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The First South American Free Online Virtual Morphology Laboratory: Creating History

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Background: Biomedical teaching has been revolutionized through multimedia and global collaboration. In a joint effort between Argentina and the UK, a Virtual Laboratory has been created for teaching morphological topics interactively pertaining to cell biology, histology and embryology intended for Health Science students at the National University of Cordoba, Argentina. **Aim:** To observe whether the online resource has changed the attitudes of student-users and offers a suitable replacement to traditional laboratory work. **Methods:** Through a central website that has evolved for almost a decade and most likely the first of its kind on the continent, the virtual laboratory program was launched and students were recruited to participate in a basic survey on the significance of the virtual laboratory program to their learning needs, attitudes to using electronic media and whether they agreed that classroom teaching should be obsolete altogether. **Results:** 291 student-users were recruited in the academic year of 2010. 267, of whom 92% used the virtual laboratory as a principal tool for learning. The online virtual practical work-guide designed by faculty was the most commonly used supplementary resource. A minority of students still preferred to supplement their learning by traditional methods such as books and classroom notes as well as external online resources. **Conclusion:** Our interactive virtual program was unanimously preferred as the principle learning tool for morphological sciences. The Virtual Laboratory, using popular electronic multimedia and inter-continental partnership, will enhance all aspects of biomedical education as a unique teaching resource in South America.

Keywords: Anatomy; Embryology; Microscopy; Online; South America; Virtual Laboratory

Introduction

Straightforward Teaching of a Complicated Topic: Definitions & Outlines

Biomedical education has been revolutionized through multimedia and global collaboration. Integration of technology in basic science education can contribute to a better understanding of both human and social dimensions which are essential to the creation of new learning cultures. Education is a fundamental objective in continuing professional development for health personnel.

Advances in communication and information technology have drastically altered delivery and quality of education. Nowadays, most students have access to personal computers and internet connections to learn from medical literature databases and online resources to consolidate curricular learning objectives. The web combines hypertext and hypermedia (e.g. audio and digital video imaging stores large volumes of information and offers user-choice interactive learning environments).

Tele-education, an integral part of tele-medicine, provides useful services such as: 1) a central online platform for the provision of pertinent study material with enhanced graphics (e.g. micrographs, diagrams, videos, etc.); 2) development of both real-time and fragmented interaction between teachers and students as well as peer-peer communication independent of geography, race and culture; and 3) hosting schedule consultations outside classroom hours.

Morphology education (histology, anatomy and embryology) is essential in biomedical curricula in order to fully appreciate concepts in physiology and pathology. The subject is a requirement within international medical education frameworks and usually studied during pre-clinical years in greater detail. Unfortunately, there is very little focus given to the subject afterwards until a minority specializes in post-graduate laboratory research, anatomy instruction or pathology. Learning microscopic anatomy depends crucially on the correct interpretation of images but requires frequent practice. Yet, it is difficult to revise for such subjects due to biological variations of slides in which some structures may be sub-optimally visible or having only a limited time in the laboratory with limited demonstrators.

The core principle of teaching embryology consists of ana-

lyzing developmental stages. Orthodox teaching is based on explanatory and illustrative methods developed on a biological paradigm (Samar et al., 2001). Tele-education has potential in morphology education where complicated abstract ideas can be more easily taught with the use of high resolution visual imaging aids. Recent research and subsequent scientific contributions in embryology, and molecular embryology in particular, have led to significant progress in the scientific basis for development (Carlson, 2002). In addition, the successful emergence of assisted fertilization techniques, manipulation of embryos and manually reconstructing the human genome, have introduced new bioethical issues and the demand to re-evaluate the teaching of embryology (Samar & Avila, 2002; Avila et al., 2005).

Current Educational Concerns of the Nation: Need for Reform

Health Science subjects like Medicine, Dentistry and Veterinary sciences on the South American continent are facing grave problems due to relying solely on teaching and learning in classrooms. Major concerns include a decline in academic performance throughout the course with no protected revision time in later years. Also, there is a high student dropout in preclinical years due to poor access to information to consolidate knowledge gained in the laboratory. Latin America is also suffering the effects of a brain drain and with students seeking higher quality education elsewhere. Regional universities are under pressure to keep updated with contemporary curricular requirements whilst also providing equally high standards in education.

In Argentina the National Assessment and Accreditation (CONEAU, 1999), under the Ministry of Education Regulations, approved the criteria for the national undergraduate medical curricular framework. Within this document, Annex I sets out the basic contents of the materials required within a medical career, and the curriculum is considered uniform to all accredited medical schools. Sections on "Medical Use of Information" and Annex I highlights that higher educational establishments should provide access to computers and information networks for teachers and students by means of acquiring basic educational skills. Computer resources should support the educational programs of the Faculty of Medicine at all appropriate levels.

Based on these recommendations, the Faculty of Medical Sciences at the National University of Cordoba (Argentina) proposed the creation of the first ever continental Virtual Laboratory in collaboration with the United Kingdom, providing e-learning modules for teaching cell biology, histology and human embryology and their biological, social and ethical implications to students in Health Sciences. Through a central online website, we present research projects from the Anatomy and Medical Embryology unit as well as advertising external websites to international institutions. Advertising our projects will allow future leaders to keep updated and to participate in the advancement of medical literature.

