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Medical Learning Applications Used by Undergraduate Medical Students in Cluj-Napoca: A Cross-Sectional Survey

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Abstract
Introduction: This study explores the utility of and attitude towards medical learning applications (MLAs) among undergraduate students of medicine in Cluj-Napoca and the use of these apps in finding solutions to five case-based medical scenarios. *Materials and methods:* A cross-sectional design using an online survey was conducted between June 8th and July 19th, 2019. The English and Romanian students were personally invited to participate in the survey via social media platforms (Facebook/WhatsApp student groups). A three-section questionnaire was developed to anonymously collect demographic data, study habits and the answers to the five case-based medical scenarios. *Results:* Ninety-three students between the age of 19 and 50 (median 24 years) participated. Most of the responding students (81.7%) were in the clinical years of study and studied up to 3 hours per day (67.7%). The use of MLAs ≥2 hours per day is reported by 18.3% of respondents. The MLAs were mainly used for studying throughout the semester (69.1%); 30.9% of the students used MLAs only for their exam preparation. The top-three MLAs were 'AMBOSS' (30/93), 'Medscape' (9/93) and 'Dr. Najeeb Lectures' (6/93). In around half of the cases, the students paid for the MLA (46.4%). The maximum obtainable score (6 points) in the clinical cases was reached only by 3 students without significant differences between the scores of those students who used or did not use resources (MLAs, books, other) to find the case solutions (Mann-Whitney test P=0.594, median of correct answers = 3 for both groups) or between the scores of those who used or did not use MLAs for learning (P=0.594, median of correct answers = 3 for both groups). *Conclusion:* One third of the participating students used MLAs but this is not reflected in the number of correctly answered clinical cases.

Keywords: Medical Learning Application (MLA); Learning resources; Undergraduate; Educational technologies; Problem-Based Learning

Introduction

New approaches other than studying in the "traditional" sense (i.e., from textbooks) during medical school have evolved with the steady increase in the number of available medical learning

applications (MLAs) during the past two decades. These new ways of studying include using 3D apps for learning anatomy [1], programs providing visual content embedded in cases for preparing for the medical imaging fields (e.g., 'UBC Radiology Teaching App' for radiology) [2], constantly updated online resources featuring short and concise explanations of pathologies and treatment options (e.g., 'UpToDate') [3], video lectures (sometimes interactive) about nearly every conceivable medical topic (e.g., 'Dr. Najeeb Lectures') [4], as well as offering online question banks for self-assessment purposes (e.g., 'Kaplan Medical USMLE Step 1 Qbank') [5].

The currently most used medical learning application is 'Essential Anatomy 5' by 3D4Medical [1]. The accurate visualization of the human body (male and female models with over 8.200 structures) and an intuitive user interface make it a helpful tool for medical students who are seeking a better understanding of the human body; apart from that, the app is also used by health care providers working in a hospital setting or in a medical practice who are looking for a simple way to quickly review anatomical structures or a graphical aid while giving patients explanations about pathologies [1].

Using an anatomy app, be it 'Essential Anatomy 5' or any other 3D anatomy app (e.g., '3D BODY' available at 'drbeen' [6]) has many advantages for medical students:

- There is no (or less) need for dissecting human cadavers anymore, and hence:
    - the student does not need to be present in the anatomical dissection rooms;
    - he/she can learn at his/her own pace;
    - less specimens will be in a bad condition due to improper handling;
    - quick switching between structures is possible.
- Info boxes providing extra information about structures largely eliminate the need of flipping textbook pages or consulting the internet, and highlighting or marking structures through customized pins and taking screenshots and in-app notes aid in the learning process.

However, anatomy apps can come along with some major drawbacks. They represent what their developers thought to be the 'classical' structures, leading inevitably to a lack of anatomical variation – or to an overrepresentation of structures that are *in vivo* not as common as the app imposes upon students. Questions like "Will there be a complete circle of Willis in this specimen?", "Is there a third head of the biceps brachii present?" or pathology-related questions like "Is this left ventricle indicative of someone who suffered for a long time from hypertension?" are some of the reasons that make the dissecting process itself so exciting – features that are currently missing in the leading anatomy apps [1]. Furthermore, even though the information provided by the apps usually overlaps with the information given by leading textbooks, the user might notice at times discrepancies or even mistakes in the represented structures [7]; this could easily lead to confusion or frustration among students or, in a worst-case scenario, a student totally mistrusting and abandoning an otherwise helpful learning tool.

