

Interactive Digital Microscopy at the Center for a Cross-Continent Undergraduate Pathology Course in Mozambique

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Abstract

Background: Recent medical education trends encourage the use of teaching strategies that emphasize student centeredness and self-learning. In this context, the use of new educative technologies is stimulated at the Faculty of Medicine of Eduardo Mondlane University (FMUEM) in Mozambique. The Faculty of Medicine of University of Porto (FMUP) and FMUEM have a long-lasting record of collaborative work. Within this framework, both institutions embarked in a partnership, aimed to develop a blended learning course of pathology for undergraduates, shared between the two faculties and incorporating interactive digital microscopy as a central learning tool. **Methods:** A core team of faculty members from both institutions identified the existing resources and previous experiences in the two faculties. The Moodle course for students from the University of Porto was the basis to implement the current project. The objective was to develop educational modules of mutual interest, designed for e-learning, followed by a voluntary student's survey conducted in FMUEM to get their perception about the process. **Results:** We selected contents from the pathology curricula of FMUP and FMUEM that were of mutual interest. We next identified and produced new contents for the shared curricula. The implementation involved joint collaboration and training to prepare the new contents, together with building quizzes for self-evaluation. All the practical sessions were based on the use of interactive digital microscopy. The students have reacted enthusiastically to the incorporation of the online component that increased their performance and motivation for pathology learning. For the students in Porto, the major acquisition was the access to slides from infectious diseases as well as autopsy videos. **Conclusions:** Our study indicates that students benefited from high-quality educational contents, with emphasis on digital microscopy, in a platform generated in a win-win situation for FMUP and FMUEM.

Keywords: B-learning, digital microscopy, medical education, pathology

INTRODUCTION

Universidade Eduardo Mondlane (UEM) is the first university established in Mozambique in 1962 and until 2007, the only institution responsible for medical education in the country. Since its establishment, the *curricula* of the Faculty of Medicine of UEM (FMUEM) for undergraduate students underwent several revisions and updation. The last and current *curriculum* reinforces a more interactive and student-centered teaching strategy with emphasis on independent learning, aiming to strengthen skills and attitudes of future medical doctors, including those related to ethical and social values. Thus, efforts are placed to empower the students to have more autonomy in the

learning process, including opportunities for adjustment to individual needs. Additionally, strategies were put in place to increase the use of the new information and communication technologies.^[1]

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Pathology is a nuclear discipline of the undergraduate curriculum in medicine. The practical component of the discipline has classically relied upon the use of glass slides and conventional microscopy. However, conventional microscopy requires sufficient number of functional microscopes, maintenance of the equipment, and also continuous need for renovation of glass slide collections.

Important changes have occurred in the last years in the teaching of pathology at FMUEM to meet the new methodologies to increase student's autonomy in the learning process. The annual discipline was subdivided into two biannual disciplines: Pathology I (general pathology) and Pathology II (special pathology – by system and organ). The number of theoretical classes was reduced, the number of practical sessions (microscopy and autopsies) was increased, and seminars were introduced. Microscopy classes consisted in observation of histopathology slides, preceded by an introductory explanation by the teacher and projection of slide images. After that, the students had a set of slides to observe in the microscope and to make a brief report over a schematic drawing of the slides. This format of the practical sessions needed functional microscopes, as well as constant renovation of the slide collections. At this moment, there are only two microscopy rooms shared by different departments in the FMUEM. Due to limited maintenance capacity and funding resources, most of the microscopes are not operational and slide collections are incomplete and insufficient for all students. With the number of students increasing in the last years, with the same number of teachers, this became an untenable situation.

All these aspects contributed to a demotivating education process for the students and collide with the ambition to increase autonomy in the learning process.