Goals & Aims

The National University of Cordoba (Argentina), in an international collaborative effort with the United Kingdom, proposed to create the first ever virtual laboratory in South America using the World Wide Web to enhance the education of morphological sciences. Alongside web pages, both e-mail and discussion boards were also utilized in enhancing the learning process. Since 2000, the institution has conducted a pilot study of remote education surrounding various virtual activities in the fields of cell biology, histology and embryology (Avila et al., 2002, 2009a, 2010; Samar et al., 2004; Avila & Samar, 2008). The proposed virtual program allows users to update their knowledge on biomedical sciences while interactively participating in activities supervised by staff, thus enriching their learning throughout their course.

Albeit, the university still integrates orthodox techniques.

Based on the use of new technology and new-age communication media, the university took on the challenge to produce educational material in the form of electronic multimedia (e.g. online virtual practicals and interactive CD-ROMs since not everyone may have easy access to Internet services). This project has successfully spanned multiple campuses, making up one super electronic portal between the Faculty of Agriculture and Veterinary Medicine of the National University of Rio Cuarto and the Faculty of Medical Sciences at the National University of Cordoba, Argentina. In 2009, intra-continental collaboration with Cuba led to the development of online medical education exchange between experts, educators and students (Iglesias et al., 2009). Much like the reformed program set up by Pinder et al. (2008) in Canada, the unique Latin American network is set to use video-conferencing for real-time interaction across multiple sites, thus maximizing on the expertise of more teachers for the ultimate benefit of more students.

Similarly, the latest English CD-ROM projects include "Junqueira's Basic Histology" (Mescher, 2009) and "Histology: A Text & Atlas" (Ross & Pawlina, 2010). Such software depends on integrating the basic principles of histological structure with function, hence allowing students to reinforce difficult and abstract concepts through visual models. Universal access to information and communication enabled by the Internet and use of ICT has led to the emergence of an innovative program in morphological sciences (Samar & Avila, 1999; Avila & Samar, 2004).

Another aim is to illustrate the experiences of virtual education in our online morphology laboratory. This research will be one of its kind as no other publication to date comments on virtual laboratory teaching on the continent that draws from evidence-based research from international peer-reviewed journals in multiple languages. This is a unique analysis on the first and only virtual morphology laboratory in South America. Similar programs have drastically evolved for over two decades and has been successfully introduced, if not fully converted to, on other continents including Australasia (Kumar et al., 2006), Europe (Boutonnat et al., 2006; Bertheau et al., 2008; Merk et al., 2010), Asia (Raja, 2010), Africa (Pagni et al., 2011) and North America (Blake et al., 2005; Krippendorf & Lough, 2005; Michaels et al., 2005; Bloodgood & Ogilvie 2006; Mikula et al., 2008; Pinder et al., 2008; Braun & Kerns, 2009; Dee, 2009; Husmann, 2009; Weaker & Herbert, 2009; Weinstein et al., 2009; Triola & Holloway, 2011).

The aims of the virtual laboratory are: 1) improving the teaching quality by using multimedia modalities; 2) increasing exposure of embryology during a time of increased relevance, (e.g. stem cells); 3) offering easier access to information and glossary of terms, thus breaking barriers of distance or possession of study material on the biological basis of heredity, and genetic components of evolution and disease; 4) reinforcing

visual learning of complex subjects, given that the website contains colorful animations and microscopy imaging to aid the understanding of organogenesis; and 5) offering an accurate overview of human development at different time intervals.

Literature Review

New technologies of information and communication (ICT) have demonstrated great potential for the development in education to support conventional teaching and learning ideas. With the use of the Internet comes a new teaching paradigm based on a socio-constructivist approach to learning (Mattheos, 2007). Moreover, conventional educational frameworks for a core curriculum related to morphological sciences have their difficulties because it is performed in a given space and time with pre-established services (Avila et al., 2009b). Currently there are new opportunities in distance learning on medical informatics using ICT and the Internet whilst breaking communication barriers between Spanish and English speaking nations (Otero et al., 2010).

Virtual biomedical laboratories have been applied to distance education and Monge-Nájera et al. (1999) define them as simulated and manipulative practices that can be created for students physically away from a university and teachers. These digital labs are reduced to a computer screen with two or three dimensional simulation or strictly speaking, to a more realistic depth of field and binocular vision, which places the user in a virtual reality. Kumar et al., (2004) illustrates how using appropriate software can transform specimen slides onto a web browser in a manner that closely simulates examination of glass slides with a real microscope.

Paulsen et al. (2010) reviews international online virtual laboratories which may either be freely accessible or require an institutional subscription for exclusivity. Silva & Monteiro-Leal (2003) created a digital library for histology and anatomy specimens in Brazil which was the first step to closing the technological gap between less and more economically developed countries. Digital images are frequently added onto an ever-expanding database to increase availability and variations accessed easily over the Internet. Yet, no virtual interactive laboratories or portable media (e.g. CD ROMs) of histology, embryology and anatomy atlases exist in Latin America until now.

Virtual laboratories may consist of differing complexities (Monge-Nájera et al., 1999). The simplest level consists of static texts and drawings, whereas the next level consists of those that use animations using JPEG/Bitmap/GIF formats, compatible with HTML web pages. The consequent level corresponds to the use of videos which demonstrate practical procedures, but the most complex laboratory model displays objects or depicts scenes that can be controlled by users as part of real-time digital interaction to allow user-choice. Additionally, integration of a virtual laboratory with the Internet offers diverse tools of communication such as e-mail, chat forums, courses and hyperlinks to internal and external resources.