Also, the issue with paywalls is not to be neglected. Even though most apps come along with a fairly cheap price tag (at least compared to textbooks), some apps require users to install extra payments for the full app version, future updates or additional content (e.g., 'Essential Anatomy 3' [7]). In this way, expenses for study material can rise pretty quickly.

Finally, since apps are technical in nature, issues can arise from this side, too. The user needs to own a compatible device (e.g., 'Essential Anatomy 5' is only available for MAC [1], but Windows users could use the older version ‚Essential Anatomy 3' [7])) with enough free space on his/her hard drive (e.g., for 'Essential Anatomy 3' around 850 MB of memory are needed), and might sometimes experience freezes, bugs or crashes.

Currently, a continuously growing number of studies is assessing how medical students use e-learning tools like 'Essential Anatomy 5'. A study conducted by Wynter et al. in 2019 investigated the educational resources used by undergraduate and postgraduate medical students in Australia (University of New South Wales and University of Sidney). The vast majority of students reported the use of e-learning tools such as online lectures (92%) and question banks (90.6%). However, for learning new material, students most frequently relied on textbooks and taking written notes, while online or downloaded question banks were most frequently used for revision purposes. The authors concluded that traditional resources like attending face-to-face lectures still remain the most frequently used ones when it comes to learning new material [8].

Similarly, a second Australian study investigated the use of online learning resources among first-year medical students. The authors reported that despite the fact that the students had access to online journals and scholarly databases, the most commonly used non-university sites were Google and Wikipedia, while the most commonly accessed resources (via an university learning platform) were lecture notes; also, students were more likely to select learning resources according to the recommendation by fellow students rather than by teaching staff. The authors concluded that even though medical students had easy access too high-quality resources, many of them did not take advantage of them [9].

As opposed to the previously mentioned study which investigated the study habits of first-year medical students, Scott et al. used learning analytics and a questionnaire to study the learning habits of final-stage medical students during their pediatrics clerkship. The authors reported an extensive use of online e-learning resources for self-directed learning, especially two weeks before the final examination, peaking the day before the written examination. Around 30% of all students indicated that they never read the course textbook, while all students used digital formative assessment [10].

The main goals of our study were: a) to find out whether undergraduate students from the Faculty of Medicine, "Iuliu Haţieganu" University of Medicine and Pharmacy Cluj-Napoca used MLAs, b) to identify which ones (if applicable) they preferred, and, c) to see whether the use of MLAs (regardless of whether used as a general learning tool throughout the semester or whether used solely to find the answers to the five clinical cases) would have an impact on the number of correctly solved medical scenarios presented in our survey.

Materials and Methods

Participants

Eligible for the study were all undergraduate medical students who were at the time of our study enrolled in the Faculty of Medicine at the "Iuliu Haţieganu" University of Medicine and Pharmacy Cluj-Napoca, Romania, in either the English or Romanian study section. Students enrolled in the same university but studying medicine in the French language or studying nursing, physio-kinesiotherapy and rehabilitation, radiology and medical imaging, as well as those studying dentistry or pharmacy were excluded.

Methods

The participants were invited to take part in the survey via links posted in the existing WhatsApp and Facebook student groups. The groups were created earlier by (and consisting only out of) students enrolled in the university for the purpose of quickly sharing university-related information, such as notifying group members about important announcements or distributing study material. Following the designated links, the participants were directed to Google Forms, an application that allows data collection through an implemented survey or quiz mode. The use of Google Forms also allows storing the raw data in an Excel sheet [11].

