


Digital information and communication technologies on histology learning: What to expect?—An integrative review

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Abstract

This integrative review summarizes the scientific evidence about the use of information and communication technologies in the teaching of histology and discusses its implications. The authors used the descriptors 'Educational Technology', 'Information Technology', 'Histology', 'Teaching', 'Learning', and their corresponding Portuguese translation for a comprehensive search of the published literature. This research was performed in May 2020 and targeted the PubMed, SciELO, LILACS, WOS, and SCOPUS databases. Studies published between 2010 and 2020 in Portuguese, English, and Spanish were included in the analysis. After excluding dissertations, reports, and duplicate reviews, 11 articles were identified for an in-depth analysis, which discussed the use of different technologies, such as digital platforms, mobile apps, virtual microscopy, and video classes for the teaching of histology. All studies concluded that these technologies could have a considerable impact, both positive and negative, on academic performance, the correct interpretation of histological structures, as well as students' motivation and satisfaction. The authors' analysis indicates that the use of the above-mentioned technologies in combination with traditional methods has the potential of transforming the teaching and learning process for histology. However, how such technologies impact students' learning success needs to be carefully considered.

KEYWORDS

digital information and communication technologies, education, e-learning, histology, teaching

1 | INTRODUCTION

The advent of computers and digitized images had a great impact on education in general, but particularly on the morphofunctional sciences that are highly dependent on the intensive use of images (Bloodgood & Ogilvie, 2006). In biomedical education, curricular changes affecting basic science courses have contributed to an increased use of Digital Information and Communication Technologies (DICT). Many educational institutions are faced with such changes, often caused by financial constraints which resulted in a reduced

length for students' laboratories sessions (Drake et al., 2014; Rheingantz et al., 2019). The aim of this increased use of DICT is to maintain or improve the quality of teaching for these basic science subjects, to use teaching time more efficiently, as well as to offer more theoretical and practical content (Rheingantz et al., 2019).

Including a wide variety of computer systems, hardware and software, as well as Internet technologies and mobile apps, DICT encompass technological strategies that allow users to easily create, access, store, transmit, and manipulate information (Sallai, 2012). For students, the addition of or the increased access to these

technologies allows them to individualize their pace of learning and it stimulates the development of research and creativity in and outside of the classroom (Nóbrega et al., 2018).

From this perspective, the use of DICT for the teaching of histology represents an excellent choice for this subject which is based on the recognition and analysis of images. Especially, virtual microscopy and interactive virtual atlases offer students the panoramic views of microscopic samples and allow detailed and in-depth analyses of histological structures and foster learning through informative texts, including those highlighted by moving the cursor over the image (Chapman et al., 2020; Nwizu et al., 2017). DICT also allow students to access to content anytime and anywhere, as well as provide interactivity and learning opportunities that are normally guided by an educator (Donkin et al., 2019).

In addition to these benefits, the use of virtual microscopy for histology permits the observation of an image by more than one student at the same time (Alotaibi and ALQahtani, 2016). In the medium and long term, the duplication of digital images, their easy storage, sharing, management, and indefinite use and/or the use of virtual microscopy offer a significant reduction of costs when compared with the production and maintenance of glass slides and the purchase of light microscopes. Furthermore, hard-to-obtain and rare biological specimens become more accessible to all students (Nwizu et al., 2017; Sallai, 2012).

Regarding students' learning success in histology, published studies give contradictory outcomes when comparing the use of DICT with traditional histology instruction. Some studies report an improvement in students' performance after the introduction of new technological resources (Naurhia & Ramdass, 2019) and even suggest the complete substitution of traditional lectures in favour of e-learning strategies (Gadbury-Amyot et al., 2013). In addition, most students prefer e-learning resources (Holaday et al., 2013; Johnson et al., 2015). However, other researchers reported no significant improvement in the academic performance of students using digital technologies in their histology learning process (García-Iglesias et al., 2018).

As a result, some studies recommend the use of DICT only as complementary strategies to traditional histology education adding a new learning experience and improving the quality of histology education (Bains et al., 2011; Kuo & Leo, 2019). As a consequence, the debate over the importance of traditional microscopy for the development of skills of health professionals during clinical practice is still ongoing (Hortsch, 2013; Tian et al., 2014).

To better understand the real impact and possible benefits for students and health professionals of introducing DICT for histology education by institutions of higher education, this study was conducted to identify and evaluate the scientific evidence about the use of DICT for this specific basic biomedical subject. This review may also help educators and students who had to adapt to social distance learning during the COVID-19 pandemic, as mentioned in the publications of Darici et al. (2021) and Amer and Nemenqani (2020), to better understand the use of DICT for teaching and learning histology.

2 | MATERIALS AND METHODS

This research consists of an integrative review of the literature focusing on the use of DICT for the teaching of histology. In addition, it identified gaps in the literature that need to be filled (Botelho et al., 2011). It also critically analyses the existing scientific evidence on the subject investigated.