Traditional versus Virtual Teaching: Why Do We Have to Pick Sides?

Significance of Virtual Modality

A 2007 survey by the American Association of Anatomists calculated that just over 70 hours on average are reserved for microanatomy teaching, more or less equally divided into didactic lecturing and laboratory work (McBride & Prayson, 2008). Bloodgood & Ogilvie (2006) and Sugand et al. (2010) highlighted the long-term trend of declining total laboratory teaching hours in both US and UK medical schools, with a parallel reduction in hours of faculty time devoted to teaching. To overcome such challenges, computer-aided instruction (e.g. digital atlases, virtual microscopy etc.) has been employed to maintain the quality of education. Optimally annotated and high resolution magnified images can now be accessed in a virtual laboratory at any time, thus reducing time required in the laboratory to learn the same information (since instructors can swiftly direct students to focus on particular structures without the need for individual attention; McBride & Prayson, 2008).

Accounting for biological variation, virtual microscopy can now finally level the playing field as optimal specimens can not only be shared but also better studied online using zoom function. Crucial annotations will allow better understanding of the visual aids and hence a better grasp of morphology, macroscopic anatomy, embryology and then physiology as well as pathology. Physicians will only be able to identify abnormalities if the norm has been well established at the beginning of their medical education.

In an attempt to teach from an inter-disciplinary approach (**Figure 1**), the faculty frequently invites numerous departmental Chairs and Heads of related services (e.g. Gynecology, Obstetrics, Pediatrics, Family Medicine etc.) to provide teaching, exercises and other resources on the website. Some related pertinent topics also discussed include epidemiology of congenital disorders, bioethical implications (**Figure 2**) as well as the role of genetic counseling for couples. With a high patient burden, educators are able to teach in real-time from remote locations via video-conferencing across multiple campuses or "virtual nodes".

Change in Attitudes to Learning

Students were also observed progressing more rapidly through the content and interacting more within the group. Virtual education teaches fostering of communication and teamwork skills which are crucial qualities in medical and veterinary education (Downing, 1995; Cotter, 2001; Dee & Meyerholz, 2007; Braun & Kerns, 2008; Sugand et al., 2010). Maybury and Farah (2009) point out the consequent educational reformation from teacher-directed learning to student-centered learning, thus redefining pedagogy as andragogy in which university pupils make a crucial leap into becoming independent adult learners. In a technology-driven society, multimedia teaching modalities should help to generate interest in students too.

The benefits of a virtual laboratory include the reduction in the need of instructors, lab equipment, especially if institutions convert to virtual study solely (Boutonnat, et al., 2006; Kumar et al., 2006), and having no excuse to accommodate for global curricula reformation (Cotter, 2001; Sugand et al., 2010). Virtual microscopy has also been successfully implemented within summative examinations (Kumar et al., 2006; McBride & Prayson, 2008; Pinder et al., 2008; Triola & Holloway, 2011); similarly, Higazi (2011) found a statistically significant average increase in exam performance by 16% with the introduction of live digital imaging and smart board magnification in classroom teaching. Conveniently, there has not been a predictable decrease in the number of institutions that depend on traditional microscopy teaching but instead wisely blend with instructional

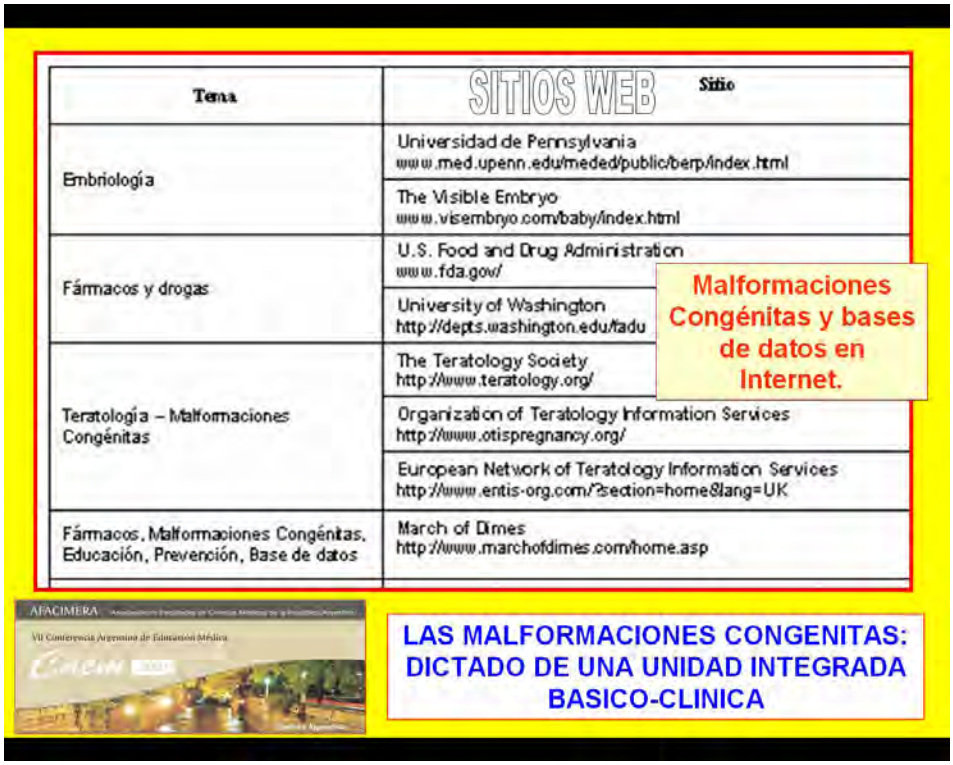

Figure 1.
External learning resources recommended by a multi-disciplinary team of educators for teaching congenital malformations.