The questionnaire was organized into three sections: a) demographics, b) study habits and c) problem-based scenarios – five medical cases. The demographics section asked for the participants' age, gender, year of study and study section (English/Romanian). The section evaluating the study habits requested the average study time per day if the participant studied alone or within a study group and if in a group, the number of students in the group. It also asked about the study material used (textbooks, including books or e-books provided by the university, handouts or PowerPoint presentations, and MLAs). If MLAs were used, the participants were asked to name their three preferred learning resources and the average time spent with them per day and if the MLAs were used throughout the semester or only during the exam preparation. Furthermore, the participants were also asked to name the devices on which the MLAs were used (e.g., mobile phone, tablet, laptop, desktop computer), and the location (e.g., at home, during lectures or practical activities, on the go), and finally, how the participants got to know about them (recommended by teachers or friends, advertisement in books, journals, papers, book stores or online). If the participants paid for the MLAs

they used, they were asked whether they paid a monthly fee or if they made a single payment, and what they thought would be a reasonable cost for an MLA. Finally, the participants were asked whom they would prefer to be the content creator of MLAs (e.g., renowned experts in the specific medical field, common medical doctors, doctors from other fields, medical students) and whether they were willing to pay an extra fee if an MLA contained a question bank.

The last section featured five clinical cases (Table 1) from different specialties (nephrology or cardiology, gastroenterology, orthopedics, and hematology; reviewed by teachers of the university) with five-possible answers. The participants were also subsequently asked about a) the average time needed to solve these cases, b) the resources used to solve these cases, and, c) if MLAs were used to solve these cases, the names of these MLAs. The cases were designed by the authors and no participant was given the chance to see them beforehand. Abbreviations were explained in an introductory text and the possibility of having multiple correct answers was mentioned at the beginning but the questions were not marked as single- or multiple-choice questions).

The survey was open from June 8th to July 9th 2019.

Table 1. Case-based scenarios and solutions

No.	Scenario	Solution
1	A 42-year-old 30-weeks pregnant woman comes to your practice for a general check-up. Her BP is 160/90 mmHg. An urine dip-stick test reveals that she has no proteinuria. Going through her files you recognize that in the last 2 months she had blood pressures of 159/100 mmHg and 158/110 mmHg, respectively. What is your solution for this patient? a) You do not prescribe anything but ask her to come for another check-up in 2 weeks. b) You prescribe her an ACE-I and ask her to come for another check-up in 2 weeks. **c)** You prescribe her alpha-methyldopa and ask her to come for another check-up in 2 weeks. d) You prescribe her an ARB and ask her to come for another check-up in 2 weeks. **e)** Labetalol can be considered an alternative for alpha-methyldopa.	Gestational hypertension is defined as a blood pressure higher than 140/90 mmHg that has developed after the 20th week of pregnancy. According to European guidelines, all cases of gestational hyper-tension should be treated; according to American guidelines, treatment is necessary only if the systolic blood pressure is ≥ 160 mmHg or the diastolic blood pressure is ≥ 110 mmHg. Alpha-methyldopa or labetalol are the first-choice drugs for HTN in pregnancy [12, 13]. Calcium channel blockers (e.g., nifedipine) are another option [13]. Pure beta-blockers are to be avoided (especially atenolol) [13]. ACE-I and ARB are strictly contra-indicated in pregnancy because of their teratogenic effect [15]. Check-ups are scheduled at intervals of 2 weeks after 28 weeks of pregnancy and can be even more frequent in high-risk pregnancies if the doctor considers it necessary [14].
2	A 44-year-old African-American woman comes to your practice for a general check-up. Her BP is 160/90 mmHg. Going through her files you recognize that during her last check-up her blood pressure was 150/100 mmHg. The patient does not report any symptoms, physical examination and personal history are non-contributory (no history of DM). What is the next step? a) You do not prescribe her anything but ask her for another check-up next month. b) You prescribe her an ACE-I and ask her for another check-up next month. **c)** You prescribe her amlodipine (calcium channel blocker) and a diuretic and ask her for another check-up next month. d) You prescribe her an ACE-I and a diuretic and ask her for another check-up next month. e) You prescribe her an ARB and ask her for another check-up next month.	Since the patient had repeated blood pressure values consistent with grade 2 HTN (systolic blood pressure 160-179 mmHg and/or diastolic blood pressure 100-109 mmHg), medication needs to be considered. There are special precautions for African-American patients: It is not recommended to prescribe an ACE-I as a first-choice drug (less effective and higher risk of developing angioedema) [16]. The best option in this case would be to prescribe a calcium channel blocker and a diuretic. If the patient suffered from DM, a calcium channel blocker and an ARB could have been a better choice (note: it is known that there can be a cross-reactivity of ACE-I with ARBs in terms of angioedema [17]).

