

# The virtual pathology lab experience

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**Abstract** Learning pathology is a challenge, students must develop the skills to identify microscopic abnormalities, explain the interaction of functional disorders, and their causes. This study assesses a novel approach to teach pathology using clinical cases through digital images, virtual online slides, and a learning management system. Satisfaction of 83 students in the Pathology class was assessed with an online survey, using a Likert scale from 1 to 5 where 1 stands for total disagreement and 5 for total agreement. Regarding the impact of virtual pathology lab experience in their academic performance, 97.6% of students believe this approach was useful to achieve learning objectives as it allows self-directed learning, easier feedback, and collaboration between peers.

**Keywords** Medical education · Technology · Pathology · Virtual

## 1 Introduction

Medical school is challenging and there is an exponential growth of knowledge in all health-related subjects. Students sometimes perceive basic science disciplines as difficult and they cannot see their application in a clinical setting, making those subjects not hard to appreciate and learn. Integrating clinical information can make some of the classes more interesting and at the same time, the information learned can be afterwards applied in several medical disciplines.

Pathology is a particularly good example where students constantly perceive themselves as vulnerable, especially due to terminology and ability needed to identify cells under the microscope. Students need to recognize the different types of cells, and process interactions that the histopathological analysis of tissues can reveal. They should also consider that making a diagnosis burdens a huge responsibility, since it will be giving crucial information used for deciding the adequate treatment and prognosis each patient will receive. Most students learn by reading articles or books, and are not yet familiarized with the images of tissue samples. In Pathology, to be able to fully understand the information, the student must identify the main characteristics of normal non-pathological tissue, the typical cell architectural organization and the visualization of the slide with traditional coloring techniques. The development of the competences includes the identification and knowledge based decision of choosing the appropriate traditional or special stain for the best interpretation of the slide. This process depends on the patient's disease and the expected histopathological findings. As well as on the tissue characteristics that need to be enhanced by the special dyes for making the appropriate diagnosis. The distortion of the tissues must be minimized to offer a truly representative image that can be used for the teaching–learning process. Traditionally, pathology courses were taught as lectures accompanied by a lab session where microscopic examination took place. During the theoretical class, the teacher provides valuable information that helps the students identify the type of changes tissues sustain due to the pathologic process, that is, the specific disease the patient suffers. The student must be able to link the patients' signs and symptoms to the morphological changes in the different organs, as well as on their function or dysfunction, while comprehending the compensatory mechanisms the organism suffers when injured. This understanding is crucial, since

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most medical schools are focused on the identification of images alone, a simple process that does not help the student understand what the patient is going through.

Students first need to be able to recognize the characteristic findings that specific disease incite in cells, tissues, and organs. Once they have been exposed to the first part of the process, they are asked to identify the same abnormalities of the same disease in different slides, mostly from different patients. The context where this is done is in a lab where they can practice multiple times. These labs were based on the use of histological glass slides of diverse pathologies that required the student to use a microscope to be able to observe and study the slide. Most students were familiarized with the use of a microscope. Nevertheless, they received a brief introduction about the materials available for them in the lab, where to find them, how to use them and their responsibility in doing so. Usually, the students get involved in these sessions as a group. This made it difficult for everyone to have their own microscope. Dividing the group had several advantages. The teacher could be closer to each student and aid them with their uncertainties and enquiries. Materials and microscopes availability is restricted, furthermore, the physical limitations of this method bounded the course instructor to help one student at a time, during a specific lab schedule. This disadvantage made the teacher spend long hours after class with the students that could not identify specific abnormalities in the slide. This method of traditional observance does not ensure that the fundamental microscopic alterations for the diagnosis of this disease taught by the instructor, are being understood by the student. But most importantly it is not possible to guarantee that the students are observing the same alterations during their time at the microscope. There was no effective way to know accurately the information the student was learning and the level of comprehension obtained by the student.

Several professors at our university felt frustrated in their efforts to enhance students' learning. They decided to make a change and encourage the students' and teachers' commitment to the course by introducing new technology and learn how to incorporate this in the daily practice.