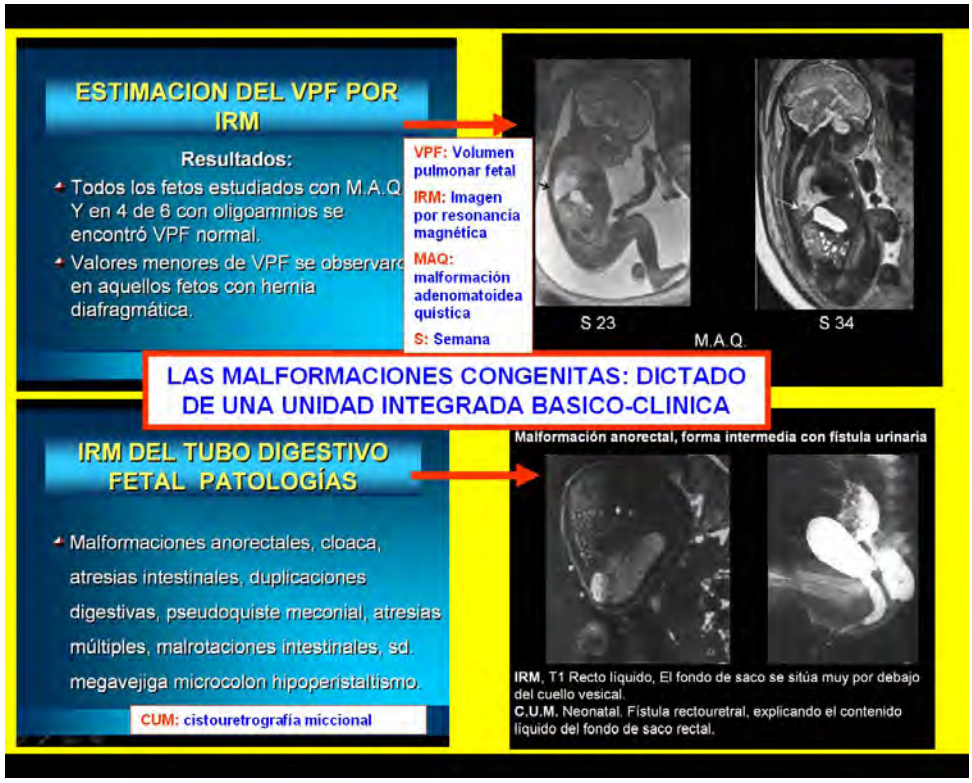

Figure 2.
Bioethical issues were also discussed such as the “anencephaly & interruption of pregnancy” case. Furthermore, multimodal imaging including ultrasound was included.

technologies. A survey by Braun and Kerns in 2008 indicated that 50% of the respondents preferred having both optical and virtual microscopes but the key message is that web-based histology resources have consistently produced high user-satisfaction rates (Boutonnat et al., 2006; Kumar et al., 2006; Patel et al., 2006; Pinder et al., 2008; Merga et al., 2010; Sugand et al., 2010).

Financial Implications

Online education lowers the cost of materials. Scanning and storage of images is straightforward and can be regularly updated to improve the content of the website with a minimum of effort, compared to printing (Juri et al., 1991). The web can instantaneously disseminate knowledge, insights and results of research projects and thus promote international partnerships, debate and advancement of professional practice (Avila et al., 2010). The initial establishment of a virtual laboratory maybe expensive, in the long-term it is of note that little maintenance is required and need for numerous optical or electron microscopes reduced. In fact, it may be more economical to invest into the supply of desktops and laptops for students who can then access the virtual laboratories at any time.

Materials & Methods

The virtual project has now spanned for a decade on a feasible budget for a developing medical school. All content has been produced in Spanish with an aim to translate into English for an international audience in the near future. Free online support is designed for student-users. Digital images of human histological sections were obtained using an image analyzer (Image ProPlus), connected to an Olympus BX50 photomicroscope (for both optical and electron microscopy imaging) and a video camera which were then converted into JPG and GIF extensions and uploaded onto our online library. Furthermore, we compiled multiple databases for histology and histopathology which led to the publication of several virtual atlases in CD-ROM format (Samar et al., 2005a, 2005b) for both classroom teaching while dispersing information easily for continuous personal learning.

To develop the website (http://www.histologiavirtual.fcm.unc.edu.ar/) the following design tools and programming software were utilized to create the *Cordoba Model*:

- *Microsoft Office Share Point Designer*: a program allowing a complete view of a web project. This program creates dynamic web pages through scripting while at the same time allowing global management of the entire project (e.g. hyperlinks, navigation, directories, etc.)
- *HTML* (*HyperText Markup Language*): formatting hypertext documents by means of labels (tags) subsequently leading to browsers (e.g. Netscape Navigator, Firefox or Internet Explorer) and redirecting hyperlinks.
- *Dynamic HTML* (DHTML): the language that permits interactivity with web pages.
- *JavaScript*: a scripting language, interpreted and a derivative of Java that allows web pages to add effects and additional functions to those provided in standard HTML.