Table 1. (continued)

No.	Scenario	Solution
3	A 55-year-old Caucasian man comes to your practice complaining of retrosternal chest pain 'with a burning feeling' radiating to both sides of the chest that started 15 minutes after lunch while talking a walk home. Anamnesis reveals that he is known to have been suffering from GERD for the past three years for which he is currently under treatment (pantoprazole 20mg/day). A carotid ultrasound performed last year showed bilateral atherosclerotic plaques. What is the best next step? a) Increasing the dosage of pantoprazole to 40mg/day. **b)** ECG. c) Esophageal manometry. d) Upper endoscopy. e) Changing pantoprazole to an H2-inhibitor (ranitidine).	In case of chest pain, before considering an esophageal origin of the pain, a coronary disease must be excluded. Post-prandial retrosternal chest pain can be experienced both in GERD or coronary artery disease. The carotid plaques, male gender, and age are arguments that may suggest a cardiac cause of the pain. Either way, an ECG is strongly recommended as a first step [18].
4	A patient comes to your practice complaining of pain in the right upper arm associated with paresthesia. Anamnesis reveals that he was on a bicycle trip with his friends yesterday when he suddenly fell off his bike. Physical examination reveals a bruise and Celsian signs on the side of injury (right shoulder) among with crepitus. He took pain medication (2×500mg paracetamol). Which of the following is the best next step? a) MRI of the right shoulder b) Immobilization, ice packages and 400mg ibuprofen **c)** Temporary immobilization in a sling and X-ray of the right shoulder d) CT scan of the chest and right shoulder e) Physical therapy	Patient history, bruise, and crepitus suggest a fracture; paresthesia suggests nerve damage. An X-ray is needed to confirm the diagnosis [19, 20].
5	An 18-year-old girl comes to your practice complaining of fatigue and dyspnea when climbing stairs. Physical examination reveals pallor of the skin, tachycardia, hair loss, and brittle nails. Which of the following findings are most likely seen in this patient? a) Decreased Hb, decreased MCV, decreased iron, decreased ferritin, decreased MCH. b) Decreased Hb, increased MCV, increased homocysteine. c) Decreased Hb, normal MCV, normal MCH, decreased homocysteine. d) Decreased Hb, decreased MCV, low transferrin, teardrop cells. e) Decreased Hb, increased ferritin, decreased iron, schistocytes.	The patient suffers from iron deficiency anemia; schistocytes can be seen in DIC, vasculitis, and endocarditis but also in association with iron deficiency (iron-deficient erythrocytes are fragile and can fragment more easily). Also, teardrop cells can be seen most frequently in thalassemia but also in severe iron deficiency; an increased MCV can be found in folic acid or B12 anemia. In iron deficiency anemia ferritin levels are low and transferrin levels are high, therefore the only correct answer is a) (values typically altered in iron deficiency anemia). [21, 22].

Statistical Analysis

Qualitative data were reported as numbers and percentages and associations were tested with Chi-square test or Fisher's exact test according to the expected values. The differences between proportions were tested with the Z-test for proportions. Quantitative data were summarized as a median and interquartile range since they turned out not to follow the normal distribution (Kolmogorov-Smirnov test: $P<0.05$). Differences between groups regarding quanitative data were tested with the Mann-Whitney test.

Statistical analysis was made with the Statistica program (v. 8, StatSoft, OK, USA) except for the Fisher exact test that was done with the online resource available at https://www.quantitativeskills.com/sisa/statistics/fiveby2.htm.

All tests were two-tailed and conducted at a significance level of 5%. The graphical representation of the medical learning resources listed by respondents was created with the online resources available at https://worditout.com/word-cloud/create.