The idea of the incorporation of virtual microscopy through the virtual pathology lab was conceived as a new interactive approach to teach pathology to medical students, and incorporate technology that motivates them. Students' motivation is crucial for learning. Nowadays most of the students are immerse in the use of technology, incorporating educational technology could be the right change.

To evaluate the benefits of the implementation of the innovation, several research questions arise: What impact those the experience of using the virtual pathology lab had in the students' perception about pathology? What elements of the virtual pathology lab aid in the learning process of this course?

## 1.1 Teaching pathology

Pathology is a discipline in medicine that studies disease through the anatomic and histologic alterations in organs, tissues, and cells, integrating causes, mechanisms, and consequences of those processes [1]. It is usually catalogued in general and systemic pathology. General pathology studies the basic response of cells and tissues to general stimuli, while system pathology studies the etiologic and pathogenic processes that affect and generate a response involving the different organs and systems in the human body. All these processes are complex to understand by students if they are only presented with the histologic images. In order to provide a context for learning, they are required to read about the signs and symptoms patients have, and the general evolution of a disease in order to be able to understand the underlying changes that they will be seeing in the slides.

Previous knowledge of cellular biology, histology, and physiology, is required to aid in the construction of new knowledge with epidemiologic and etiologic factors that alter normal metabolism causing physio-pathologic macroscopic and microscopic alterations within organs and systems [2]. This content interaction helps integrate basic and clinical sciences in the formative curriculum of medicine. The students have received these courses as a pre-requisite to the pathology courses in our university. Their ability to identify specific tissues is crucial to the subsequent courses of pathology. Some students get involved in the tutoring program where they collaborate with younger students in the histology lab. Allowing them to be more proficient in their abilities to work with the slide, and more confident about their performance. This is due to the time spent in this environment, which appears more familiar to them, and to the repeated process of explaining the clinical case as well as the analysis that they performed to other students.

Pathology is not a technical process of slide interpretation, it is a science that functions as a bridge between a physio-pathological process and the patient clinical manifestations, helping understand and integrate the pathological diagnosis and establishing a proper therapeutic approach as well as a prognosis [3]. Every pathophysiology class can benefit from the students' ability to identify tissue abnormalities, since they are more critical about the physical findings in a patient, especially since they have seen the morphological changes in disease.

The main objective in teaching pathology to undergraduate students is to provide a framework of knowledge so they can understand disease at every level: molecular, cell, tissue, organ, system, and organism, to explain what, how, and why a disease is affecting their patient, as well as, what will their prognosis be. Students are able to understand that there is a direct correlation between the patient's history and physical exam, and the histologic findings. Having a pathology

lab promotes students' abilities to identify at microscopic level, the morphologic alterations that tissues undergo during the pathologic process of disease. Therefore, they can remember more accurately the underlying signs and symptoms.

Traditional observation using the microscope has been used for years in teaching pathology laboratories [4]. Most of those laboratories had antique and obsolete equipment, representing a disadvantage for the ideal observation of the study material. Keeping the microscopes updated represents a huge economic investment for the academic department. Required to equip their labs, usually once at the beginning of the initiative, some of the microscopes are 20 or more years old, making their repair and maintenance hard to keep.

During the lab session, the instructors find it difficult to approach and aid each student in a group effectively, due to the number of students and to the amount of attention requested by each. When possible, instructor and student observe in the same microscope, but the necessary technology to signalize or point out the precise patterns or cells where the abnormalities are in the microscopic image is not available, therefore the meaningful diagnostic areas sometimes go unnoticed in the microscopic field. Sometimes causing a gap between what the instructor is seeing and what the student is seeing.

During the twentieth century, the most innovative practice in teaching pathology under the microscope was limited to projections of microscopic images shown to the whole class group. Projectors were used in special classrooms, suited for these classes. Nevertheless, the support of fixed images or projections was not enough to provide students a general conception of the morphological alterations of the examined tissue. Usually, students had to seek further assistance, looking for their tutors to obtain counseling or an extra lab practice to achieve what was initially intended to be the outcome. It was not until the beginning of the twenty-first century that digitization of histologic preparations started and the first virtual images were obtained. The manipulation of digital images, with the use of the right interphase, provides the ability to increase or decrease magnification of images. Image banks were created. Later, several initiatives emerged where these huge banks were shared through the Internet, making them available for others to observe, even in places where the use of digitalizing equipment was not available. This has contributed to the creation, especially in the United State and Europe, of virtual laboratories in universities' sites, supported by informatics resources by a third party and complemented with conferences and clinical simulations [5]. Nowadays, there are full virtual pathology courses available online, for example the Virtual Pathology of Leed University, Pathology Education Instructional Resource PEIR Path, and the United States and Canadian Academy of Pathology (USCAP).