The images used belong to the university laboratory research faculty. Images on the website contain either JPG or GIF extension:

- *JPG* format that supports 24 × 8 bits per pixel gray scale images used for photographs.
- *GIF* (Graphics Interchange Format) format that supports up to 256 colors. It is used for titles, logos and graphics with less than 256 colors.
- *Video*: digital video files uploaded on the website are AVI (Audio Video Interleaved) format or consist of continuous video frames (in bitmap formatting) to generate moving images.
- *Support*: e-mail, chat forums and video-conferencing after recording laboratory sessions were used for providing online contact. This free online support acted as a backbone for consolidating knowledge and revision when suitable for students outside laboratory time. The Faculty also promotes external links to other university laboratory sites to empower self-learning and an international perspective. Our online virtual laboratory is freely accessible and is mainly intended for undergraduate and graduate biomedical students, as well as complementing auxiliary careers within Health Sciences.
- *Online library*: the website has frequently been updated with more content and virtual activities (i.e. drawings, images of histology sections and videos) which can all be freely accessed online at the following address: http://www.histologiavirtual.fcm.unc.edu.ar/. The main portal shall soon implement traffic counters to measure the popularity of user-content and analyze those desired characteristics to integrate within all study material.

For students to qualify for certification and accreditation on the course, one ought to download and work through our complimentary virtual practical work-guide, electronically record evaluations of the virtual laboratory services and then finally sit a summative assessment (**Figure 3**) based on the online content. Having taken full advantage of the communication capacity on the web, laboratory staffs are easily contactable via chat forums and e-mail.

The virtual atlases share one home page with links to other pages consisting of theory and clinical significance, clip art and literature references. The atlases (**Figures 4** and **5**) were awarded "mention for best national production' in the fourth International Film Festival for Physicians & Scientists in 2003 and again in 2005 (organized by the Medical Council of the Province of Cordoba and World Association of Medical & Health Films) and our online resource was honored with a special mention in e-learning and education category at the World Summit Award (World Summit Online, 2005) and by the International Telecommunication Union which is a United Nations specialized agency. Both resources still play a pivotal role in teaching students today all over the continent as both virtual microscopic imaging and online guidelines are supplied for free. Worksheets have been created for different levels of difficulty in order to promote continuity in education (**Figures 6** and **7**).

The main online histology portal hosts another two hyperlinks: ODONTOWEB and PIMEG. Each site covers various pertinent topics in anatomical sciences and practicals correspond to separate screens with multiple thumbnail images and assessments. Each image has a brief text that identifies structures as well as the original color and degree of staining all under optical and electron microscopes in the following topics: 1) Introduction to Tissues, 2) Co-ordination systems, 3) Transport & Defense, 4) Alimentary canal, 5) Respiratory and 6) Urinary system which are all found on ODONTOWEB (**Figure 8**).

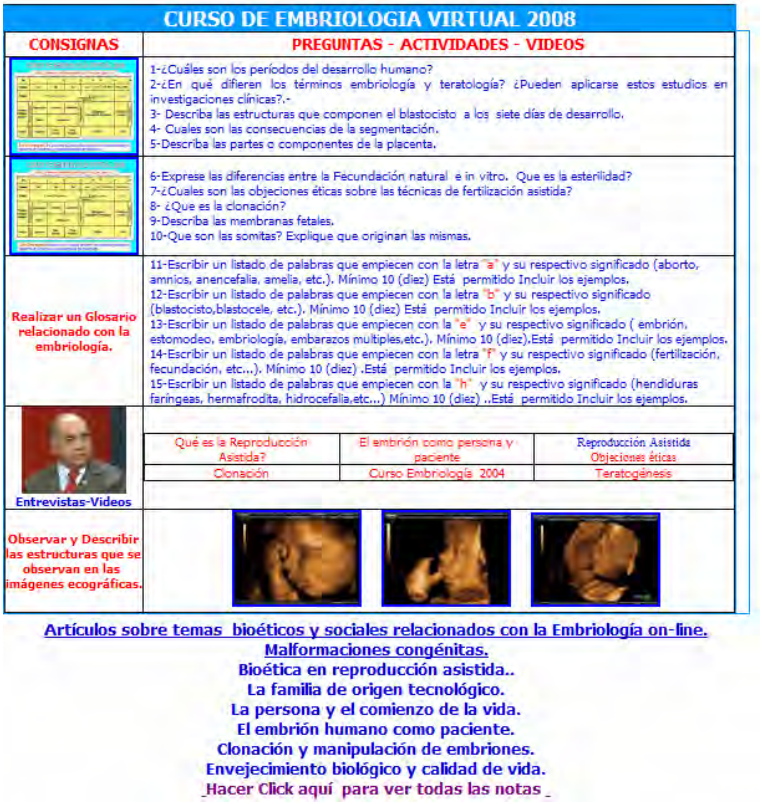

Figure 3.
Formative interactive assessments with both digital photographs and videos allow students to drive independently their own revision and reinforcement of learning objectives. As students learn at their own pace, quizzes and self-assessments can be carried out at their leisure outside laboratory time.

Figure 4.
Selected images on the contents of the Atlas Virtual de Histología CD-ROM (Samar et al., 2005b).

