei-domnul-klaus-iohannis-privind-instituirea-starii-de-urgenta-pe-teritoriul-romaniei (accessed on 24 July 2020)

32. Mihai FC. Assessment of COVID-19 Waste Flows During the Emergency State in Romania and Related Public Health and Environmental Concerns. Int J Environ Res Public Health. 2020;17(15):5439. doi:10.3390/ijerph17155439
33. Tavakol M, Dennick R. Making sense of Cronbach's alpha. Int J Med Educ 2011;2:53-55. doi:10.5116/ijme.4dfb.8dfd
34. Zumla A, Yew WW, Hui DS. Emerging respiratory infections in the 21st century. Preface. Infect Dis Clin North Am 2010;24(3):xiii–xvi. doi:10.1016/j.idc.2010.04.014
35. Rose S. Medical Student Education in the Time of COVID-19. JAMA 2020;323(21):2131-2132. doi:10.1001/jama.2020.5227
36. Khalil R, Mansour AE, Fadda WA, Almisnid K, Aldamegh M, Al-Nafeesah A, et al. The sudden transition to synchronized online learning during the COVID-19 pandemic in Saudi Arabia: a qualitative study exploring medical students' perspectives. BMC Med Educ 2020;20(1):285. doi: 10.1186/s12909-020-02208-z
37. Wu SJ, Fan YF, Sun S, Chien CY, Wu YJ. Perceptions of medical students towards and effectiveness of online surgical curriculum: a systematic review. BMC Med Educ 2021;21(1):571. doi:10.1186/s12909-021-03014-x
38. Chaudhuri JD. Stimulating intrinsic motivation in millennial students: a new generation, a new approach. Anat Sci Educ 2020;13:250-271. doi: 10.1002/ase.1884
39. Bringman-Rodenbarger L, Hortsch M. How students choose E-learning resources: The importance of ease, familiarity, and convenience. FASEB Bioadv. 2020;2(5):286-295. doi:10.1096/fba.2019-00094
40. Ahmed H, Allaf M, Elghazaly H. COVID-19 and medical education. Lancet Infect Dis. 2020;20(7):777-778. doi: 10.1016/S1473-3099(20)30226-7
41. McCoy L, Pettit RK, Lewis JH. Developing technology-enhanced active learning for medical education: challenges, solutions, and future directions. J Am Osteopathic Assoc 2015;115(4):202-211. doi: 10.7556/jaoa.2015.042
42. Orlando J, Attard C. Digital natives come of age: The reality of today's early career teachers using mobile devices to teach mathematics. Math Ed Res J 2016;28:107-121. doi:10.1007/s13394-015-0159-6
43. Biggs J. Constructive alignment in university teaching. HERDSA Review of Higher Education 2014;1:5-22.
44. Backley S, Sheffield R. Digital andragogy: A richer blend of initial teacher education in the 21st century. Issues Educ Res 2015;25(4):397-414.
45. How does the pandemic affect U.S. college students? Temple University, Philadelphia. CNN interview. (Apr 2020). Available from: http://www.pbs.org/wnet/amanpour-and-company/video/how-does-pandemic-affect-low-income-students-nufk5j/ (accessed on 24 February 2022).
46. Bauchner H, Sharfstein J. A bold response to the COVID-19 pandemic medical students, national service, and public health. JAMA 2020;323:1790-1791. doi: 10.1001/jama.2020.6166
47. Buja LM. Medical education today: all that glitters is not gold. BMC Med Educ 2019;19(1):110. doi: 10.1186/s12909-019-1535-9.
48. Macdougall C, Dangerfield P, Katz D, Strain WD. The impact of COVID-19 on Medical education and Medical Students. How and when can they return to placements? MedEdPublish 2020;9:159. doi:10.15694/mep.2020.000159.1
49. Pather N, Blyth P, Chapman JA, Dayal MR, Flack N, Fogg QA, et al. Forced Disruption of Anatomy Education in Australia and New Zealand: An Acute Response to the Covid-19 Pandemic. Anat Sci Educ 2020;13(3):284-300.
50. Gishen F, Bennett S, Gill D. Covid-19-the impact on our medical students will be far-reaching. Available from: https://blogs.bmj.com/bmj/2020/04/03/covid-19-the-impact-on-our-medical-students-will-be-far-reaching/ (accessed on 17 May 2021)
51. Lei L, Finley J, Pitts J, Guo R. Which Is a Better Choice for Student–Faculty Interaction: Synchronous or Asynchronous Communication?. Journal of Technology Research 2011;2:1-12.