Results

Ninety-three students participated in our survey, most of them from the English section (58/93). The age of the participants varied from 19 to 50 years, with a median of 24 years and the value of the third quartile equal to 25 years. No significant differences regarding the age was observed among genders (Mann-Whitney Test: Z-statistic = -1.36, p-value = 0.175) or among sections (English vs. Romanian; Mann-Whitney Test: Z-statistic = -1.64, p-value = 0.101). Among the students from the English section, a significant percentage were men (36/56, 64.3%), while from the Romanian section a significantly higher percentage of participants were women (22/35, 62.9%) (χ^2 = 6.385, p-value = 0.012; two participants preferred to not disclose their gender).

Most of the participants regardless of the section were in their clinical years of medical education (4th to 6th years), with a tendency to statistical significance between groups (English vs. Romanian: 47/58 vs. 29/35; χ^2 = 2.91, p-value = 0.088).

With only two exceptions, the participants from the English section displayed a similar study behavior as the ones from the Romanian section in terms of the number of study hours per day and the university and other material as sources for learning (Table 2).

Table 2. Study behavior by section expressed in numbers and percentages (round brackets)

Characteristics	English section (n=58)	Romanian section (n=35)	p-value
Average no. of hours studied/day [a]			0.011
up to 2	30 (51.7)	9 (25.7)	
3	13 (22.4)	11 (31.4)	
4	5 (8.6)	6 (17.1)	
5	2 (3.4)	7 (20.0)	
>5	8 (13.8)	2 (5.7)	
Usually, I study [a]			0.291
Alone	56 (96.6)	31 (88.6)	
With one friend	1 (1.7)	3 (8.6)	
In a group (≥3)	1 (1.7)	1 (2.9)	
Learning resources used [b]			
University materials	50 (86.2)	35 (100.0)	0.023
Books	30 (51.7)	21 (60.0)	0.436
Video lectures	30 (51.7)	20 (57.1)	>0.999
MLAs	23 (39.7)	11 (31.4)	0.421
Flashcard apps	11 (19.0)	8 (22.9)	0.652
Question banks	11 (19.0)	7 (20.0)	0.906
Other (wikipedia)	2 (3.4)	0 (0.0)	0.270

The comparison between groups was done with the Fisher exact test (a) or the Z-test for proportions (b)

More students from the English section (37/58, 63.8%) provided the name of the MLAs used as compared to those from the Romanian section (16/35, 45.7%), but the difference is not statistically significant (χ^2 = 0.049, p-value = 0.826). Different MLAs were listed (Figure 1) and 'AMBOSS' was the one more frequently used among English section respondents (Table 3). The main features with regard to the use of the MLAs among the investigated sample is given in Table 3.

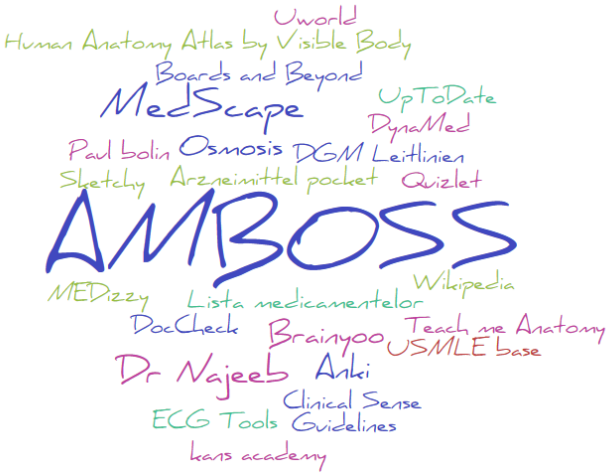

Figure 1. Medical learning apps listed by respondents (the larger the name of the app, the more frequently listed)

Table 3. Study behavior by section express as number and percentage (round brackets)