The widespread use of mobile devices has made it necessary to find a way for this technology to be applied to mobile users. Some of the created apps for mobile devices are JH PanAtlas, ePathViewer, and InterpathHD, allowing users to manage histologic slides on mobile phones and tablets. Some also offer clinical case scenarios that can be used as simulation for teaching different pathology subjects [6]. This technological improvement has made it possible for students and pathology professionals all over the world to share their learning experiences using digitized histologic slides [7]. Through this benchmarking, virtual pathology lab was designed for teaching-learning pathology with a novel approach. Implemented for the first time on August 2013 at a school of medicine and health sciences in a northern university in Mexico. As for now, in Latin America, there is no other pathology course teaching with this innovative approach, and in the United States, there are only few using it for undergraduate medical students [8,9].

## 1.2 The virtual pathology lab

The development of the virtual pathology lab included three phases: design, implementation, and analysis. The design phase included the search and selection of the histologic material ideal to learn the objectives of the course. Then it continued with the digitization of slides to be able to prepare images for *Microsoft DeepZoom*. These images were stored in an intranet computer at our medical school.

### 1.2.1 Establishment of learning objectives

The virtual pathology lab design was initially conceived because the teachers involved in the project had the intention of making changes to the academic program. They designed a curricular re-design, which included a laboratory practice in the course. Now all pathology courses were required to have practical content as part of the course. The teachers were sure this would provide further support for the students learning processes. So, with the new syllabus a list of the pathologies needed to help achieve the learning objectives was created. This list would serve as a guide as to what types of images were to be sought and used in the courses.

### 1.2.2 Search and selection of material

With this list, a search in the academic medical center pathology department data bank was made to find and retrieve the available glass slides that the pathologies needed for the course. The glass slides were reviewed and the important areas marked for digitalization, taking in account the level of expertise for the students attending that course.

### 1.2.3 Digitalization of slides and image preparation

A *Zeiss AxioImager 2* light microscope and glass scanner with motorized and automated processes for up to 8 glass slides digitalization through a high definition camera *Axiocam MRc* and *ZEN Digital Imaging* software. An open microscope system for automated material analysis with single user interface with the option of control via TFT technology. The image data obtained through the scanning software had .czi format and it was converted to .jpg for easier image manipulation. *Microsoft Silverlight DeepZoom* software provides the ability to interactively view high-resolution images. *Microsoft DeepZoom* enables the user to interact with high-resolution images by changing their magnification without affecting the application's performance. A *DeepZoom* image is an image pyramid composed of tiles of JPEG images at different resolutions. Each tile is stored in a separate file, and each level of the pyramid is stored in a separate folder. Enabling *DeepZoom* to use only those tiles required for the size of the image on screen, instead of downloading the entire image, thus economizing byte transfer. *DeepZoom Composer* was the software used to build the image pyramids. Released by *Microsoft* as an open-source library, *Seadragon Ajax* is a pure *JavaScript* implementation of the *Seadragon technology*. It allows for the seamlessly smooth transition between the tiles and layers amongst the *DeepZoom Collection*. Image storage in an intranet computer.

The image data was later stored in an intranet computer used as a repository. The images were only available in campus using the campus on line system and only to students that were enrolled in the pathology course and to its faculty. The importance of acquiring a server to store the contents as well as a connector software for remote administration was noted.

During the implementation phase the following was considered: server acquisition and preparation for image management, upload, design, and structural operation of the material in the learning management system, the functionality and maintenance of the slide visor, as well as its execution in the course.