Methodologies that incorporate digital technologies facilitate the learning process and minimize the limitations previously described. Digital microscopy through whole-slide imaging (WSI) has been used in training programs of pathology residents and as a component of education for undergraduate students in several medical-related schools, mainly in histology and pathology subjects.^[2-12] WSI is also used in histopathological routine diagnosis, substituting conventional microscopy.^[13-15] The images are stored in high resolution and samples can be manipulated, similarly to conventional light microscopy.^[10,16] In the context of education in cooperative format, WSI has many advantages including that digital slides can be copied, saved, and shared; used by an unlimited number of students at the same time; visualized at any time in the classroom or anywhere; and used simultaneously for education or research purposes. Finally, WSI eliminates the need for expensive maintenance of microscopy laboratories.^[10,14]

UEM and University of Porto (UP) have a regular collaborative agreement and practice for many years. Since 2013, there are frequent exchanges of personnel in education, and an agreement was settled for sharing e-learning courses. Under

this overarching umbrella partnership, in 2014, a project between the Departments of Pathology from the Faculty of Medicine of UP (FMUP) and FMUEM was implemented, aiming to develop a pathology course by sharing e-learning tools. The previous experience of FMUP with an online course of pathology for medical students, in Portuguese language, facilitated the process.

The goal was to share educational contents of pathology, increasing the quality of the learning process by giving the students access to high-quality material, namely high-quality digital images, to eliminate the need for continuous maintenance of conventional microscopes and slide collections and to increase the motivation and autonomy of the students. Blended learning (b-learning) provides a combination of face-to-face learning and digital activities that facilitate anytime/anyplace learning.^[17] Here, we describe the process of creation and implementation of the shared b-learning pathology course.

METHODS

This is a descriptive study about the process of creation and implementation of the shared b-learning pathology course between FMUP and FMUEM.

Design

A core team from UP and UEM, composed by four faculty members with experience in teaching pathology (two from UP and two from UEM), one expert in informatics (UP), one e-learning instructor (UP), and one informatics technician (UEM), was assembled.

Initial steps included meetings with stakeholders from both universities; coordination meetings between core team members via Skype; and visits from the core team to both institutions to identify the existing capacity and needed resources, to participate in training sessions, to prepare new educational material, and to attend thematic classes. Both at-distance and in-person sessions to develop the shared course content and to monitor and evaluate the work progress were needed. Tutorials using video conferences were also used.

Existing resources

The UP has a reference Educational Technology Unit which gives technical and pedagogical support to the academic community and also promotes and supports the use of b-learning and e-learning technologies as a teaching tool. In 2003, the UP started the development of a pilot project on the curricular units of biopathology based on b-learning methodology, and the content units became available online for the academic community in 2005/2006 via Web Course Tools platform. In 2008/2009, the platform migrated to Moodle UP (<http://moodle.Up.pt>). The online support space contains, for each curricular unit, program, calendar, evaluation methods, and material for the study of subjects not completely developed in the recommended books, as well as a glossary with links to diagrams and figures, introductory texts and images for the

practical sessions, bi-weekly quizzes for student's evaluation, and links to websites with relevant information for pathology. This Moodle course was the basis for the new shared course that we developed. Whole images from histology and cytology are prepared by the Digitalization slides Unit of Instituto de Patologia e Imunologia Molecular da Universidade do Porto with high quality and resolution. The images are used in the practical sessions and in seminars in the context of clinical case discussions.

FMUEM, through the Medical Education Partnership Initiative Program (2010–2015), created a virtual library infrastructure to be used by the students. The room contains a server with very high capacity and 45 monitors.^[18,19] The FMUEM has another informatics room with thirty computers for student's use, and is managed by a unit of support to informatics technology which is handled by one informatics technician. Internet facilities with large band are available and supported by the Informatics Centre of the UEM. The infrastructural and material facilities for teaching are shared with the Pathology Laboratory of the Hospital Central de Maputo (MCH). An autopsy teaching room equipped with a system of video projection and sound facilities allows students to see the autopsies in a safe way.

Participants

The target group to be trained in Mozambique consisted in four faculty members from the Department of Pathology, four residents from MCH, two informatics technicians, and 126 undergraduate students from FMUEM during 2015–2016.

The faculty team and the e-learning team of the FMUP were responsible for training the Mozambican personnel.

Student's survey

Satisfaction survey

Students of Pathology I (general pathology) of the FMUEM of year 2015 that had the first contact with an e-learning platform in a practical session were surveyed regarding their satisfaction about conditions of access to the platform, facilities and challenges to access the Internet, and expectations about the new online ambience. Fifty-nine of the 126 students voluntarily participated in the survey. The students were also asked to identify critical factors for success of the b-learning process as well as challenges related with local reality in open questions. The survey was administrated in the 2 weeks after the end of the course.