Figure 5.
Selected images on contents of the Atlas Virtual de Anatomia, Embriologia e Histologia Oral CD-ROM (Samar et al., 2005a).

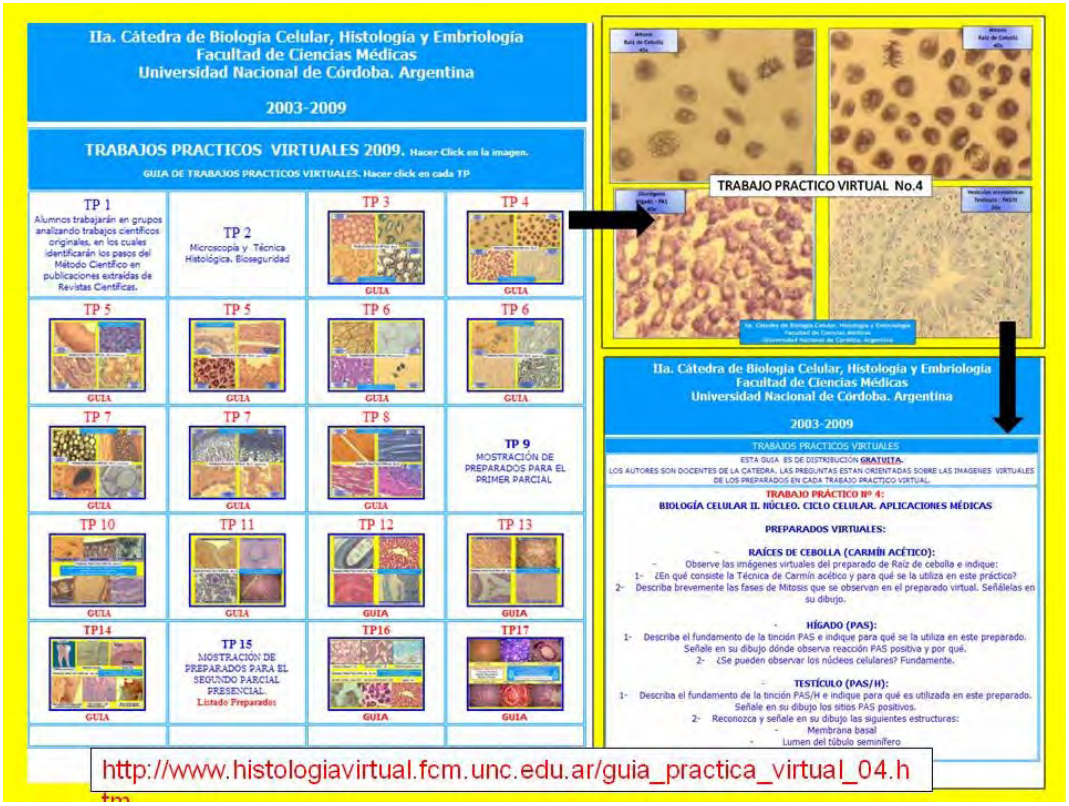

Figure 6.
URL: http://www.histologiavirtual.fcm.unc.edu.ar/guia_practica_virtual_04.htm. Screen image showing the pictures in thumbnail featured next to questions within the virtual practical workbook.