### 1.2.4 Server acquisition and preparation

Economical support was needed to achieve the acquisition and administration of the server. It was decided to participate as a project in Novus 2013, an institutional program at Tecnológico de Monterrey that provides grants as economic incentives to innovative educational projects. Since its creation in 2012, Novus has provided economical support to 288 projects in which more than 1200 professors participated. NOVUS has the finality to support experimentation proposals in different themes referred to the teaching-learning process. An expert scientific committee evaluated the projects con-

sidering three important aspects in the proposal: innovation, originality, and improvement in the learning-teaching process as its principal objective. The project was one of the 55 projects selected out of more than 200 proposals in Novus 2013 and the fund was obtained for the acquisition of a server and the connector software. A HP ProLiant DL380p Gen8 Server with Intel® Xeon® E5-2640 (2.50GHz/6-core/95W) and HP 16GB (2x8GB) Single Rank x4 PC3-12800 (DDR3-1600) Registered CAS-11 Memory. The software HP ILO ADV E-LTU INC 1YR TS& U SW to connect to the administration port. The server was initially formatted, software was installed and an IP address was obtained.

### 1.2.5 Digitized slide link upload and design in an educational technological platform

The institutional educational model regularly uses a technological platform called *Blackboard Learn* for the management of their courses. *Blackboard Learn* was previously called the *Blackboard Learning Management System*, it is a virtual learning environment and course management system developed by *Blackboard Inc.* It is web-based server software that allows integration with student information systems and authentication protocols, where on line elements can be added.

The pathology course calendar, syllabus, and *PowerPoint* presentations were already on an online learning platform. A special section was created to include the lab slides links. Including the images as a list of resources for the lab was not considered as an important instrument to improve the teaching-learning process. That is why according to the team of professors a new design of the pathology virtual lab should be created. Emphasis was directed on improving the academic aspect of teaching pathology, focusing not only on the images but on the construction of knowledge, self-direction, enhance critical thinking and solve problems. Instead of only including the links of slides, the pathology group of professors constructed for each lab session clinical-pathological cases to match the pathological slides and the courses' learning objectives.

The made-up cases have clinical information about the patient's signs and symptoms that are typical for the pathology being studied. Each case also has radiologic or clinical pictures obtained from the web to help support and complete the case. They also include one or two digitized slides from real cases that match the fictitious case and the pathology objectives. Included in each lab session students have a pdf file with the instructions of the activity and the important aspects they need to find in the digitized slides.

Students have access to the learning platform and to the virtual pathology lab on off-school hours providing them with wide resource availability to strengthen what they have

learned as well as to practice and acquire key concepts at home without all the limitations mentioned before.

### 1.2.6 The functionality and maintenance of the slide visor, as well as its execution in the course

At the institution, IT personnel had the responsibility to manage the slides visibility and the server's functionality, and maintenance. Since its initial startup, the functionality has only been affected once with a software update that needed reprogramming several instructions in the server and on the learning management system.

The analysis phase includes the evaluation of the results of the experience for continuous improvement, based in students' perception, as it was directed to create studying habits, abilities, and competencies for success in a global environment. It mainly evaluated student experience, including their perception of achievement of the course learning goals as well as an improvement in their outcome.

This project impacts annually around 600 medical students that are in any of the four Pathology courses of the medical curriculum. The virtual pathology lab objectives are to increase student motivation and engagement in their own learning with innovative and mobile technology, increase resource availability so students can access pathological cases at any time and in any place for self or peer study, promote collaborative learning and facilitate the teaching-learning process.

In the project, the strategy incorporated was bring your own device or BYOD, where each student brings their own tablets, smartphones, or other devices to access data and complete class assignments. Originally proposed by Intel's chief security in 2009 for employees to bring their devices to the workplace, cutting costs and improving productivity [10]. This strategy has also been known as consumerization of IT, and has been used to reduce cost in IT infrastructure and equipment by many employers, including universities. For a little more than a decade BYOD has been used in education, sometimes referred as 1-to-1 learning program [11]. The authors proposed five potential models of BYOD:

1. School-defined single platform laptop.
2. School-defined single platform laptop, plus another device.
3. School-defined multi-platform laptops.
4. Student-choice of laptop or tablet.
5. Bring your own whatever connects to the Internet.

In the virtual pathology lab, students were encouraged to bring a laptop, but tablets and smartphones were also permitted, even though the lab virtual images were not used to their full potential if they were seen in a small screen.