Digital microscopy

WSIs were acquired by using Hamamatsu NanoZoomer HT with a $\times 40$ objective. Eighty-five of a total of 122 iconographic documents analyzed in the practical sessions were WSI. Activity regarding the digital microscopy usage, during four semesters of implementation (2015–2016), was measured by selecting the number of "clicks" performed by students as the simplest and easiest metric to interpret the overall usage. In this context, a "click" is any action taken when using the WSI viewer: moving around, changing magnification, selecting an area, etc.

The study obtained written approval of the Joint Institutional Bioethics Committee for Health of the Faculty of Medicine of the Eduardo Mondlane University and Maputo Central Hospital (CIBS FM and HCM) (meeting minute 12/2017, protocol number CIBS FM and HCM/87/2017).

Analysis

For the student's survey, data were laid in Excel sheet, and descriptive statistics (number and percentage) were calculated and presented as a frequency table. Digital image usage is presented in a frequency graph of number of clicks.

RESULTS

The intervention phase evolved according to several lines of action: (a) analysis of pathology curricula of both medical courses and selection of already existing contents from FMUP to be shared at FMUEM; (b) identification and production of new contents for the practical sessions and seminars to be incorporated in the new shared curricula; (c) training in informatics methods and in the production of new contents; (d) implementation of the new shared course; (e) development and implementation of a survey to the students about the new b-learning methodology applied for the pathology disciplines at the FMUEM; and (f) analysis of digital microscopy usage by students.

Analysis of pathology curricula and selection of already existing contents

Curricula of Pathology I and II from FMUEM were adapted to include seminars and new practical sessions with digital microscopic images and selected contents already produced in the pathology courses of FMUP with interest for the local setting in Maputo. The timetable that was very heavy before this action, with 116 classroom-hours per semester (4 h of theoretical classes, 2 h of microscopy, and 2 h of autopsy classes every week during 17 weeks), was adapted. The number of theoretical classes was reduced to 35 h and eight seminars were incorporated. Overall, in-person classes were reduced from 150 h to 85 h.

Identification and development of new contents for the new shared curricula

Five new contents related to infectious pathology with relevance for Mozambique, and also to Portugal, were identified to be incorporated in four practical sessions and in one seminar. This included malaria, tuberculosis, schistosomiasis, leprae, and opportunistic diseases associated with acquired immunodeficiency syndrome and human immunodeficiency virus. The production of the new contents included the preparation of the theoretical contents, slide digitalization, design of learning objectives, and development of a specific glossary and image gallery. A video of an autopsy was also prepared. All contents were generated from material of the FMUEM. Faculty members also learned how to prepare quizzes, to be implemented in a second phase after provisional testing. For the students in Portugal, the new materials were

instrumental to expand their acquaintance with rare infectious diseases, including virus-induced cancers. Apart from the pedagogical aspects, the new contents are at the center of new developments in the cancer field and the autopsy video was, for most students in Portugal, the first and single contact with the challenge of a medical autopsy.

Support and training in informatics and in the development of new contents to the e-learning platform

The e-learning team of the UP trained the Mozambican personnel for allocation of the new shared course, management of the Moodle platform, user's management, and support to the teachers and students. The process of training included practical sessions of introduction to the UP Moodle platform and active participation in practical classes and seminars of the FMUP pathology curricula already using the Moodle UP platform.

A new informatics technician was recruited and trained to be part of the informatics unit of the FMUEM.

Implementation of the shared course

All contents of the practical sessions and seminars were integrated in the Moodle platform. The students can access all images of digital microscopy and can navigate, controlling the resolution and selecting and commenting their snapshot images; save fields of specific images; and send and/or use the material for presentation and discussion in the context of classroom.

In the following week, the students had a face-to-face class in small groups with the teacher to discuss questions and problems brought by the students after their preparative online group discussions. Figures 1-3 represent aleatory sequences of contents of the front page, practical sessions, and a digital image available in the platform.

