

# Teaching Histology in the Age of Virtual Microscopy and E-resources: Is a Tailored Approach to Domestic and International Students Warranted?

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## ABSTRACT

**Background:** Individuals' learning habits and associated challenges in medical education have rarely been studied in the present digital era. We investigated if a tailored instructional approach is needed for domestic and international students studying histology.

**Methods:** This cross-sectional study was performed in May 2019 at the Faculty of Medicine and Dentistry of Palacky University in Olomouc, Czech Republic. Census sampling was applied, and a validated researcher-made questionnaire was distributed among all students attending histology courses. We collected 192 evaluable questionnaires from Czech students and 61 from international students. Differences in opinions between the two groups were tested using Fisher's exact and chi-square test.

**Results:** Compared to their domestic peers, international students were less reliant on printed textbooks (6.9% vs. 17.3%), while showing greater interest in materials from lectures (35.3% vs. 9.2%) ( $P < 0.0001$ ). They were also more inclined to use virtual microscopy only ( $P < 0.0001$ ), and unlike their Czech counterparts, they preferred to study in small groups rather than alone (35.5% vs. 4.7%) ( $P < 0.0001$ ). As for the theoretical knowledge acquired in high school, international students were less prepared than Czech students ( $P = 0.0218$ ). Most international students (62.3%) welcomed preparatory courses aimed at solidifying their knowledge of basic sciences in advance of medical studies. However, no differences in opinions on the use of resources were found between native and non-native English speakers ( $P = 0.6506$ ). Domestic as well as international students experienced very similar problems when studying histology. All students appreciated taking interactive tests to assess their practical and theoretical knowledge.

**Conclusion:** Despite the introduction of modern digital technologies such as a Virtual Microscopy in histology courses, a tailored approach to different groups of students is needed.

**Keywords:** Histology, Virtual microscopy, E-sources, Tailored teaching approach, International students

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## Introduction

There has been a recent surge in the enrollment of international students in a number of Central European universities, including the ones in Czech Republic. This development is mainly attributed to the established traditions of these universities, as well as the economic factors. Therefore, departments and faculties admit not only domestic Czech students but also international students who receive their education in English. The current literature does not provide sufficient information as to whether a tailored approach to international and domestic students is needed, especially in view of availability of e-resources in modern times. Such an approach could potentially help both groups with their histology studies.

Early in their educational careers, medical students engage in the study of histology, which requires the ability to accurately perceive structural details and differences. This subject requires them to combine a theoretical knowledge of basic sciences from high school and other subjects in the first year of medical studies, such as Anatomy or Biology. There are no consistent views in the literature on the influence of secondary education and students' knowledge of different science disciplines on the successful completion of medical studies. According to some researchers (1-4), these two factors may not have a significant effect on students' ability to successfully complete their medical studies. The opposing view is that the level of knowledge acquired in high school plays an important role at the beginning of medical studies, especially in fields like Histology (5, 6). With regard to international students, the challenges of the first academic year are further enhanced by the difficulty in adapting to new environments, as well as other social and cultural factors (7).

Over the last two decades, we have witnessed a rapid digitization process across all medical disciplines, especially in educational spheres. In line with this trend, there has been a major transition from glass slides to virtual microscopy with the aim of

facilitating the teaching of histology at medical schools around the world (8-11). This method of teaching histology has elicited positive responses, and students indicate a preference for this method of teaching (8, 9, 12-19). The Faculty of Medicine and Dentistry at Palacky University in Olomouc has had a decade of experience with this approach. Along with virtual slides, an extensive range of electronic study materials can supplement histology courses, thereby creating a comprehensive multimedia system, which makes it possible (and relatively easy) to establish remote access for students. On the other hand, there are abundant resources for histology, including electronic and printed textbooks, which could make it challenging for students to establish and maintain orientation within the available resources (12).

We hypothesize that there are differences between domestic and international students in terms of 1) background knowledge of related disciplines, 2) their study style, learning methods and resources, 3) their perception of major challenges and obstacles in learning histology and their proposed solutions.