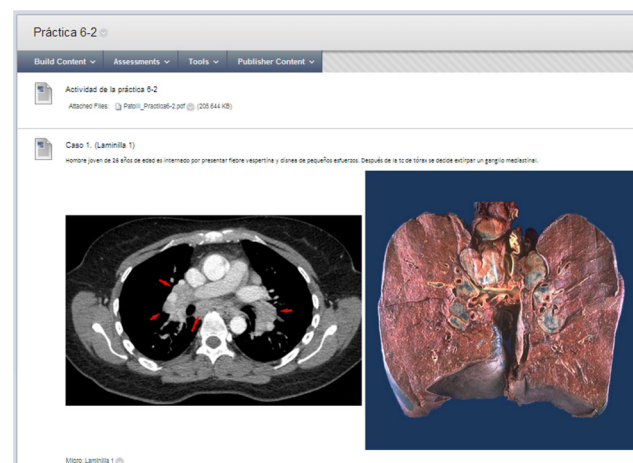
No matter what device students used the virtual pathology lab also gives the students the ability to freely manipulate magnification levels in the digitized images. Students can easily signalize cells or tissue patterns and if necessary, indicate their specific inquiries to their peers and teacher. This new approach is a promising tool for the students to expand their learning skills, promote critical thinking and improve their knowledge construction. The project also reduces lab costs by decreasing the need of special facilities, the amount of glass slide copies, microscopes, and human resources like professors, lab instructors, and cleaning personal.

Optimizing the use of resources such as: physical spaces is invaluable, glass slides required special containers and drawers, but besides having the proper storage facilities these could deteriorate with the passing of time and their periodic renovation is necessary.

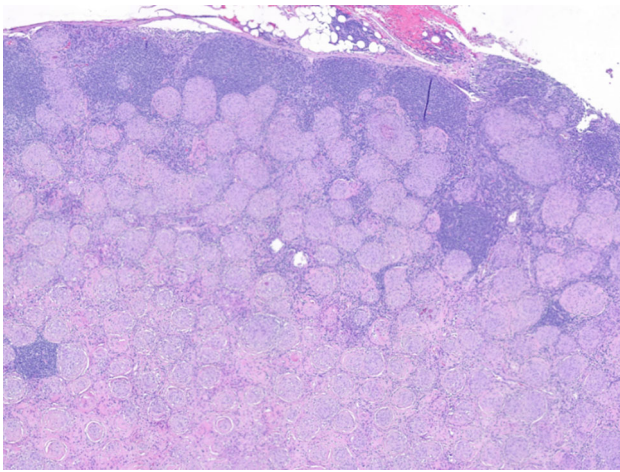
All the glass slides used for the course belong to the Hospital San José Tecnológico de Monterrey pathology laboratory being cases of patients that really suffered from the diseases discussed in this part of the course. Glass slides were selected by pathologist, who later also selected histological fields and marked them for their posterior digitization. Making sure the selected area contained all the morphological factors required by the design of the practice session. It is only in this context that the exposure and digital display will be helpful to the student.

The students are provided with a weekly activity in their lab practice based on five clinical-histopathological cases with digitized slides. Each case tries to cover a part of the content and objectives of the theoretical course, representing genetic, inflammatory, degenerative, or neoplastic pathological processes.

In Fig. 1, an example of the online learning platform is open in one of the lab practice sessions web pages, where it includes the clinical-pathological cases as well as the activity's instructions and assessment rubric. The first case of the



**Fig. 1** Clinical pathological case in online learning platform



**Fig. 2** Participant's access to the virtual pathology slide

practice session includes a hypothetical case of a patient with the typical clinical information as well as a magnetic resonance and a macroscopic image that correspond to a similar case giving the student the complete picture of the patient's disease. The link to the virtual slide with the pathology corresponding to a sarcoid hilar lymphadenopathy.

Each lab practice is designed to support and reinforce the learning goals for that week. Problem case scenarios were created where students in small teams needed, using collaborative techniques as well as interpretation and analysis, to draw diagnostic conclusions. After observing real-life histopathological images (digitized slides) and made up clinical cases, students can integrate their theoretical and practical knowledge. All cases are available in the course technological platform during the entire semester and they can be seen in mobile technology. In Fig. 2, the participant's access to the virtual slide is observed, the case presented is a patient's lymph node with multiple non-caseating granulomas.