This review was developed following a step-by-step strategy: (1) identification of the theme and drafting the research question; (2) definition of databases and establishment of inclusion and exclusion criteria of the studies; (3) determination of information to be obtained from the studies; (4) evaluation of the studies included in the integrative review; (5) interpretation of results; and (6) presentation of the review (Botelho et al., 2011).

2.1 | Drafting the study's guiding question

To draft the study's guiding question, we used the strategy *Population, Variables and Outcomes* (PVO), which is recommended for this type of study (Faram et al., 2014). Thus, as Population (P), the Teaching of Histology was established; as variables (V), the Digital Information and Communication Technologies (DICT); and as Outcomes (O), we opted to investigate the implications, which resulted in the formulation of the following guiding question: What are the implications of the use of Digital Information and Communication Technologies for the teaching of histology?

2.2 | Search method and selection of publications

The search and selection of publications took place in May 2020. The following databases were used: United States National Library of Medicine (PubMed), Scientific Electronic Library Online (SciELO), Latin-American and Caribbean Health Sciences Literature (LILACS, in Portuguese), Web of Science (WOS) and Scopus. We used descriptors from the Medical Subject Headings (MESH) and Health Science Descriptors (DECS, in Portuguese), represented by 'Educational Technology', 'Information Technology', 'Histology', 'Teaching' and 'Learning' and their corresponding translation in Portuguese. They were combined with the Boolean operators 'AND' and 'OR' for the simultaneous occurrence of these subjects.

2.3 | Inclusion and exclusion criteria

For this analysis, we included articles published in Portuguese, English, and Spanish, between 2010 and 2020 (Figure 1). We eliminated duplicates from various databases, as well as reviews, dissertations, and reports. To focus only on the most recent publications in the field, a 10-year time period was chosen. We followed the methodology of 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) for the selection of studies (Shamseer et al., 2015).

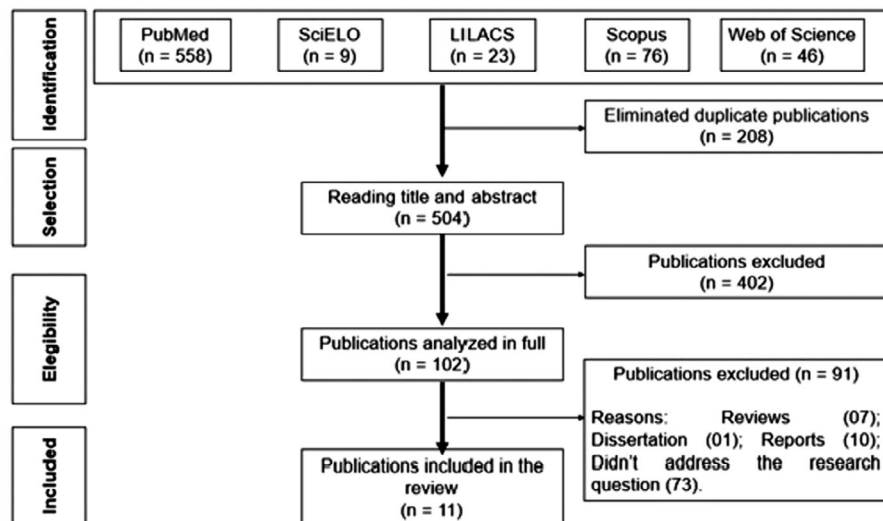


FIGURE 1 Flowchart describing the identification of studies used for this integrative review

To ensure a greater reliability of data/references collected, the search and analysis (inclusion or exclusion of relevant publications) were carried out independently by two researchers (Zoltowski et al., 2014).

2.4 | Data extraction and synthesis

The following information was extracted from the selected publications: (1) database and journal where the study was published; (2) authors; (3) year of publication; (4) study's country of origin; (5) type of study; (6) type of DICT; (7) objective; and (8) main results.

3 | RESULTS

Of the 11 articles included in this study, 7 or 63.63% were found in Web of Science, three articles or 27.27% were found in Scopus and 1 or 9.09% in PubMed. 27.27% ($n = 3$) of the selected articles were published in the journal BMC Medical Education, 18.18% ($n = 2$) in Anatomical Sciences Education, and the remaining in six other scientific journals. Regarding the year of publication, 27.27% ($n = 3$) of the articles were published in 2019, 18.18% ($n = 2$) in 2018, and 18.18% ($n = 2$) in 2013. Most selected publications were published by authors located in the United States (27.27%— $n = 3$), and (18.18%— $n = 2$) by authors located in Finland (Table 1).

Regarding the type of study, experimental research articles were represented with 27.27% ($n = 3$), followed by quasi-experimental with 27.27% ($n = 3$), and cohort studies with 18.18% ($n = 2$). Considering all the studies included in this review, 36.36% ($n = 4$) and 27.27% ($n = 3$) addressed online platforms and mobile apps as Digital Information and Communication Technologies, respectively. Most of the studies involved undergraduate medical students (54.54%— $n = 6$) and a smaller number of undergraduate veterinary medicine students (9.09%— $n = 1$).