Development, implementation, and analysis of a student's survey

Students of Pathology I of the FMUEM that had the first contact with an e-learning platform in a practical session were surveyed regarding their satisfaction about conditions of access to the platform, facilities and challenges to access the Internet, and expectations about the new online ambience to complement classroom sessions. The students identified critical factors for success of the b-learning process as well as challenges related with local reality.

Fifty-nine (59) of the 126 students answered the questionnaire. Table 1 summarizes the results of the survey. In general, students have reacted very positively to the incorporation of an online component complementary to the classroom teaching.

The students accessed the Moodle platform from their house and from faculty and they considered the platform to be user friendly. Fifty-three (94.6%) students considered that the online component increased their performance and the motivation to the discipline.



Figure 1: Front page of the course after accessing the Moodle platform (<http://moodle.up.pt>). Logos from the institutions involved in the project are displayed in the front page. Then follows general information, including news, course plan, autopsy manual, and satisfaction inquiry

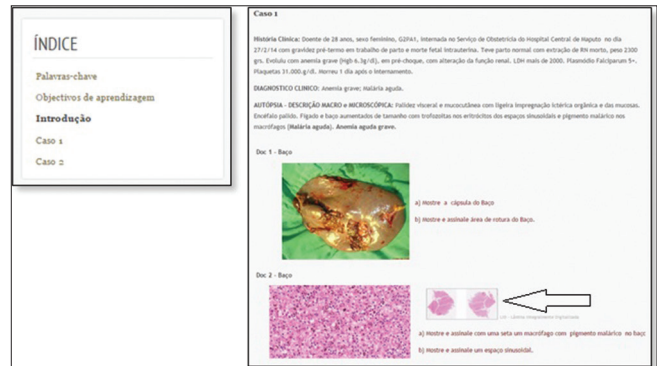


Figure 2: Practical session: Recognition and identification of macroscopic and microscopic features of malaria. The last figure (arrow) links to the digitalized slide that can be manipulated in any computer or electronic device

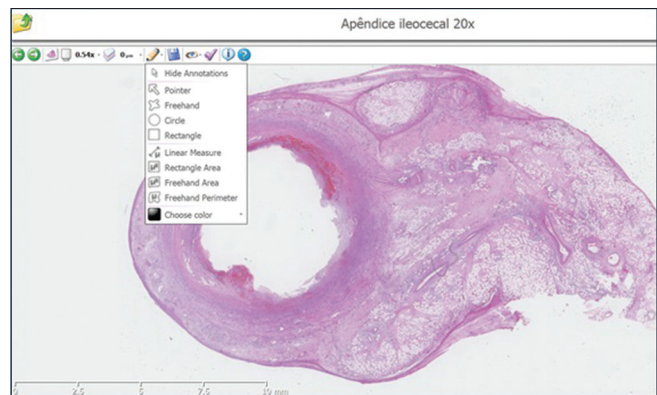


Figure 3: Example of a digitalized image available for student's training

The overall student's feedback about the introduction of the new methodology of b-learning was extremely positive.

The most positive features appreciated by students were the possibility to access the site anywhere and simultaneously, as well as the possibility to study in detail each slide with high quality well above the conventional microscopy. The students referred that small group discussions facilitate the understanding of the contents and the communication and sharing knowledge between students and that contents of seminars are very educative. They also mentioned the stimulus for research activities and more integration between the contents of theoretical and practical classes.

The more negative features were the low quality, instability, and slow speed of Internet access in the faculty.

Digital microscopy usage by students

The analysis of activity regarding the digital microscopy usage, during the four semesters (2015–2016), revealed a similar pattern of use in the same corresponding semesters.