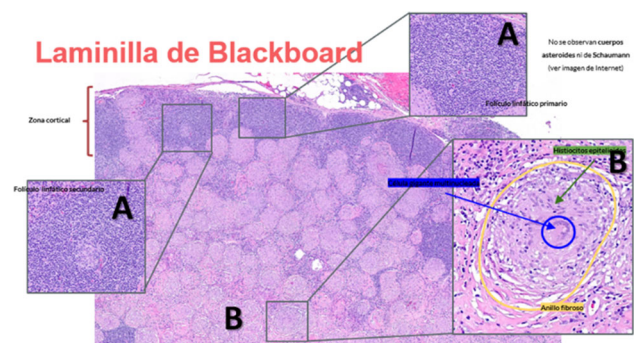
In Fig. 3, the view of a virtual slide through the iPad is observed. The student can manipulate the image either by the "+" or "-" controls at the bottom of the images or with his own fingers, zooming in and out to their desire magnification.

Students can take screen-shots of their tablets or screen capture clips of the laptop and save the images to later build a *PowerPoint* presentation with all the criteria specified for that activity.

For each lab session, in the learning platform, the lab practice instruction sheet was included, it mainly contained information about how to build their presentation and which criteria is important to complete the learning process. For each case, students were required to find the typical clinical manifestations, the clinical diagnosis, etiology, physio-pathological process, differential diagnosis, and a web similar microscopic image. The most important part of the activity had to do with the virtual slides, for each ses-



**Fig. 3** Participant's access to the virtual slide through a tablet



**Fig. 4** Sample of student's analysis: *A* Student identifies the normal lymph node architecture and *B* how it was distorted by non-caseating granulomas

sion, specific morphological criteria needed to be found by the student and correctly signaled. The screen shots and screen clips were required as well as the correct demonstration of having identified the microscopic findings important for each case.

Students receive tutoring by their professor during or outside of class via email. Students can send their images signaled with circles, squares and arrows having an accurate communication of their doubts or findings. Evaluation rubrics for each lab practice are also found in the platform. Figure 4, presents an example of an extract of a student's work including the image analysis, where arrows and signalization are observed.

During each week lab sessions students had a quiz about those week cases, so even though the presentations were made up by teams of five students, each student had to study and be responsible for their own knowledge acquisition demonstrated by the weekly evaluation. At the end of each month a practical exam was applied, it was constructed similarly as the weekly lab practice, containing seven clinical pathological cases with web images and virtual slides.



**Fig. 5** Students during monthly pathology virtual lab session evaluation

The exam had multiple choice questions and it is a valuable feedback of the lab sessions effectiveness. Figure 5 show students at the evaluation center during a virtual lab session examination.

## 2 Materials and methods

The objective of this study was to evaluate students' perception and satisfaction level with the use of the virtual pathology lab in the teaching of Pathology. The study was performed during 2014, with an online survey applied to 6 groups of students in the Pathology course. A sample of 83 students participated.

The evaluation was done with an . survey which uses a Likert scale ranging from 1 to 5, where 1 stands for total disagreement and 5 for total agreement. The instrument assesses the incorporation of clinical cases as iconographic support, the use of images and clinical cases in the theoretical class the impact on the development of abilities to diagnosis through images, the perception of the incorporation of technology like internet and email for feedback, the correlation between the exam and the contents presented, the possible technical difficulties and the perception of distance tutoring.

The survey considered the following items:

1. Do you consider that the teaching of pathology with the use of clinical cases and digitized slides has been useful for your practical formation in medicine?
2. Do you consider that teaching pathology using images and clinical cases is more useful than traditional theoretical class?
3. Do you consider that the new technologies like internet aid on the development of clinical judgment for making a diagnosis through an image?

4. Was it easy to obtain images and course information through the web?
5. Do you consider that the digitalized slides aided you to develop self-direction of learning?
6. Do you consider that the incorporation of technology enriched your learning of Pathology?
7. Do you consider that the virtual pathology lab experience had an impact in your academic performance of the class?
8. How would you score the quality of the cases and images available in the virtual pathology lab?