A majority of studies evaluated the effects on students' academic performance and compared DICT with traditional methods of

instruction. The academic performance, precision in the diagnostic of histological structures, interactivity, flexibility of time and space, students' motivation, and satisfaction were analysed and how these variables were influenced by DICT (Table 2).

4 | DISCUSSION

This integrative review summarizes the scientific evidence for the use of DICT in the teaching of histology and its impact. The importance of this study is based on the observation that DICT are increasingly present in most students' lives and are valuable resources that offer new opportunities to interact and to create spaces to support the teaching-learning process (Donkin et al., 2019; Helle et al., 2013). Understanding their impact on the teaching of histology will contribute to maximize their potential and may direct future research in the field of morphological education.

Based on the number of studies identified in this report and comparing it with similar analyses in other fields of knowledge, research discussing the use and perspectives of DICT on the teaching of histology still requires additional work. Considering the distribution of the studies among the different databases, the relevance of the subject discussed in this report is evident, even though a large number of articles were listed in only one database. Furthermore, our results also indicate the importance of DICT for education in other health science fields (Mongeon & Paul-Hus, 2014).

Over recent years, more and more studies have been published in a wider variety of journals analysing and discussing the use of DICT in curricular development, performance evaluations, and in evidence-based medicine. Our results also indicate the importance of e-learning technologies in the education of other health science subjects (Rheingantz et al., 2019).

Most of the studies discussed in this review originate from the United States, indicating that significant changes have been implemented in histology education in that country. The main driving forces for this development are a reduction in the course load, time

TABLE 1 Characterization of publications included in this review, by database, journal, authors, year, country, type of study, and type of technology investigated

N.	Database	Journal	Authors and year	Country	Type of study	Type of DICT ^a	Undergraduate course
1	PubMed	<i>BMC Medical Education</i>	Felszeghy et al. (2019)	Finland	Quasi-Experimental	Mobile app	Medicine and Dentistry
2	Web of Science	<i>BMC Medical Education</i>	Donkin et al. (2019)	Australia	Quasi-Experimental	Online platform	Medicine
3	Web of Science	<i>Indian Journal of Pathology and Microbiology</i>	Naurhia and Ramdass (2019)	United States of America	Randomized Control	Virtual microscopy	Medicine
4	Web of Science	<i>BMC Veterinary Research</i>	García-Iglesias et al. (2018)	Spain	Quasi-Experimental	Online platform	Veterinary Medicine
5	Scopus	<i>Academic Pathology</i>	Parker et al. (2017)	United States of America	Cohort	Mobile app	Medicine
6	Scopus	<i>Anatomical Sciences Education</i>	Selvig et al. (2015)	United States of America	Descriptive	Recorded lectures, online virtual microscopy	Medicine
7	Web of Science	<i>International Journal of Morphology</i>	Becerra et al. (2015)	Chile	Experimental	Online platform	Dentistry
8	Web of Science	<i>BMC Medical Education</i>	Tian et al. (2014)	China	Experimental	Virtual microscopy	Medicine
9	Scopus	<i>Journal of Dental Education</i>	Gadbury-Amyot et al. (2013)	United States of America	Cohort	Online platform	Dentistry
10	Web of Science	<i>Anatomical Sciences Education</i>	Helle et al. (2013)	Finland	Experimental	Online platform	Medicine
11	Web of Science	<i>Procedia - Social and Behavioural Sciences</i>	Golchahi et al. (2012)	Iran	Clinical trial	Mobile app	Medicine and Dentistry

^aDigital Information and Communication Technologies.

TABLE 2 Synthesis of information about the articles included in the review, according to objective, main results, and recommendations