## Material and Methods

### Study Design and Settings

We conducted a survey among the target population. The students completed the questionnaires in May 2019 (end of summer semester), i.e., in the middle of their histology studies at the Faculty of Medicine and Dentistry, Palacky University in Olomouc, Czech Republic. The survey questionnaires were filled out on a voluntary basis.

### Target Population and Sample Size Calculation

The target population included Czech (n=211) and international (n=69) medical students attending scheduled histology classes in their freshman year. A total of 61 international students from 14 different countries (88% of all foreign students) completed the questionnaires. Among them, 16 were native English speakers, 33 were

non-native speakers, and 12 did not specify their native language. The distribution of international students by country of origin is illustrated in Table 1.

Census sampling was applied, and the sample size was calculated using Cochran’s correction formula for categorical data:

$$n = \frac{n_0}{1 + \frac{n_0}{\text{population}}}, \text{ where } n_0 = \frac{t^2 * pq}{d^2}, \text{ assuming}$$

a standard deviation of 0.5, and an acceptable margin of error of 0.05 (20).

### Data Collection Tools and Variables

We used a researcher-made structured questionnaire with a total of 11 questions including 9 closed and 2 open-ended questions, designed for testing our hypothesis through the measurement of variables. A list of 10 individual questions and the possible answers is presented in Table 2. For all multiple-choice questions, students were permitted to tick more than one answer. In addition, 2 free-text questions were presented (Table 3). The questionnaire was validated by 4 experts from the Faculty using CVR and CVI. The reliability was measured using Cronbach’s alpha coefficient. For present study, the CVR scores were found to be 0.5 (for 3 items) and 1.0 (for 8 items), and for the entire questionnaire the CVI was reported as 0.86. The Cronbach’s alpha coefficient for the reliability of the questionnaire was measured to be 0.87.

### Data Analysis and Statistical Methods

The results were presented in figures and percentages of the total responses. The differences in opinions between Czech and international students were tested using Fisher’s exact (questions 2, 3, 4) and chi-square test (questions 1, 5-9) at the significance level of P<0.05. The results were analyzed using GraphPad Prism 6 software. The same procedure was applied to evaluate and compare the responses of native and non-native English speakers.

### Ethical Considerations

The study was conducted under the

**Table 1.** Distribution of international students by country of origin

Native English speakers	
Canada	1
UK	10
Czech	1
Pakistan	1
Not provided	3
Non-native English speakers	
Israel	13
Portugal	3
UK	2
Germany	2
Sweden	1
Japan	3
Taiwan	1
China	1
Pakistan	1
Iran	1
Iraq	1
Poland	1
Not provided	3
Country and English language status not provided	12
Total	61

supervision of the Faculty of Medicine and Dentistry, Palacky University in Olomouc, Czech Republic. The study objectives were explained to all students. Their participation in the questionnaire survey was voluntary and their answers were confidential and anonymous.

## Results

### Participants

A total of 192 Czech and 61 international first-year medical students participated in our study. The minimum sample size was calculated to be 136 Czech and 59 international students. The numbers of returned questionnaires were sufficient to obtain representative results. The response rates were 91% for Czech students and 88% for their international peers.

### Comparison of Domestic and International Students

Interestingly, for all questions, the responses of Czech and international students differed significantly. Detailed results are