A quantitative approach is used to make a descriptive analysis of the students' evaluations. For the data, statistical analysis Minitab 16.0 package was used to codify and process the information. For each item the distribution was estimated per the Likert scale, 1 through 5, considering favorable values those between 3 and 5 values of the scale.

## 3 Results

The feedback received from the students indicates that the teaching of pathology incorporating the use of clinical cases and digitized slides has been considered by 97.6% of the students as useful.

The perception of teaching of pathology using images and clinical cases was regarded as more useful than the traditional theoretical class by 92.8% of the students. The incorporation of new technologies and their effect in the development of clinical judgement for making a diagnosis through an image was considered useful by 95.2% of them. An approximate of 98.8% of the students believe that the availability of images and course information through the web was adequate and of easy access. According to 85.5% of students, the incorporation of digitized slides aided in the development of their self-direction of learning. And about 97.6% consider that the incorporation of technology enriches their learning. A total of 96.4% of the students believe that the virtual pathology lab experience had an impact in their academic performance of the class.

Finally, the general course evaluation with the virtual pathology lab was considered by 97.6% of students as of high quality because of its cases and digitized slides. The students' perception is summarized in Table 1.

## 4 Discussion

Students have widely accepted the virtual pathology lab, not only because of its attractive use of technology, but also because its helps them achieve the learning goals.

They considered the teaching of pathology with the use of clinical cases and digitized slides was useful for their practical formation pathology and more useful than a traditional

**Table 1** Distribution students' perception on the virtual pathology lab

Item	1	2	3	4	5
1. Do you consider that the teaching of pathology with the use of clinical cases and digitized slides has been useful for your practical formation in medicine?	2 (2%)	2 (2%)	6 (7%)	18 (22%)	57 (68.7%)
2. Do you consider that teaching pathology using images and clinical cases is more useful than traditional theoretical class?	2 (2.4%)	4 (4.8%)	5 (6%)	13 (16%)	59 (71.1%)
3. Do you consider that the new technologies like internet aid on the development of clinical judgment for making a diagnosis through an image?	2 (2.4%)	2 (2.4%)	8 (9.6%)	22 (27%)	49 (59%)
4. Was it easy to obtain images and course information through the web?	1 (1.2%)	0 (0%)	2 (2.4%)	3 (4%)	77 (92.8%)
5. Do you consider that the digitalized slides aided you to develop self-direction of learning?	6 (7.2%)	6 (7.2%)	13 (15.7%)	18 (22%)	40 (48.2%)
6. Do you consider that the incorporation of technology enriched your learning of Pathology?	1 (1.2%)	1 (1.2%)	2 (2.4%)	8 (10%)	71 (85.5%)
7. Do you consider that the virtual pathology lab experience had an impact in your academic performance of the class?	2 (2.4%)	1 (1.2%)	16 (19.3%)	15 (18%)	49 (59%)
8. How would you score the quality of the cases and images available in the virtual pathology lab?	1 (1%)	1 (1%)	3 (4%)	5 (6%)	75 (90.4%)

theoretical class. They appreciate new technologies as an important aid in the development skills for acquiring clinical judgment in making diagnosis. Specially using a digitized image as an aid in doing so.

As is reported in the literature, the ease of access to images and course information help in promoting outside of class studying and collaboration.

As suggested by Hamilton [12], the digitized slide promoted easier discussion of the content between students, allowing for group-work collaboration and different teaching techniques and assignments to be applied. Improving individual and group learning, providing a more meaningful learning experience. Students were excited to use the pathology slides at their own time and place, and manipulate the images with their tablets or smartphones. Even though this was their first contact with digitized slides, they considered the virtual pathology lab with slides and the clinical cases as of good quality and an ideal instrument for learning pathology.

Students agreed that self-direction of learning was also promoted with the virtual pathology lab, they had to self-

manage and organize their time to view, analyze, research and solve the lab cases.

Using real-life slides associated with “made-up” clinical cases, gave the students the responsibility needed to resolve real-life cases, improving their motivation and enthusiasm towards learning. They are more involved in their learning, more enthusiastic about the class, participating actively toward their knowledge construction. The support that the project brings to the theoretical class has also been referred by the students, as it helps in connecting theory and practice, making the learning content more meaningful for the student and helping in the retention process.