Characteristics	English section (n=58)	Romanian section (n=35)	Statistic (p-value)
Top three MLAs[a]			
AMBOSS[b]	24 (41.4)	6 (17.1)	n.a. (0.015)
Medscape	6 (10.3)	3 (8.6)	n.a. (0.788)
Dr. Najeeb Lectures	5 (8.6)	1 (2.9)	n.a. (0.279)
Average no. of hours of MLA use/day[a]			
≤1	33 (56.9)	23 (65.7)	n.a. (0.401)
2	9 (15.5)	1 (2.9)	n.a. (0.057)
3	5 (8.6)	2 (5.7)	n.a. (0.607)
Missing data	11 (19.0)	9 (25.7)	n.a. (0.446)
When are the MLAs used?[b]			1.361 (0.243)
Only to prepare for an exam	16/45	5/23	
Throughout the semester	29/45	18/23	
Where do you use the MLAs?[a]			
At home	40 (69.0)	20 (57.1)	n.a. (0.245)
During practical activities	12 (20.7)	12 (34.3)	n.a. (0.147)
During lectures	8 (13.8)	8 (22.9)	n.a. (0.260)
On the go	17 (29.3)	17 (48.6)	n.a. (0.061)
The device used to access MLAs[a]			
Mobile phone	32 (55.2)	19 (54.3)	n.a. (0.933)
Laptop	26 (44.8)	14 (40.0)	n.a. (0.651)
Tablet	17 (29.3)	1 (2.9)	n.a. (0.002)
Desktop PC	5 (8.6)	1 (2.9)	n.a. (0.279)
Missing data	15 (25.9)	12 (34.3)	n.a. (0.387)
MLA, payment[b]			9.655 (0.002)
Yes	27 (60.0)	5 (20.8)	
No	18 (40.0)	19 (79.2)	
Willing to pay additional fees for Qbank[b]			2.741 (0.098)
Yes	22 (78.6)	10 (55.6)	
No	6 (21.4)	8 (44.4)	
Who recommended you the app?[a]			
A friend	41 (70.7)	14 (40.0)	n.a. (0.004)
Online advertisement	9 (15.5)	6 (17.1)	n.a. (0.839)
A teacher	5 (8.6)	4 (11.4)	n.a. (0.658)
Printed advertisement	3 (5.2)	2 (5.7)	n.a. (0.918)

The comparison between groups was done with the Z-test for proportions (a) or the Chi-square test (b)

Most of the respondents were of the opinion that the creation of the content in the MLAs should be done by renowned experts in the specific medical field (51.6%) or common medical doctors (48.4%). A smaller number mentioned doctors from other fields (biology, biochemistry, etc.) (22.6%) or medical students (21.5%).

The score associated with the five presented scenarios varied from 0 (no correct answer) to 6 (all case-based scenarios answered correctly; one question had two correct answers). Statistically significant differences were observed when the case-scenario scores of students from different academic years were compared, with an increase of the scores with every academic year (Kruskal-Wallis test: statistics = 17.04, p-value = 0.004). The median of the score equal to 4 obtained by students from the 6th year of study (24 participants) proved significantly higher as compared to the median of score equal to 1 obtained by students from the 1st year of study (4 participants).

The maximum score of 6 was obtained by only 3 students, one in the fifth year of study and two in the sixth year of study. No statistically significant differences were observed in the score with regard to different gender (Figure 2a), the use or non-use of any resources to answer the case-based scenarios (Figure 2b), the use or non-use of any flashcard(s) or MLAs to find the solutions to the case-scenarios (Figure 2c) or among students from the English section as compared to those from the Romanian section (Figure 2d).