Table 1: Results of the student’s survey on the Moodle platform

Questions in the survey and answers	Number of students (%)
Is the access to Moodle platform easy and simple?	
Yes	54 (93.1)
No	4 (6.9)
Location were the Moodle is accessed	
Home	28 (48.3)
Faculty	28 (48.3)
Cybercafé	0 (0.0)
Other	2 (3.4)
How do you access the Moodle platform?	
Faculty computer	7 (12.3)
Personal computer	39 (68.4)
Tablet	4 (7.0)
Cell phone	7 (12.3)
Are you satisfied with the graphic layout of the Moodle?	
Very satisfied	12 (20.7)
Satisfied	38 (65.5)
Somewhat satisfied	7 (12.1)
Unsatisfied	1 (1.7)
How frequently do you access the Moodle?	
Daily	2 (3.5)
Two to three times a week	32 (55.2)
Weekly	18 (31.0)
Bi-weekly	0 (0.0)
Sporadically	6 (10.3)
Do you have time to perform the tasks that are requested?	
Yes	47 (85.5)
No	8 (14.5)
Does the online component help your performance?	
Yes	53 (94.6)
No	4 (5.4)
Does the online component help to increase your motivation?	
Yes	56 (96.6)
No	2 (4.4)

The results are very impressive and far exceeded our best expectations, especially if we take into consideration that the WSI viewing experience was impaired, in general, by an insufficient Internet bandwidth. Nevertheless, we registered over 950,000 “clicks” during the four semesters, as depicted in Figure 4. We also monitored the inside/outside faculty usage and could observe two interesting points: (1) There was similar usage inside/outside the medical faculty and (2) There was significant periods of faculty infrastructure breakdown which was somehow compensated by the outside usage that, in contrast, kept a more steady usage pattern.

Unfortunately, the Moodle platform does not give information on time spent on tasks, but from the output generated by the students in PowerPoint presentations in the practical sessions, we can subjectively appreciate that the images were thoughtfully incorporated in the learning process. Also, in open-answer questions in the questionnaires, the most frequently highlighted positive item in the platform was the friendly access to the slide images.

DISCUSSION

The aim of introducing a b-learning pathology course in the FMUEM in Mozambique was fully achieved during a 2-year project. The course is currently run by the local team that has gained autonomy for creating new contents, including queries and quizzes.

The quick and very efficient implementation of the course was largely dependent on the existence of previous networks of collaboration and mutual trust. In addition, pathology is in a way a privileged area of medical knowledge for sharing, since microscopy images are the object of study of the discipline and at present, digital images have a resolution that competes with the classic microscope-based observations.^[6,9,10,14] In the case of FMUEM, the introduction of digital images also came at a critical moment when microscopes were attaining exhaustion and local difficulties were curtailing the capacity to modernize the equipment. The situation was even more afflicting since

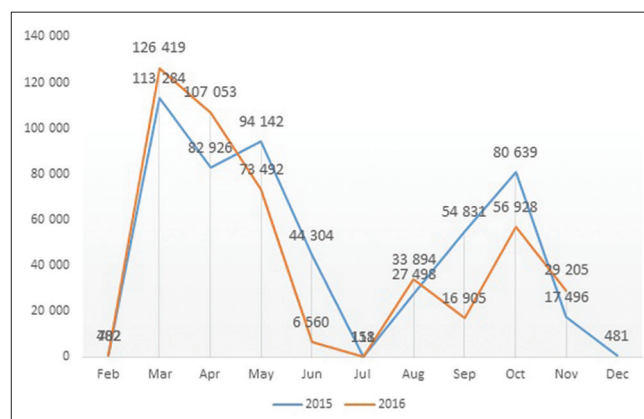


Figure 4: Number of “clicks” logged during whole-slide image visualization per month. The total number of “clicks” for the four semesters exceeds 950,000

the number of students was increasing in recent years, which also contributed to the workload of the faculty. This situation of weakness of the infrastructure is globally the same in other sub-Saharan countries.^[20]

With this project, the number of in-person class sessions reduced from 150 to 85 h per student, by reducing the number of theoretical classes and the number of in-person microscopy sessions. The teaching staff is fully supportive of the new teaching methodology that increased student's motivation in the in-person classes and also the interactivity in seminars and practical sessions. The reduced number of in-person hours gave the reduced staff personnel the possibility to better prepare and optimize time spent with students. The perception is that the quality of time spent with students had a substantial increment.

The shared course we have built allowed cross-enrichment of the high-quality image databases of the two departments. In fact, the students in Portugal benefited from infectious disease images they have never seen, but that actually may soon become a part of their clinical practice due to a high mobility of work labor between the two countries. Furthermore, the molecular aspects involved in viral causation of cancer showed to be extremely pedagogical and recovered into the teaching scenario the relevance of viral oncogenes in understanding the role played by oncogenes at large. Similarly, students from Mozambique can accompany new developments of molecular pathology that will soon be a part of their daily clinical life.