N ^o	Objective	Main results
1	Investigated if Medicine and Odontology students using Kahoot participated more in the course and performed better in tests than students, who did not use technology in their histology course	Did not observe significant differences in the average scores between groups. Students who received education based on gamification had higher grades in tests, expressed satisfaction with the game, reported self-confidence, interactivity, and preferred to play in groups
2	Analysed whether students who were enrolled in a science program for medical laboratories, engaged more with the theme and had higher grades, when receiving input from online videos and other resources	Students who watched videos about specialized histology techniques or concluded an e-learning online module, showed significant increases in their final score. An increase in voluntary engagement was observed for the video group
3	Compared the performance of students on standardized tests after learning histopathology with optical or virtual microscopy	Students who used virtual microscopy showed better performance in both phases of the study. Most students expressed a preference for virtual microscopy
4	Evaluated the usefulness of mixed class support in two basic courses of Veterinary Sciences to optimize the efficacy of the student support in a college environment	Did not find significant differences between courses without mentorships and with mentorships. However, observed an increase in approval rates when online mentorship took place
5	Evaluated the effect of a web app on diagnostics, confidence, and interest in histology in a cohort of medical students in the second year at the Washington University School of Medicine	The app significantly increased precision in the identification of histological structures. Students reached 100% precision in most organs and more than 95% precision in 14 of 19 organs in the post-test
6	Correlated academic performance in histology with educational motivation, learning strategy, and use of specific learning resources	Students who reported previous experience with histology/pathology, perception that histology is important for their professional career and participated in learning guided by teachers had increased scores. Students who preferred to watch lecture videos, instead of in-person classes, exhibited a significantly lower academic performance
7	Compared the academic performance and perception of students about three learning methods in the teaching of histology: digital versus optical microscopy, and a combination of both	The group that used both systems had a greater percentage of correct answers for diagnostic and identification questions of tissue structures, in addition to obtaining significantly higher scores than the group that used only the digital system. Most students reported feeling motivated by the use of traditional method
8	Described and discusses the use of virtual microscopy for undergraduate students and evaluates the effects of promoting active learning and problem-solving skills	There was no substantial difference between the two groups in the average score. The group that used virtual microscopy had better results in the categories 'identification of tissue structure' and 'case analysis questions'
9	Described the transition of an oral histology course, from a traditional format to online hybrid	Students in the online teaching modality had significantly higher average grade compared to students in the traditional teaching modality
10	Evaluated students' reactions and the impact of various measures on increasing the understanding of histopathology emphasizing the knowledge of normal cells and tissues	The experimental group had a significant increase in the average grades in the exam carried out 1 week after the beginning of the course about knowledge of cells and tissues. Regarding knowledge of histopathology, the control group had significantly higher average scores
11	Compared the effect of e-learning in a histology course for students from the University of Medical Sciences of Guilan	Results indicated that the intervention group had significantly higher average scores. The failure ratio in the intervention group was lower than in the control group

dedicated to anatomy instruction, the costs associated with the upkeep of optical microscopy laboratories, as well as the desire to improve the quality of histology education (Bloodgood & Ogilvie, 2006; McBride & Drake, 2018).

Most of the studies identified in our analysis are of an experimental or quasi-experimental research nature, evaluating the results obtained after the implementation of DICT for the teaching of histology. In fact, these study types are considered the gold standard, since they use more rigorous research methods and consider the interference of casual relationships. To that end, they

involve manipulation, control, and randomization (Polit & Beck, 2011).

According to Chapman et al. (2020), virtual microscopy can be defined as a software or app which works as a digital interface to simulate conventional microscopy. However, it is not difficult to find studies relating virtual microscopy to DICT. The possibility to zoom in or zoom out part of a histology image is another crucial concept to characterize the virtual microscope (Lima et al., 2020) while DICT, constitute technological strategies allowing users to easily create, access, store, transmit, and manipulate information (Sallai, 2012).

The most common technologies identified in this review were online platforms (Becerra et al., 2015; Felszeghy et al., 2019; Gadbury-Amyot et al., 2013; García-Iglesias et al., 2018; Helle et al., 2013; Tian et al., 2014) and mobile apps (Felszeghy et al., 2019; Parker et al., 2017). This was not unexpected as over the recent past, these resources have become important for the creation, transmission, and dissemination of knowledge (Becerra et al., 2015; Sallai, 2012). In addition, they allow for the design of a more flexible teaching environment (Helle et al., 2013) and for more innovative learning experiences (Gadbury-Amyot et al., 2013).

Another type of technology discussed in these studies was virtual microscopy (Naurhia & Ramdass, 2019; Tian et al., 2014), which is based on the complete, high-resolution digitization of tissue samples on glass slides. These digital files can subsequently be observed on computer screens, tablets, or smartphones with Internet access using a specialized viewer software (Chapman et al., 2020; Mione et al., 2013). This technology provides high-quality histological and pathological images to students. They can also be highlighted, annotated, and viewed at different levels of magnification (Chapman et al., 2020; Naurhia & Ramdass, 2019). Virtual microscope has many advantages for the study of cellular and tissue structures when compared with the traditional method, the use of glass slides and light microscopes. These advantages include easy access to learning material inside and outside of the laboratory, overcoming limitations of space, unavailability of equipment and rare specimens (Tian et al., 2014), and upkeep costs (Lee et al., 2018; Mione et al., 2013). In addition, the virtual microscope enables an unlimited number of students to observe the same high-quality slides, which can be analysed and discussed in group settings (Tian et al., 2014).

The use of video-recorded lectures and instructional sessions is also mentioned in some reviewed articles (Donkin et al., 2019; Selvig et al., 2015). This is another important new technology in the teaching-learning environment for histology. Since this approach allows for a combination of visual and auditory sensations, a limited emotional teaching experience is possible (Bruno, 2010; Lima et al., 2019), as well as the sharing of content with clarity and dynamism, a connection with the students may be established and consequently learning and the development of skills are fostered (Lima et al., 2019).

Different digital technologies for teaching and learning histology, cytology, and histopathology have been applied in medicine, dentistry, and veterinary medicine undergraduate courses. These resources represent an opportunity for pedagogical innovation (Felszeghy et al., 2019; Gadbury-Amyot et al., 2013; García-Iglesias et al., 2018; Gatumu et al., 2014), especially for the active participation of students in the process of building their knowledge and for sharing learning responsibilities. In addition, they allow for active interactions with the digital technologies and for more flexibility in the teaching and learning process once it is independent of space and time (Gatumu et al., 2014).