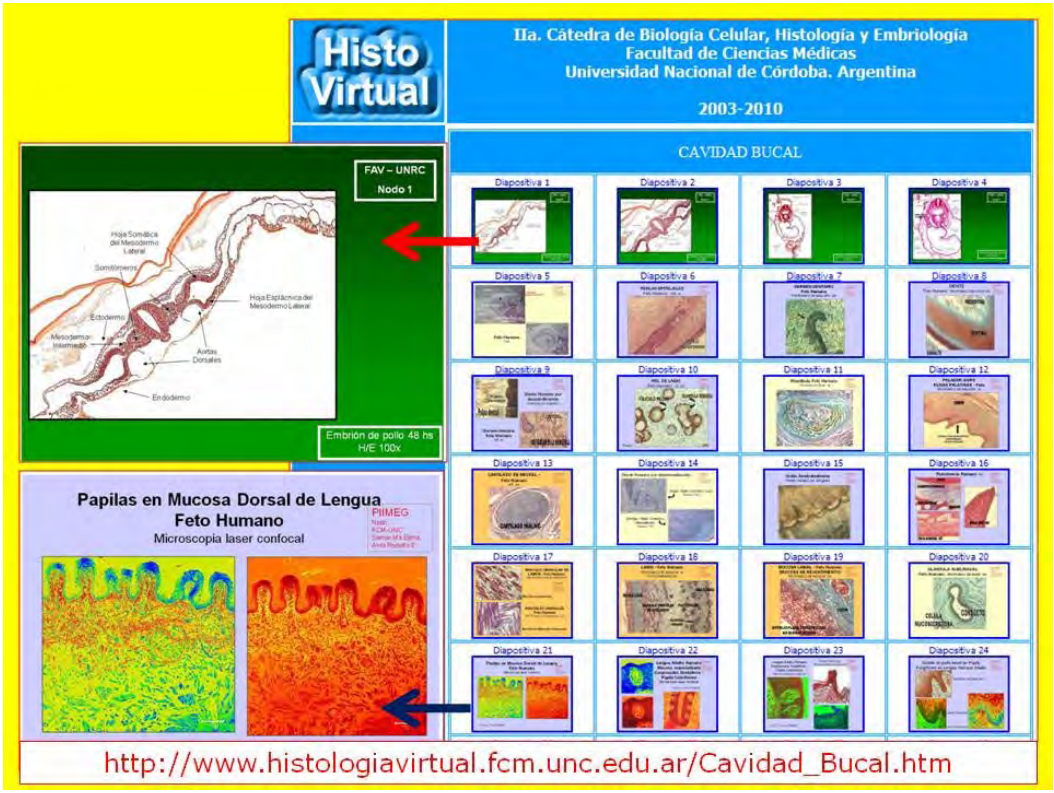

Figure 7.
Online virtual imaging showing a selection of 24 pictures as thumbnails featured in the virtual practical work guide on oral cavity. Clicking on them will take the user to another screen with the image magnified, thoroughly annotated and opportunities to test oneself with questions.

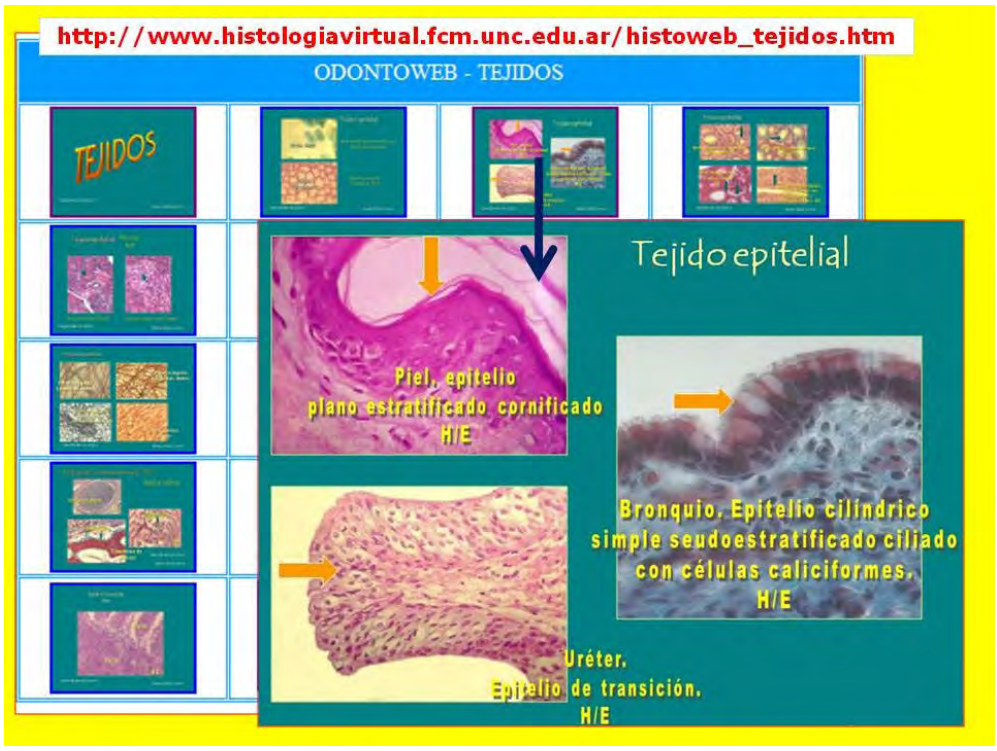

Figure 8.
A screen with thumbnail images of epithelial tissue in their natural and stained states with clear labeling of structures.

Piimeg

(http://www.histologiavirtual.fcm.unc.edu.ar/PIIMEG_2009_2010_01.htm) aims to improve research and education in oral sciences. Virtual practicals consist of displaying images of oral cavities belonging to different species along with questions (**Figure 7**). User-friendly interaction also fosters interests and encourages users to explore the content for themselves to take responsibility ultimately for their own learning potential.

Finally, it is up to the user-students to ultimately judge the virtual programs and offer feedback on its necessity. They evaluated the incorporation of new methodologies to support usual teaching practices. Students were recruited anonymously throughout the academic year of 2010 and out of 291 in the School of Medical Sciences in the National University of Córdoba, 267 participated in the questionnaire survey to comment on various aspects of the usefulness of the web resources offered.

Results

Using the online resources as the primary learning tool was unanimously favored as seen in **Table 1**. Learning was supplemented with practical guides available on the website, own notes and textbooks. The faculty will be conducting further extensive surveys and end of year evaluations to observe whether students who participate in virtual exercises perform better in standardized exams in lieu of using printed practical work-guides. To date the majority of students have welcomed the online educational services. They perform better in exams since the interactive online portal not only teaches new topics but importantly allows users to revisit the interactive virtual tutorials, practicals and workshops to reconsolidate knowledge throughout studies.

Student-users particularly appreciated the ease of access to hundreds of slides online which also highlighted all the learning objectives in each virtual slide. There was no longer a need to carry heavy atlases, revise from dense texts and have no point of reference to the printed practical work-guides on offer. All pertinent information was finally collated onto one accessible interactive online source which would continuously expand and improve to accommodate for varying levels of studying morphological sciences.