Regarding digital microscopy usage by the students, the number of WSI clicks was very high. Although we have no information on time spent by students on tasks, the output generated in their presentations in the practical sessions allows us to perceive that the images were thoughtfully incorporated in the learning process.

After 2 intense years of project implementation, with the project running smoothly, it is time to profit from a better allocation of duties of the limited faculty at FMUEM and the increment on the staff dedicated to support teaching activities. The informatics technician contracted under the project at no cost during project implementation was absorbed by the faculty to sustain teaching activities. The University Centre of Distance Learning is currently setting the course locally, without any additional costs, and contributing for the sustainability of our action and for local expansion of similar teaching activities. Some issues have however to be incremented to gain full local autonomy. The most important, and also described in other English-speaking countries in Africa,^[21] is to get local teams to interact to improve Internet connection. Expansion of the production of local contents, including quizzes for formal evaluation, will be also part of the next step. In general, the students can adapt easily to Internet-based learning.^[22] In our work, the students also adhered very easily to the new system and are the ones, together with the faculty, that will allow no way back to previous teaching modalities. Like anywhere else, students in Mozambique had no difficulty in navigating the system and are participating and moving forward the

new learning approaches. The inquiries show their positive appreciation of the process. They will also probably be major players in spreading the word for expanding these learning approaches to other disciplines at the medical faculty. The single aspect we can use to evaluate the possible impact on the outcome of the students is based on the comparison of the success rate of the students in the year before implementation of the new curricula (2014) with the rate of student's approval after introduction of the b-learning courses (Pathology I and Pathology II). The results were quite similar: 77.8% and 83.9%, respectively, in 2014 and in 2015 after the introduction of b-learning, the approval rate was 83.9% for Pathology I and 89.5% for Pathology II.

For most students in Portugal, the autopsy video was the first and single contact with the challenge of a medical autopsy. This experimental test is certainly going to expand, and we are planning to build a valuable video platform of autopsies for teaching purposes. Already, another University in Portugal has shown interest in participating in the process and one team member (CC), who is currently an invited Professor at Universidade da Beira Interior, in Portugal, is going to precisely discuss the autopsy with their medical students.

Limitations of the study

Despite the relevant results and the achievement of an end product that is on the ground, our study has several limitations. The surveys were obtained only in the FMUEM and we do not have the feedback from FMUP's students on shared contents, or a structured feedback of the faculty members. Also, only half of the pathology class of FMUEM answered the survey. Therefore, the results of the survey only represent the perceptions, comments, and suggestions of the students that participated in the survey. We cannot discard, given this limitation impossible to solve retrospectively, that the nonresponders were deterred from participating by being afraid to be identified.

CONCLUSIONS

Pathology plays a critical role in medical training, not only because it lends a quasi-physical support to the medical terminology, but also because it is a core and universal language within the medical field. In addition, pathology is the territory where new discoveries integrate a coherent evolution of medical practice. In this specific project, each country separately gained access to high-quality pathologic material from disease conditions prevalent locally (e.g., infectious diseases material in Mozambique, and rare cancers from aging Western populations in Portugal).

Initiatives that contribute for a better learning process in pathology have multiplicative effects on the whole medical training process. All instruments, such as created in the current project, that increase autonomy and the capacity to evolve continuously in the learning process are certainly going to have a positive impact on the medical activity of future doctors