A more objective evaluation was achieved, having a similar process as their weekly activities, they had also weekly and monthly evaluations using the digitized slides and cases.

Students had a positive appreciation of their performance in the course, considering the virtual pathology lab experience as an important factor in its achievement. As project leaders, and pathology teaching advocates, it is a very stimulating feedback knowing that the impact of the virtual pathology lab not only motivates the students but also has a more tangible impact on their learning.



Further studies are needed to measure not only the impact of our students' perception of their acquisition of learning objectives but on the numeric improvement of their final grades.

The draw backs of the project are the technological problems that can affect the virtual pathology lab, as internet transmission speed and reliability. In different occasions in the semester, the internet was slow, or students couldn't connect. Automatic updates are sometimes enabled in students' computers and when they start during class or evaluation time, difficulties are encountered. Even though precautions are taken to diminish this eventuality, some are inevitable, as students are responsible of their own devices. Although it does not happen often, teachers need to know how to solve basic computer problems and manage the educational platform adequately to aid students when adverse condition happened.

Telepathology and digitized slides had been used for years, but using a virtual pathology lab with digitized slides with clinicopathological cases for education in medical school is still not widely widespread, especially in Mexico.

In 2005 Lam et al. [13] tried to "resuscitate the teaching of pathology in undergraduate medical education" by reactivating the clinicopathological conference (CPC) and in their study the pathology module to improve pathology profile in their school and had positive feedback about it.

Hassan [14], states that a well-presented CPC is still a useful teaching tool that can offer clinicopathological correlation and at the same time aid in building its competence, providing a platform for intellectual interaction. The original CPC involves the presentation of the case, finding the diagnostic data (includes patient's signs and symptoms, as well as lab results and imaging study analysis), discuss the differential diagnosis, and analyze how they narrowed it down to their probable diagnosis, including in the process the patient's prognosis and a gross overview of the treatment.

Even though in the virtual pathology lab it was not organized as a conference we did used clinicopathological unknown cases for learning purposes and asked students to collaboratively identify and later present their findings. The findings should include, as in the CPC, the case information, the relevant clinical data for the diagnosis, the lab results, pathogenesis of the disease, differential diagnosis and having a special and more extensive portion of the macroscopic and microscopic findings in the slides, and how this relevant information supported their clinical diagnosis. Students were also required to look on the internet for similar histopathological images and marked them in the same way as their digitized slides, providing evidence of their acquired knowledge and understanding of the pathological findings.

On class and online discussions provided a collaborative learning environment that extended outside the classroom. Students organized a Facebook course group for discussing

the pathology lab cases. It was widely used and it included information about the histopathological findings in the digitized slides as well as shared internet resources for analyzing the cases.

According to Downer and Swindells [15], there are two main types of case studies: (1) fully develop narratives, and (2) short-case presentations. The latter are more frequently used in medical education.

Presenting the information in case studies is more interesting for the students than having the complete didactic material in PowerPoint presentations. They offer development of higher-learning skills [16], as are analytical and problem-solving skills and application of knowledge while confronting challenging situations.

The cases need to be relevant and to include enough information that leads the student to the correct analysis and completion of the learning objectives of the module.

On the pathology lab students have their clinical cases related to the weeks' topic, with their corresponding slide and activity information, to guide them through the process but at the same time challenging them to discover and interpret their findings. Case studies are an effective tool in engaging and promoting students' decision-making, as well as an excellent tool for medical education.

The virtual pathology lab brings reality, efficiency, and opportunities for collaborative learning that pathology education did not widely used before. Students' engagement and appreciation of the meaning of pathology has been reinforced and especially its significance in the development of disease as well as its understanding helps students have a more meaningful learning of the pathophysiological process a patient is undergoing. Giving the student a more pragmatic and less hypothetical view of a disease.

Learning how to use this technology for teaching, can aid educators to challenge students of new generations. The virtual microscopy is not limited to pathology, it can be applied to any discipline where a traditional microscope is used, good examples are histology, parasitology, and microbiology. The use of the lab can be transposed to several disciplines and its flexibility facilitates its delivery.

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