Discussion

Harris et al. (2001), Heidger et al. (2002) and Dee et al. (2003) discovered that utilizing virtual images in teaching maintains educational benefits similarly inherent in using a real microscope and allow students to understand better the complex abstract concepts of morphology. After studying labeled diagrams online, students are tested with virtual micrographs and are tested on micro-structures, whilst being given an unlimited number of opportunities to test themselves and monitor personal progress. Advantages mentioned consist of an unlimited number of users, independent from time and place, who can examine specimens with superimposed references and explanations to an ever-expanding digital archive. Online tests with virtual slides integrated into case studies can offer good examples of early physiology as well as immediate feedback to the student on progress.

Table 1.
5-point questionnaire.

	YES	NO	Total
Students willing to participate in survey	267 (92%)	24 (8%)	100%
Used the main website as a primary learning resource	245 (92%)	22 (8%)	100%
Relied on the following as a secondary learning tool:			
a) online practical work guide	91 (37%)		
b) classroom notes, textbooks, other sources of images & videos	89 (36%)		100%
c) printed practical work guide	65 (27%)		

Those investigating the use of computers in education are well aware of its potential as a tool to enhance the learning process. Personal computers and others mechanisms such as integrated technical environments offer enormous potential to enrich various educational situations (Maiztegui et al., 2002). Blake et al. (2003) mentioned that histological images rendered on a CD-ROM allow students to view the pictures at anytime and anywhere with the use of portable laptops in which the benefits were originally emphasized by Ogilvie (1995). Hence, both students and teachers showed a strong support for the use of CD-ROMs and online libraries for teaching morphology. The Web provides students a greater degree of active learning experiences, whilst facilitating student participation in projects that promote collaborative investigating, solving research problems and developing strategies to provide them with better preparation and understanding for their future professional careers.

The aim is not to replace didactic classroom teaching but to enhance, interact and consolidate key educational messages with the option of revising outside sessions as the user sees fit. Cotter (2001) and Michaels et al. (2005) also encouraged use of light microscopy in conjunction with web-based resources with high-quality imaging, therefore, retaining many useful traditional and contemporary aspects of a fundamental biomedical subject. In developing nations virtual education is advantageous, as high-quality electronic microscopes are expensive and not available at all times for students to use. A virtual laboratory is a feasible framework to provide high standard education at any place and time with little restrictions on students and faculties (Goldberg & Dintzis, 2007).

Our online program has relied on different types of virtual laboratories that have been adapted to the core learning objectives of cell biology, histology and embryology as well as permitting self-evaluation by student users. As our students are the most frequent users of the virtual labs, it is vital to empower them to provide constructive feedback in order consistently to improve the software for future generations of users. Students who wish to perform well in the course are expected to achieve the following aims:

1) Regularly access virtual classrooms for Q & A sessions with laboratory demonstrators;

2) Read and study materials recommended by lecturers;

3) Participate in online forums with instructors and class fellows to discuss the content;

4) Comply with the work set by teachers;

5) Send at least six feedback forms to evaluate the course, content and teachers;

6) Estimated commitment time required is at least 8 to 10

hours per week for students to optimize the learning potential from the virtual online resources.

The survey responses demonstrated the overwhelming interest that students had using our virtual laboratories as a principal tool for learning morphology. Mills et al. (2007) suggested that a virtual microscope is a flexible and enjoyable resource that could be useful to enhance the learning of microscopic structures. Also, Husmann et al. (2009) found that increased accessibility, ease of use, and the ability to understand the material were important components of the virtual microscope for students in their survey. An increase in collaboration was noted because students were able to discuss specific learning objectives after viewing an image simultaneously. Moreover, learning through a virtual lab allows for continuing education and integration with clinical sciences as proposed by Kumar et al. (2006).

Long gone are the days where students spend a substantial amount of their pre-clinical years in laboratories studying 35 mm slides using light microscopy. Novices will mostly not know exactly what to look at (Patel et al., 2006) and how to relate the function of histology to physiology. Disadvantages are predominantly financial. There are also purists who may feel that virtual microscopy may very well eventually, if not inevitably, be the death of an art but this has been contested (Patel et al., 2006).

Education is selfless because it should be shared as a gift rather than kept secretive. It is certainly a grave responsibility of scientists, regardless of field specialization, to contribute to the expansion of scientific literature. However, since dissemination of information is mostly dependent on technology, many less economically developed nations have more difficulty to access evidence-based data which ultimately then leads to a reduced rate in improving scientific infrastructure. Our online laboratory does not only add to the virtual interactive experience for our students but will also have the potential to teach international audiences as well as improve the quality of education delivered in local institutions. The online program is a great leap forward for our nation to interact and collaborate with international establishments, much like what has been accomplished by working together with Cuba and the UK on this instance.

With a high patient to physician ratio in most South American countries, especially in rural settings, more importance ought to be given to training our doctors to deliver holistic and evidence-based medicine, that is to say optimal management to each individual patient with differing bio-psycho-social needs. The laboratory will create a ground-breaking platform which will contribute to revolutionizing biomedical education, research and training. Our website will soon feature social issues related to reproductive health and post-partum care, integration of family planning services and the prevention and treatment of sexually transmitted infections intended for public access and political reform.

Conclusion

We conclude that the use of virtual laboratories to further support conventional morphology education was positively received and that using multimodal multimedia is more effective than simply using traditional methods. Students prefer a balanced mixture of both traditional and technological input into their education. Most importantly, a feasible step-by-step model has been constructed to guide other laboratories in developing nations into entering the twenty-first century with the use of multimedia multimodal teaching.

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