**Table 2.** Comparing the opinions of Czech, international, native and non-native English speaking medical students.

Questions	Possible Answers	Czech vs. International students			Native vs non-native English speakers		
		General Medicine Czech students (%)	General Medicine international students (%)	Statistical difference	Native English speakers (%)	non-native English speakers (%)	Statistical difference
1. How difficult do you consider Histology, compared to other subjects?	Very difficult	10 (5.2 %)	6 (10.0 %)	* (P=0.017)	1 (6.7 %)	2 (6.0 %)	ns (P=0.209)
	Equally difficult	166 (86.0 %)	42 (70.0 %)		9 (60.3 %)	27 (81.0 %)	
	Easy	17 (8.8 %)	12 (20.0 %)		5 (33.5 %)	4 (12.0 %)	
2. Do you consider your knowledge of Basic Sciences (Biology, Chemistry and Physics) from high school to be sufficient for a good understanding of Histology?	Yes	117 (62.6 %)	28 (45.9 %)	* (P=0.022)	9 (56.7 %)	14 (42.0 %)	ns (P=0.363)
	No	70 (37.4 %)	33 (54.1 %)		7 (44.1 %)	19 (57.0 %)	
3. In your opinion, is your knowledge of other subjects (Anatomy, Biology and Biochemistry) sufficient for a good understanding of Histology?	Yes	173 (92.0 %)	49 (83.1 %)	* (P=0.046)	13 (81.9 %)	24 (76.8 %)	ns (P=0.761)
	No	15 (8.0 %)	10 (16.9 %)		3 (18.9 %)	7 (22.4 %)	
4. Would you consider enrolling in a Preparatory course (for a fee) focused on basic sciences to prepare you for your medical studies?	Yes	N/A	38 (62.3 %)	N/A	4 (25.2 %)	25 (75.0 %)	*** (P<0.001)
	No	N/A	23 (37.7 %)		12 (75.6 %)	8 (24.0 %)	
5. Which method of studying Histological slides do you consider to be most effective in understanding the structures?	Virtual microscopy only	115 (60.2 %)	43 (71.7 %)	*** (P<0.001)	11 (73.7 %)	22 (66.0 %)	** (P=0.006)
	Glass slide only	0 (0.0 %)	5 (8.3 %)		4 (26.8 %)	1 (3.0 %)	
	Combination of both	76 (39.8 %)	12 (20.0 %)		0 (0.0 %)	10 (30.0 %)	
6. Which resources do you use most frequently to study Histology during the course of the semester?	Lectures	26 (9.2 %)	36 (35.3 %)	*** (P<0.001)	8 (29.6 %)	19 (39.9 %)	ns (P=0.655)
	Textbook	49 (17.3 %)	7 (6.9 %)		1 (3.7 %)	6 (12.6 %)	
	Study guides and presentations from virtual microscopy database	168 (59.2 %)	47 (46.1 %)		14 (51.8 %)	25 (52.5 %)	
	Other resources (on-line videos, google, etc.)	41 (14.4 %)	12 (11.8 %)		4 (14.8 %)	6 (12.6 %)	
7. Which resource do you use most extensively in preparation for an exam?	Lectures	50 (12.3 %)	34 (33.7 %)	*** (P<0.001)	7 (3.8 %)	18 (34.2 %)	ns (P=0.651)
	Textbook	196 (48.3 %)	12 (11.9 %)		3 (11.4 %)	7 (13.3 %)	
	Study guides and presentations from virtual microscopy database	127 (31.3 %)	42 (41.6 %)		11 (41.8 %)	23 (43.7 %)	
	Other resources (on-line videos, google, etc.)	33 (8.1 %)	13 (12.9 %)		5 (19.0 %)	5 (9.5 %)	



8. How frequently do you use the online access to the database of virtual slides?	Regularly	21 (10.9 %)	20 (32.3 %)	*** (P<0.001)	4 (25.2 %)	12 (34.8 %)	ns (P=0.337)
	Sometimes	91 (47.4 %)	35 (56.5 %)		9 (56.7 %)	20 (58.0 %)	
	Never	80 (41.7 %)	7 (11.3 %)		3 (18.9 %)	2 (5.8 %)	
9. Which of the following is your preferred study style?	Studying alone	183 (95.3 %)	40 (63.5 %)	*** (P<0.001)	16 (100.0 %)	18 (54.0 %)	** (P=0.005)
	With a study partner	5 (2.6 %)	21 (33.3 %)		0 (0.0 %)	14 (42.0 %)	
	In a study group	4 (2.1 %)	2 (3.2 %)		0 (0.0 %)	1 (3.0 %)	

provided in Table 2. A vast majority of domestic (86.0%) and international (70.0%) students considered histology to be as difficult as other subjects. It is worth noting that 20.0% of the international students considered histology an easy subject, whereas only 8.8% of domestic students shared this opinion.

Based on the obtained responses, in terms of theoretical knowledge obtained in high school, international students were less prepared than their Czech counterparts (P=0.022). In total, 117 Czech students (62.6%) declared sufficient high school knowledge, whereas for international students this figure stood at 28 (45.9%). The same trend can be observed with regard to the other first-year subjects, namely anatomy, biology and biochemistry. In this respect, 173 (92.0%) Czech and 49 (83.1%) international students declared sufficient knowledge (P=0.046). The majority of international students (62.3%) appreciated taking preparatory courses aimed at solidifying their knowledge of basic sciences before starting medical courses.