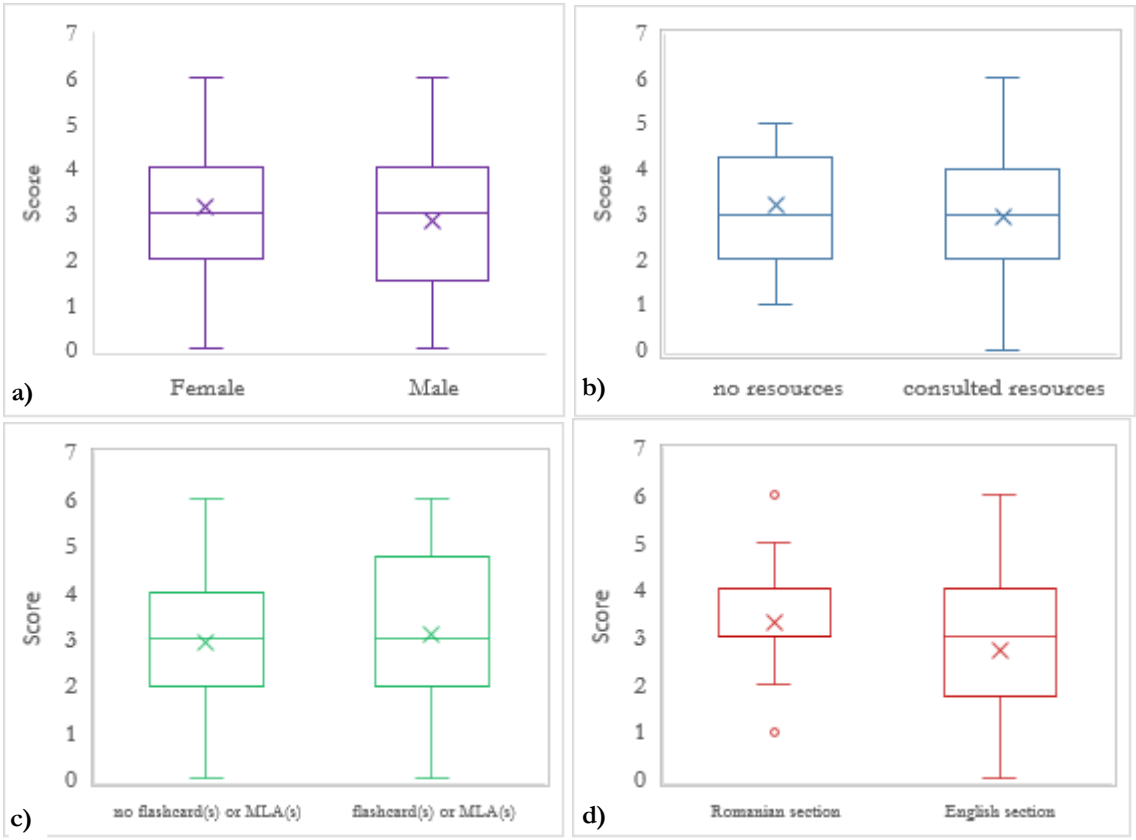

Figure 2. Case-based scenario scores **(a)** by gender (42 females vs. 49 males; Mann-Whitney test – p-value = 0.175); **(b)** by the use of (any) resources for finding case solutions (10 using no resources vs. 83 using resources; Mann-Whitney test – p-value = 0.594); **(c)** by the use of flashcard(s) or MLAs for finding the solutions for the case-scenarios (12 flashcard(s) or MLAs vs. 81 no flashcard(s) or MLAs; Mann-Whitney test – p-value = 0.594); **(d)** by section (Romanian vs. English; Mann-Whitney test – p-value = 0.075)

Discussion

To our knowledge, this is the first study in Romania to examine the impact of medical learning applications (MLAs). It is also the first formal survey conducted on a medical student population that assesses their ability to solve clinical cases in order to evaluate the efficacy of MLAs. The data that was collected is relevant for understanding the extent of MLA use, for detecting medical students' attitudes towards these applications and for providing an objective evaluation of MLAs' usefulness. Therefore, the study helps to shape the landscape of mobile health applications' role in this geographic area.

Among responders, 36.5% reported using MLAs. This is less than was reported by most of the other studies in other countries. For example, Snashall and Hindocha [23] reported that in a medical student population in the UK they surveyed, 83% of the respondents used MLAs, and 85% of these used the MLAs for learning purposes. However, if more comprehensive MLAs were to be developed, 97% of the medical students would consider using them [23]. The same study states the need for regulation of the MLAs by professional bodies in order to meet educational demands as well as the need for financing the development of new and reliable MLAs to be used in the medical education environment [23].

This view is also shared by the subjects who answered our survey, most of who (51.6%) responded that the content of MLAs should be created by experts in the respective medical field. Only one-fifth of the respondents thought that medical students should be involved in the creation of these medical apps.

Payne et al. [24] reported that the use of MLAs by medical students is limited by costs, considering the smaller student budgets, but perhaps surprisingly there were more students who used MLAs than doctors. In our study, 33% of students who said they used MLAs paid for them, and the number of students in the English section who paid for the apps was significantly higher.