It is important to point out that most studies were conducted with medical students. Only one survey was conducted with veterinary medicine students (García-Iglesias et al., 2018). This may be connected to changes in modern medical curricula, which call for

more significant investments in technologies supporting education (Kuo & Leo, 2019) and clinical applications such as telepathology (Darici et al., 2021; Sagun & Arias, 2018).

Considering the publications discussed in this review, most of the students participated in first- or second-year undergraduate courses. Only three publications reported that students had previously studied cell biology, histology, and human physiology. Overall, prior experiences with educational technology may influence the ability of students to use conventional or virtual microscopy and to identify histological structures, ultimately impacting their academic performance. Previous exposure to histology and an undergraduate degree in science have been shown to correlate positively with academic performance in medical histology (Selvig et al., 2015).

Although two studies identified in this review found no difference in academic performance after the introduction of e-learning strategies (Felszeghy et al., 2019; García-Iglesias et al., 2018), most studies reported statistically significant increases in the scores of students, who learned histology using technological information and communication resources, when compared with those using only traditional methods (Becerra et al., 2015; Donkin et al., 2019; Gadbury-Amyot et al., 2013; Golchai et al., 2012; Helle et al., 2013; Naurhia & Ramdass, 2019). These results give credence to DICT elevating students' learning success in histology.

In a study that evaluated the use of a mobile app by medical students at Washington University, students with access to the app exhibited significant increases in their ability of identifying histological structures and in their confidence and motivation to explore additional histological resources. These findings were considered beneficial for the teaching and learning process (Parker et al., 2017).

Another important factor in the learning process is the motivation of students. Motivated students are more active and participative in class and more proactive in knowledge acquisition and in obtaining more information (Marcuzzo et al., 2019; Selvig et al., 2015). Teaching practices requiring a more active participation by students and a greater involvement with the taught subject are more effective in knowledge retention (Guardia et al., 2019).

In almost all studies, the authors reported that DICT have transformed the teaching and learning of histology by increasing the flexibility of time and space for the learning process. In a study carried out in Finland that investigated medicine and odontology students during their first year of professional school, researchers evaluated the effect of gamification (gaming software Kahoot) on their learning of and interest in histology. Some results improving the students' learning success were highlighted, such as self-confidence, interactivity, and a preference to play in groups/teams (Felszeghy et al., 2019). Similar results were also reported in other studies included in this review (Becerra et al., 2015; Donkin et al., 2019; Parker et al., 2017).

DICT allow teachers and monitors to use various teaching strategies that contribute to the student's cognitive development. We highlight the use of gamification, video lessons, e-mails, and social networks to help students get involved, to participate, and to get motivated for learning histology (Brandão et al., 2020; Santos, 2021).

In addition to information accessibility, the game makes the teaching and learning process more fun and pleasurable, hence encouraging students to take on a leadership role (Brandão et al., 2020).

On the other hand, despite the many advantages of DICT, the reviewed studies also raise some questions about the use of these resources in the teaching of histology. It was noted that the introduction of DICT may have negative effects, such as a decrease in attendance and procrastination, as well as a lack of student participation in practical lessons, since they believe learning histology without teacher guidance is possible (Helle et al., 2013; Selvig et al., 2015; Zureick et al., 2018).

Therefore, it is of great importance that teachers create learning environments that stimulate students' participation in discussions and activities and ensure their engagement with the material by accessing the platform/indicated material and by responding to feedback about their academic performance (Gadbury-Amyot et al., 2013; Helle et al., 2013). Indeed, the use of DICT in education requires students to be actively involved in reading the material and performing the required educational tasks (Gadbury-Amyot et al., 2013).

Another issue concerns the use of static images for the teaching of histology. This approach does not replicate the use of traditional light microscopes and can negatively affect students' academic performance (Becerra et al., 2015). In addition, most DICT resources require Internet access (Golchai et al., 2012), which can limit their use, especially in developing countries. Other aspects, such as the student's lack of physical contact with biological material, familiarity with histological techniques or the three-dimensional observation of tissues, can be considered the biggest drawback if the use of a microscope in clinical practice or experimental research is needed in the learner's professional future (Faram et al., 2014).

It is important to consider that the methodology used to generate new resources or learning strategies was not always sufficiently described in the reports discussed in this analysis. The absence of this information raises questions about the validity of the conclusion presented. Educational technologies must be created based on trustworthy and reliable information and also present the topic in a way that students understand what is being asked of them and how they will be able to apply the newly acquired knowledge (Benevides et al., 2016).

Although great care was taken to identify the main publications that address the theme investigated, the number of electronic databases searched may be considered as a possible limitation of this review. Some relevant publications may not be listed in the databases used for this analysis. The use of only English and Portuguese descriptors may also have reduced the number of identified publications. In addition, the adopted time frame for the published studies may have limited this review. Moreover, there were some studies with restricted access. Only articles with free access and available in full were included. In a future review, it would be desirable to expand the search to additional databases and to include newer studies. This would further clarify and elucidate the implications of using DICT for the teaching of histology.