The majority of Czech (60.2%) as well as international students (71.1%) preferred only virtual microscopy; however, Czech students were more inclined to use a combination of virtual microscopy and traditional glass slides (39.8% vs. 20.0%). International students relied less on printed textbooks (6.9% vs. 17.3%) and resources prepared by the University, like lectures, (33.7% vs. 12.3%), in comparison to domestic students (P<0.001). They were also more inclined to study in groups (3.2% vs. 2.1%), or with partners (33.3% vs. 2.6%), than their Czech counterparts (P<0.001). Both groups encountered very similar problems when studying histology. The most common answers to free text questions are provided in Table 3.

### Comparison of Native and Non-native English Speakers

As for the native and non-native English speakers among international students, the results revealed that non-native speakers appreciated preparatory courses before their

**Table 3.** The most frequent answers to free text questions

Question	Czech students	International students
What are the most common problems in the study of histology?	Excessive time required for anatomy studies, limiting the time the students had to dedicate to the study of histology Complex orientation within a large number of study materials Problems with correct recognition of structures	Problems with correct recognition of structures Excessive time required for anatomy studies Complex orientation given the large number of study materials
What would help you most to facilitate the study of histology?	Recommend just one main study resource Introduction of practical tests to self-evaluate their knowledge The possibility of viewing more similar specimens from the same area in the VM system.	Introduction of practical tests to self-evaluate their knowledge Access to materials explaining similarities and differences between histological slides The possibility of viewing more similar specimens from the same area in the VM system

medical studies more than native speakers (75.0% vs. 25.2%;  $P < 0.001$ ). Moreover, there were differences in study styles between the two groups. Non-native English speakers tended to study in groups (3.0%), or with study partners (42.0%), whereas native speakers (100%) studied alone ( $P = 0.005$ ). Detailed results are presented in Table 2.

## Discussion

It was revealed that domestic and international students differed significantly in terms of how they perceived their background knowledge of related disciplines, and their study styles, methods and resources. On the other hand, both groups faced nearly identical challenges and obstacles in learning histology.

According to the obtained results, the vast majority of students (86.0% of Czech and 70.0% of international students) perceived histology to be equally difficult compared to other first-year subjects. An evaluation of the difficulty of histology for students was conducted by Johnson et al. (21). In their analysis, most students perceived histology as a difficult subject at the beginning of their studies. At the end of the course, there was a shift in perception among students, most of whom rated the subject as moderately difficult (21). Results of the present study regarding an assessment of the difficulty of histology after the first semester are consistent with those of Johnson et al. It was interesting to note that a much larger percentage of international students perceived histology as relatively easy in relation to other first year subjects, when compared to their Czech peers.

International students' self-assessments revealed that they had a lower knowledge of basic high school subjects (biology, chemistry, physics) than domestic students. This could be attributed to the differences in curriculums and educational priorities in students' countries of origin and to the relatively wide range of countries they came from. It is not clear whether secondary education has a minimal influence (1-4) or a significant influence (5, 6) on the successful mastering of medical studies, especially with regard to

the learning of specific subjects like histology in freshman year. Given the conditions in the Faculty, there were significant differences between foreign and Czech students who continued their studies after the successful completion of the first year. That is, 91.1% of Czech students continued with their studies, but only 71.9% of international students did so. This fact confirms the observations of other authors regarding the impact of secondary school education on the successful mastery of subjects at the beginning of medical studies (5, 6). With regard to international students, attending preparatory courses in advance of the formal studies could facilitate the commencement of their medical school studies. Most international students, especially non-native English speakers, welcomed this opportunity, and three quarters of them answered positively in the interviews. These preparatory courses could help to not only improve the knowledge of basic subjects from secondary education and thereby facilitate the start of medical studies, but they would certainly contribute to a faster overall adaptation of students to the cultural and social learning environments in Czech Republic, as these factors also play an important role (7).