confronted everyday with new discoveries, new drugs, and new clinical approaches.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Faculty of Medicine, Eduardo Mondlane University. Curricula of the Medical Doctor Course. 2004. Available from: http://www.medicina.uem.mz/images/curriculo_medicina_UEM.pdf. [Last accessed on 2017 Oct 26].
2. Blake CA, Lavoie HA, Millette CF. Teaching medical histology at the university of South Carolina school of medicine: Transition to virtual slides and virtual microscopes. *Anat Rec B New Anat* 2003;275:196-206.
3. Chen YK, Hsue SS, Lin DC, Wang WC, Chen JY, Lin CC, *et al*. An application of virtual microscopy in the teaching of an oral and maxillofacial pathology laboratory course. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105:342-7.
4. Dee FR, Meyerholz DK. Teaching medical pathology in the twenty-first century: Virtual microscopy applications. *J Vet Med Educ* 2007;34:431-6.
5. Fonseca FP, Santos-Silva AR, Lopes MA, Almeida OP, Vargas PA. Transition from glass to digital slide microscopy in the teaching of oral pathology in a Brazilian dental school. *Med Oral Patol Oral Cir Bucal* 2015;20:e17-22.
6. Foster K. Medical education in the digital age: Digital whole slide imaging as an e-learning tool. *J Pathol Inform* 2010;1: pii: 14.
7. Goldberg HR, Dintzis R. The positive impact of team-based virtual microscopy on student learning in physiology and histology. *Adv Physiol Educ* 2007;31:261-5.
8. Mills PC, Bradley AP, Woodall PF, Wildermoth M. Teaching histology to first-year veterinary science students using virtual microscopy and traditional microscopy: A comparison of student responses. *J Vet Med Educ* 2007;34:177-82.
9. Ordi O, Bombí JA, Martínez A, Ramírez J, Alòs L, Saco A, *et al*. Virtual microscopy in the undergraduate teaching of pathology. *J Pathol Inform* 2015;6:1.
10. Saco A, Bombí JA, Garcia A, Ramírez J, Ordi J. Current status of whole-slide imaging in education. *Pathobiology* 2016;83:79-88.
11. Gopalan V, Kasem K, Pillai S, Olveda D, Ariana A, Leung M, *et al*. Evaluation of multidisciplinary strategies and traditional approaches in teaching pathology in medical students. *Pathol Int* 2018. doi:10.1111/pin.12706. [Epub ahead of print]
12. Vainer B, Mortensen NW, Poulsen SS, Sørensen AH, Olsen J, Saxild HH, *et al*. Turning microscopy in the medical curriculum digital: Experiences from the faculty of health and medical sciences at University of Copenhagen. *J Pathol Inform* 2017;8:11.
13. Al-Janabi S, Huisman A, Van Diest PJ. Digital pathology: Current status and future perspectives. *Histopathology* 2012;61:1-9.
14. Pantanowitz L, Valenstein PN, Evans AJ, Kaplan KJ, Pfeifer JD, Wilbur DC, *et al*. Review of the current state of whole slide imaging in pathology. *J Pathol Inform* 2011;2:36.
15. Pantanowitz L, Szymas J, Yagi Y, Wilbur D. Whole slide imaging for educational purposes. *J Pathol Inform* 2012;3:46.
16. Saco A, Ramírez J, Rakislova N, Mira A, Ordi J. Validation of whole-slide imaging for histopathological diagnosis: Current state. *Pathobiology* 2016;83:89-98.
17. Rajkoomar M, Raju J. A framework using blended learning for innovative teaching and learning. *Res Rev J Educ Stud* 2016;2:1-9.
18. Mocumbi AO, Carrilho C, Aronoff-Spencer E, Fuzamo C, Patel S, Preziosi M, *et al*. Innovative strategies for transforming internal medicine residency training in resource-limited settings: The Mozambique experience. *Acad Med* 2014;89:S78-82.
19. Noormahomed EV, Mocumbi AO, Preziosi M, Damasceno A, Bickler S, Smith DM, *et al*. Strengthening research capacity through the medical education partnership initiative: The Mozambique experience. *Hum Resour Health* 2013;11:62.
20. Mullan F, Frehywot S, Omaswa F, Buch E, Chen C, Greysen SR, *et al*. Medical schools in sub-Saharan Africa. *Lancet* 2011;377:1113-21.
21. Williams CD, Pitchforth EL, O’Callaghan C. Computers, the internet and medical education in Africa. *Med Educ* 2010;44:485-8.
22. Greysen SR, Dovlo D, Olapade-Olaopa EO, Jacobs M, Sewankambo N, Mullan F, *et al*. Medical education in sub-Saharan Africa: A literature review. *Med Educ* 2011;45:973-86.