5 | CONCLUSION

In this integrative review, we identified published studies discussing the use of information and communication technologies for the teaching of histology and their impact on learning. The number of studies identified is low and they mostly describe the situation in developed countries, such as the United States and Finland. The technologies discussed in these studies were online platforms, mobile apps, virtual microscopy, and the use of video-recorded instruction. These technologies in combination with traditional teaching methods have the potential to transform the teaching-learning process for histology. When properly integrated into the curriculum, they have a considerable potential to positively impact academic performance, improve histological identification skills, enable interactive learning, provide time flexibility, as well as boost students' satisfaction and motivation.

Due to the limited number of scientific studies addressing the impact of technology on histology teaching and learning, we recommend additional research, using well-defined methodologies with scientific validation, to clarify its impact on students' learning success.

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REFERENCES

- Alotaibi, O., & ALQahtani, D. (2016). Measuring dental students' preference: A comparison of light microscopy and virtual microscopy as teaching tools in oral histology and pathology. *The Saudi Dental Journal*, 28(4), 169-173. <https://doi.org/10.1016/j.sdentj.2015.11.002>
- Amer, M. G., & Nemenqani, D. M. (2020). Successful use of virtual microscopy in the assessment of practical histology during pandemic COVID-19: A descriptive study. *Journal of Microscopy and Ultrastructure*, 8, 156-161. https://doi.org/10.4103/jmau.jmau_67_20
- Bains, M., Reynolds, P. A., McDonald, F., & Sherriff, M. (2011). Effectiveness and acceptability of face-to-face, blended and e-learning: A randomised trial of orthodontic undergraduates. *European Journal of Dental Education*, 15(2), 110-117. <https://doi.org/10.1111/j.1600-0579.2010.00651.x>
- Becerra G, D., Grob L. P, M., Rodriguez R, Á., Barker M, M. J., Consiglieri L, L., Ferri G, G., & Sabag S, N. (2015). Academic achievement and perception of two teaching methods in histology: light microscopy and digital systems. *International Journal of Morphology*, 33(3), 811-816. http://www.intjmorphol.com/wp-content/uploads/2015/10/art_01_333.pdf <https://doi.org/10.4067/S0717-95022015000300001>
- Benevides, J. L., Coutinho, J. F. V., Pascoal, L. C., Joventino, E. S., Martins, M. C., Gubert, F., & Alves, A. M. (2016). Development and validation of educational technology for venous ulcer care. *Revista Da Escola Enfermagem Da USP*, 50(2), 309-316. <https://doi.org/10.1590/S0080-623420160000200018>
- Bloodgood, R. A., & Ogilvie, R. W. (2006). Trends in histology laboratory teaching in United States medical schools. *The Anatomical*