On average, the time per day that is spent by our respondents using MLAs is less than an hour, which is consistent with other studies. For senior doctors, it was found to be even shorter (less than 20 minutes) [24], probably because they use MLAs for quick references, while medical students tend to use them for more prolonged educational reading. Also, among medical students, the most frequently used apps regard diagnostics and patient management, while practicing physicians tend to use apps for calculating clinical scores or measurements (like MedCalc).

While the potential of MLAs to provide information to medical students and practitioners cannot be denied, the present study only shows a poor correlation between using these applications and the ability to solve clinical cases, suggesting that other learning methods are equally effective (Figure 1 and 2). These results are consistent with those reported by Sayedalamin et al. [25], who states that even though the progressive increase in the use of MLAs on smart devices is an established reality, their practical use for medical students seems to be minimal. The same study shows Medscape, Gray's Anatomy and UptoDate to be the three most frequently used MLAs, whereas in our study AMBOSS was the most widespread one, followed by Medscape and Dr. Najeeb Lectures [25]. According to the study conducted by Franco et al. [26], Epocrates, Medscape and MedCalc were the most commonly used medical applications; the fact that in our study AMBOSS (an app made in Germany [27]) was the most used app might be explained by the high number of German students studying in the English section of our university.

Medical apps have an undisputed advantage of accessibility and portability, which makes them usable when other learning methods would be impractical. According to Davies et al. [28], medical students use mobile information resources most frequently between patients or when they are on the go, using time that would otherwise be wasted. We found that in the population we surveyed, more than one-third of the students reported using MLAs on the go.

Davies et al. also state the importance of using MLAs as a supplementary learning method, implying that they are not to be used alone [28]. According to them, many students show a preference for learning with the help of traditional methods, a result that is also supported by our findings,where 88.5% of responders used materials provided by the university, in comparison with 36.5% who use MLAs.

While MLAs *may* be of real importance as an adjunct to medical education, the evidence remains

limited. If one goes by current trends, the number of MLAs and the number of students who use them are expected to rise in the coming years. Therefore, it is necessary for medical professionals to get involved in creating and supervising their content to ensure that they provide high quality and up-to-date information.

Study Limitations

The main limitation of our study in the voluntary response bias of participants, with those students who use medical learning apps being more likely to answer a survey regarding such apps. The population we studied is limited to one university and unlikely to be representative of all medical students. Other limitations are caused by the design of the survey study (e.g., data errors due to question non-responses, the cross-sectional design), the short time frame of roughly one month with the survey being conducted during the exam period, and the possibility of submitting more than one completed survey.

Even though Google Forms technically can prevent its users from submitting multiple responses via requesting a login prior to completing a survey [19], the conductors of this study decided to not use this option as this would have allowed the participation of subjects only who own and use a Google account; this would have in turn very likely decreased the number of participants significantly; therefore, in theory, multiple submissions by single persons could have been possible, however, it was requested in an introductory text to limit the responses to one per person).

Conclusion

One third of the participating students used MLAs but without any effect on the number of correctly answered clinical cases.

List of Abbreviations

ACE-I – Angiotensin-converting enzyme-inhibitor
ARB – Angiotensin II receptor 1-blocker
BMI – Body mass index
BP – Blood pressure
CT – Computer tomography
DIC – Disseminated intravascular coagulation
DM – Diabetes mellitus
ECG – Electrocardiography
GERD – Gastroesophageal reflux disease
Hb – Hemoglobin
HTN – Hypertension
MCH – Mean corpuscular hemoglobin
MCV – Mean cell volume
MLA – Medical learning application(s)
MRI – Magnetic resonance imaging

Ethical Issues

None. The survey was conducted anonymously and by submitting a response the students agreed to participate in this study.

Conflict of Interest

Before conducting the study, AA benefited from promotional codes (free access for 12 weeks) provided by AMBOSS.

Authors' Contributions

The first two authors defined the aim of the research and contributed in equal measure to the design and implementation of the study. MHH and SDB participated in the design of the study and performed the statistical analysis. SDB helped to draft the manuscript coordinated and coordinated its writing and completion. All authors have read and approved the final manuscript.

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