Over the past decades, there has been a sharp increase in digitization across all medical fields, especially in the area of medical education. This trend will surely continue thanks to the continuous and ongoing advances in technology. Histology is seen as an ideal discipline for utilization of digital technologies such as electronic resources and virtual microscopy, which is based on the observation of digital histological specimens. Interestingly, the digitization of histology teaching has contributed to the improvement of learning outcomes (13, 17, 22). Using virtual microscopy alone or in combination with traditional glass slides were considered by students to be the most effective means of learning histology. Similar experiences have been reported by other researchers (8, 9, 12-19). The results indicated that, compared to Czech students, a larger percentage of international

students preferred only digital teaching via VM. It is critical to note that, in the case of non-native English-speaking students, about one third considered a combination of VM and glass slides to be the most effective way of learning, and this percentage was similar to that of their Czech peers. Native English speakers among the international students had a greater preference for digital teaching using VM by itself.

There are currently a large number of learning materials for the study of histology, including electronic resources and printed textbooks. This could cause problems for many students in terms of selecting the appropriate resources for study. Students need to have prior knowledge before studying histology in practice, and should also draw on their theoretical knowledge for final exams. International students at the Faculty made the most use of electronic resources in the VM system, as well as the lectures. The same resources were used in preparation for the theoretical exam, indicating the generally low popularity of traditional textbooks among these students. The preference of these study resources by international students was very similar to those described in another study in the US (23). Czech students were most inclined to use electronic materials in the VM system for the practical study of histology during the semester, while opting for textbooks to prepare for the exam. Lectures had a far lower acceptance rate among them. The differences between Czech and international students are possibly due to the conservative outlook of Czech students who have traditionally relied on printed textbooks. A certain delay in the availability of modern technologies may also be a contributing factor. As far as working with printed sources is concerned, in the case of international students it seems essential to further develop university-prepared materials. However, for the Czech students it would be helpful to choose and recommend one primary printed source for the exam preparation.

Significant differences in preferred study styles were also found in this study.

International students had a greater tendency towards studying in pairs or in small groups to better understand histology, which was a particularly common trend among non-native English speakers. Yiping et al. reported that studying in small groups had a more positive effect on learning outcomes compared to the individual computer-aided learning (24).

The most common problems as reported by both international and Czech students included limited study time for histology in view of other time-demanding subjects like anatomy, difficulties in identifying histological slides, and orientation problems aggravated by the abundance of resources. However, there was no consensus between the two groups over the urgency of these issues. Czech students were more concerned about time, while international students focused on the complexities of structural identification. Possible solutions to these problems could be: introducing a new curriculum in which anatomy courses are offered across three semesters instead of two, adding more digital histological slides to further develop the virtual microscopy system, and introducing a system of practical tests that enable students to verify their knowledge prior to exams. This measure is in line with current trends where interactive learning resources are most popular with students (23).

The present survey study was limited to freshman students' experiences. It would be necessary to evaluate the opinions of other students from higher levels before proceeding with the findings and modifying the curriculum of histology.

Taken together, we identified the differences between domestic and international students at the Faculty. Based on their responses, international students believed that, in terms of theoretical knowledge from high school, they were less prepared than their Czech counterparts. Foreign students would also welcome a preparatory course before starting their studies. Although both groups of students indicated a preference to learn histology using digital virtual microscopy, international students mainly used support

materials prepared by the Faculty (materials in the VM system and lectures), whilst their Czech peers most often relied on printed textbooks in preparation for theoretical exams, and lectures were less popular among them. International students also tended to study more in pairs or small groups. The results showed that there is a need to further develop current digital methods of teaching, especially the interactive forms. Thus, despite progress in digitizing the teaching of histology, a tailored approach to different groups of students is still needed.

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The study was conducted under supervision of the Faculty of Medicine and Dentistry, Palacky University in Olomouc, Czech Republic. The participation of students in the questionnaire survey was voluntary and the answers were anonymous.

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### Authors' Contributions

Study concept, design, preparation and critical revision of the manuscript were developed by the authors who participated in all stages of the research process. All authors read and approved the final version of the manuscript.

### Conflict of interests

The author declares that there is no conflict of interest.

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