- Record (Part B: The New Anatomist), 289B(5), 169–175. <https://doi.org/10.1002/ar.b.20111>
- Botelho, L. L. R., de Cunha, C. C. A., & Macedo M. (2011). O método da revisão integrativa nos estudos organizacionais. *Gestão E Soc. Revista Gestao e Sociedade*, 5(11), 121. <https://doi.org/10.21171/ges.v5i11.1220>
- Bruno, A. R. (2010). Aprendizagem Plástica e Integradora: Contribuições da Neurociência e sua Articulação com os Processos de Aprendizagem em Ambientes Virtuais. *Revista Digital Tecnologias Cognitivas*, 3, 4–19. <https://revistas.pucsp.br/teccogs/article/view/52982>
- Chapman, J. A., Lee, L. M. J., & Swailes, N. T. (2020). From scope to screen: The evolution of histology education. *Advances in Experimental Medicine and Biology*, 1260, 75–107. https://doi.org/10.1007/978-3-030-47483-6_5
- da Lima, M. S. C., de Rodrigues, D. L., & Oliveira, C. T. A. (2020). Tecnologias digitais da informação e comunicação como ferramentas didáticas para potencializar o ensino na área de ciências biológicas. In: J. A. C. Gomes, & V. M. de Pontes [Orgs]. *As TDIC e o/no ensino presencial*. Pedro & João Editores, 65–79.
- Darici, D., Reissner, C., Brockhaus, J., & Missler, M. (2021). Implementation of a fully digital histology course in the anatomical teaching curriculum during COVID-19 pandemic. *Annals of Anatomy*, 236, 151718. <https://doi.org/10.1016/j.aanat.2021.151718>
- de Brandão, W. F. M., da Lima, T. C. S., Vieira, G. C., & Mendes, B. T. (2020). Gamificação no Ensino da Histologia Humana. Dans: Anais do Congresso sobre Tecnologias na Educação (Ctrl+e). Sociedade Brasileira de Computacao – SB, 445–52. <https://doi.org/https://doi.org/10.5753/ctrl.2020.11422>
- Donkin, R., Askew, E., & Stevenson, H. (2019). Video feedback and e-Learning enhances laboratory skills and engagement in medical laboratory science students. *BMC Medical Education*, 19, 310. <https://doi.org/10.1186/s12909-019-1745-1>
- dos Santos, M. M. (2021). A importância da monitoria acadêmica presencial de citologia, histologia e embriologia associada a vídeo-aulas no youtube. *Revista Interfaces Saúde, Humanas e Tecnologia*, 9(1), 983–987. <https://doi.org/10.16891/2317-434X.v9.e1.a2021.pp983-987>
- Drake, R. L., McBride, J. M., & Pawlina, W. (2014). An update on the status of anatomical sciences education in United States medical schools. *Anatomical Sciences Education*, 7(4), 321–325. <https://doi.org/10.1002/ase.1468>
- Faram, D., Marin, C. M., & Barbosa, D. (2014). Avaliação da necessidade da revisão sistemática e a pergunta do estudo. In D. Barbosa, M. Taminato, D. Fram & A. Belasco (Eds.), *Enfermagem Baseada em Evidências* (pp. 21–28). Atheneu.
- Felszeghy, S., Pasonen-Seppänen, S., Koskela, A., Nieminen, P., Härkönen, K., Paldanius, K. M. A., Gabbouj, S., Ketola, K., Hiltunen, M., Lundin, M., Haapaniemi, T., Sointu, E., Bauman, E. B., Gilbert, G. E., Morton, D., & Mahonen, A. (2019). Using online game-based platforms to improve student performance and engagement in histology teaching. *BMC Medical Education*, 19, 273. <https://doi.org/10.1186/s12909-019-1701-0>
- Gadbury-Amyot, C. C., Singh, A. H., & Overman, P. R. (2013). Teaching with technology: Learning outcomes for a combined dental and dental hygiene online hybrid oral histology course. *Journal of Dental Education*, 77(6), 732–743. <https://doi.org/10.1002/j.0022-0337.2013.77.6.tb05525.x>
- García-Iglesias, M. J., Pérez-Martínez, C., Gutiérrez-Martín, C. B., Díez-Laiz, R., & Sahagún-Prieto, A. M. (2018). Mixed-method tutoring support improves learning outcomes of veterinary students in basic subjects. *BMC Veterinary Research*, 14(1), 35. <https://doi.org/10.1186/s12917-018-1330-6>
- Gatumu, M. K., MacMillan, F. M., Langton, P. D., Headley, P. M., & Harris, J. R. (2014). Evaluation of usage of virtual microscopy for the study of histology in the medical, dental, and veterinary undergraduate programs of a UK University. *Anatomical Sciences Education*, 7, 389–398. <https://doi.org/10.1002/ase.1425>
- Golchai, B., Nazari, N., Hassani, F., & Bahadori, M. H. (2012). Computer-based E-teaching (virtual medical teaching) or traditional teaching: A comparison between medical and dentistry students. *Procedia – Social and Behavioral Sciences*, 47, 2080–2083. <https://doi.org/10.1016/j.sbspro.2012.06.952>
- Guardia, J. J., Del Olmo, J. L., Roa, I., & Berlanga, V. (2019). Innovation in the teaching-learning process: The case of Kahoot! *On the Horizon*, 27(1), 35–45. <https://doi.org/10.1108/OTH-11-2018-0035>
- Helle, L., Nivala, M., & Kronqvist, P. (2013). More technology, better learning resources, better learning? Lessons from adopting virtual microscopy in undergraduate medical education. *Anatomical Sciences Education*, 6(2), 73–80. <https://doi.org/10.1002/ase.1302>
- Holaday, L., Selvig, D., Purkiss, J., & Hortsch, M. (2013). Preference of interactive electronic versus traditional learning resources by University of Michigan medical students during the first year histology component. *Medical Science Educator*, 23(4), 607–619. <https://doi.org/10.1007/BF03341688>
- Hortsch, M. (2013). Virtual biology: Teaching histology in the age of Facebook. *FASEB Journal*, 27(2), 411–413. <https://doi.org/10.1096/fj.13-0201ufm>
- Johnson, S., Purkiss, J., Holaday, L., Selvig, D., & Hortsch, M. (2015). Learning histology – Dental and medical students' study strategies. *European Journal of Dental Education*, 19(2), 65–73. <https://doi.org/10.1111/eje.12104>
- Kuo, K.-H., & Leo, J. M. (2019). Optical versus virtual microscope for medical education: A systematic review. *Anatomical Sciences Education*, 12(6), 678–685. <https://doi.org/10.1002/ase.1844>
- Lee, L. M. J., Goldman, H. M., & Hortsch, M. (2018). The virtual microscopy database-sharing digital microscope images for research and education. *Anatomical Sciences Education*, 11(5), 510–515. <https://doi.org/10.1002/ase.1774>
- Lima, V. S., Azevedo, N. A. D. A., Guimarães, J. M. X., Pereira, M. M., Agostinho Neto, J., Souza, L. M., Pequeno, A. M. C., & Sousa, M. D. S. D. (2019). Produção de vídeo-educacional: estratégia de formação docente para o ensino na saúde. *Revista Eletrônica Comunicação Informação E Inovação Em Saúde*, 13(2). <https://doi.org/10.29397/reciis.v13i2.1594>
- Marcuzzo, S., Campos, P. M., Schneider, J., & da Régis, C. (2019). Estratégias para motivar a aprendizagem da embriologia. *Revista Internacional de Educação Superior*, 5, e019011. <https://doi.org/https://doi.org/10.20396/riesup.v5i0.8653470>
- McBride, J. M., & Drake, R. L. (2018). National survey on anatomical sciences in medical education. *Anatomical Sciences Education*, 11(1), 7–14. <https://doi.org/10.1002/ase.1760>
- Mione, S., Valcke, M., & Cornelissen, M. (2013). Evaluation of virtual microscopy in medical histology teaching. *Anatomical Sciences Education*, 6(5), 307–315. <https://doi.org/10.1002/ase.1353>
- Mongeon, P., & Paul-Hus, A. (2014). The journal coverage of bibliometric databases: A comparison of Scopus and Web of Science. *Scientometrics*, 106(1), 1–6. <https://doi.org/10.13140/2.1.4759.7762>
- Naurhia, S., & Ramdass, P. (2019). Randomized cross-over study and a qualitative analysis comparing virtual microscopy and light microscopy for learning undergraduate histopathology. *Indian Journal of Pathology & Microbiology*, 62(1), 80–90. https://doi.org/10.4103/ijpm.ijpm_241_18
- Nóbrega, T. E., Carneiro Ribeiro, E., de Oliveira, K., Júnior, J., Costa Pereira, A., & Dias da Silva, M. A. (2018). O uso das TIC como ferramenta de ensino da histologia nos cursos de Odontologia das regiões Sul e Sudeste do Brasil. *Revista Iberoamericana de Tecnología En Educación Y Educación En Tecnología*, 22, 63–72. <https://doi.org/https://doi.org/10.24215/18509959.22.e07>
- Nwizu, N. N., Owosho, A., & Ogbureke, K. U. E. (2017). Emerging paradigm of virtual-microscopy for histopathology diagnosis: Survey