52. Caldwell JE. Clickers in the Large Classroom: Current Research and Best-Practice Tips. CBE—Life Sciences Education 2007;6(1):9-20. doi: 10.1187/cbe.06-12-0205
53. Viberg O, Grönlund A. Understanding students' learning practices: challenges for design and integration of mobile technology into distance education. Learning, Media and Technology 2015;42(3):357-377. doi:10.1080/17439884.2016.1088869
54. Kay RH, LeSage A. Examining the benefits and challenges of using audience response systems: A review of the literature. Computers & Education 2009;53(3):819-827. doi:10.1016/j.compedu.2009.05.001
55. Cho MH, Cho YJ. Online Instructors' Use of Scaffolding Strategies to Promote Interactions: A Scale Development Study. International Review of Research in Open and Distributed Learning 2016;17(6):108-120. doi:10.19173/irrodl.v17i6.2816
56. Camargo CP, Tempski PZ, Busnardo FF, Martins MA, Gemperli R. Online learning and COVID-19: a meta-synthesis analysis. Clinics (Sao Paulo) 2020;75:e2286. doi:10.6061/clinics/2020/e2286
57. Succar T Grigg J. A new vision for teaching ophthalmology in the medical curriculum: The Virtual Ophthalmology clinic. In Steel CH, Keppell MJ, Gerbic P, Housego S, eds. Curriculum, technology & transformation for an unknown future. Proceedings ascilite Sydney 2010, pp. 944-997.
58. Evans DJR, Bay BH, Wilson TD, Smith CF, Lachman N, Pawlina W. Going virtual to support anatomy education: a STOPGAP in the midst of the Covid-19 pandemic. Anat Sci Educ 2020;13(3):279-283. doi: 10.1002/ase.1963
59 . Friedl R, Höppler H, Ecard K, Scholz W, Hannekum A, Öchsner W, et al. Multimedia-Driven Teaching Significantly Improves Students' Performance When Compared With a Print Medium. Ann Thorac Surg 2006;81(5):1760-1766. doi:10.1016/j.athoracsur.2005.09.048
60. George PP, Papachristou N, Belisario JM, Wang W, Wark PA, Cotic Z, et al. Online eLearning for undergraduates in health professions: A systematic review of the impact on knowledge, skills, attitudes and satisfaction. J Glob Health 2014;4(1):010406. doi:10.7189/jogh.04.010406
61. Ochoa JG, Wludyka P. Randomized Comparison Between Traditional and Traditional Plus Interactive Web-Based Methods for Teaching Seizure Disorders. Teach Learn Med 2008;20(2): 114-117. doi: 10.1080/10401330801989513
62. Drude KP, Maheu M, Hilty DM. Continuing professional development: Reflections on a lifelong learning process. Psychiatr Clin North Am 2019;42:447-461. doi: 10.1016/j.psc.2019.05.002
63. Emanuel EJ. The Inevitable Reimagining of Medical Education. JAMA 2020;323(12):1127-1128. doi: 10.1001/jama.2020.1227
64. Wang H, Kang K, Gao Y, Yang B, Li J, Wang L, et al. Remote nursing training model combined with proceduralization in the intensive care unit dealing with patients with COVID-19. World J Clin Cases 2021;9(5):999-1004. doi:10.12998/wjcc.v9.i5.999
65. Finkelstein J. Learning in real time: synchronous teaching and learning online. Washington: DCJossey-Bass 2006
66. Goh P, Sandars JA. A vision of the use of technology in medical education after the COVID-19 pandemic. MedEdPublish 2020;9(1):49. doi: 10.15694/mep.2020.000049
67. Chan KS, Zary N. Applications and Challenges of Implementing Artificial Intelligence in Medical Education: Integrative Review. JMIR Med Educ 2019;5(1):e13930. doi:10.2196/13930
68. Wartman SA, Combs CD. Reimagining Medical Education in the Age of AI. AMA J Ethics 2019;21(2):E146-152. doi: 10.1001/amajethics.2019.146
69. Holtom B, Baruch Y, Aguinis H, Ballinger GA. Survey response rates: Trends and a validity assessment framework. Human Relations 2022; OnlineFirst. doi:10.1177/00187267211070769