- of US and Canadian oral pathology trainees. *British Dental Journal Open*, 3(1), 17013. <https://doi.org/10.1038/bdjopen.2017.13>
- Parker, E. U., Reder, N. P., Glasser, D., Henriksen, J., Kilgore, M. R., & Rendi, M. H. (2017). NDER: A novel web application for teaching histology to medical students. *Academic Pathology*, 4, 1–5. <https://doi.org/10.1177/2374289517691061>
- Polit, D. F. & Beck, C. T. (2011). Fundamentos de pesquisa em enfermagem: avaliação de evidências para a prática da enfermagem. Artmed Editora.
- Rheingantz, M. G. T., Oliveira, L. B. O., Minello, L. F., & Rodrigues, R. F. (2019). A importância do atlas virtual no ensino-aprendizagem da Histologia. *Brazilian Journal of Development*, 5(7), 8904–8912. <https://doi.org/10.34117/bjdv5n7-094>
- Sagun, L., & Arias, R. (2018). Patologia Digital: Uma Abordagem Inovadora para a Educação Médica. *Philippine Journal of Pathology*, 3(2), 7. <https://philippinejournalofpathology.org/index.php/PJP/article/view/1>
- Sallai, G. (2012). Defining infocommunications and related terms. *Acta Polytech Hungarica*, 9(6), 5–15.
- Selvig, D., Holaday, L. W., Purkiss, J., & Hortsch, M. (2015). Correlating students' educational background, study habits, and resource usage with learning success in medical histology. *Anatomical Sciences Education*, 8(1), 1–11. <https://doi.org/10.1002/ase.1449>
- Shamseer, L., Moher, D., Clarke, M., Ghera, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *BMJ*, 349, g7647. <https://doi.org/10.1136/bmj.g7647>
- Tian, Y., Xiao, W., Li, C., Liu, Y., Qin, M., Wu, Y. I., Xiao, L., & Li, H. (2014). Virtual microscopy system at Chinese medical university: An assisted teaching platform for promoting active learning and problem-solving skills. *BMC Medical Education*, 14(1), 74. <https://doi.org/10.1186/1472-6920-14-74>
- Zoltowski, A. P. C., Costa, A. B., Teixeira, M. A. P., & Koller, S. H. (2014). Qualidade metodológica das revisões sistemáticas em periódicos de psicologia brasileiros. *Psicologia: Teoria e Pesquisa*, 30(1), 97–104. <https://doi.org/10.1590/S0102-37722014000100012>
- Zureick, A. H., Burk-Rafel, J., Purkiss, J. A., & Hortsch, M. (2018). The interrupted learner: How distractions during live and video lectures influence learning outcomes. *Anatomical Sciences Education*, 11(4), 366–376. <https://doi.org/10.1002/ase.1754>

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