

A blended approach to supporting student learning in clinical microbiology laboratory classes

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KEYWORDS

Clinical microbiology,
video display, microscopic
images, macroscopic
images

Abstract Traditional approaches to teaching clinical diagnostic microbiology utilise a gradual but repetitive regime of exposing students to working with and identifying various bacteria growing on artificial culture media. It was anticipated that the addition of a two camera video display system, utilising two 65 inch plasma televisions, into the microbiology laboratory would successfully enable a greater number of organism to be covered in a shorter period of teaching time. One of the main objectives of the system was to improve the ability of the students (n=52) to differentiate between potential pathogenic and non-pathogenic bacteria based upon the colony morphologies of the organisms on various culture media. 94% of the students agreed that their ability to recognize potential pathogens growing on agar media was improved by using the system. 100% of students agreed that the video projection system was a positive addition to the microbiology laboratory and 100% agreed that using the system during practical classes enhanced their learning of the material in the course. 90% feel that a similar system would be useful in other microbiology units they have studied. The system successfully enabled a content rich syllabus to be taught in limited period of time.

Background

Medical scientists are the health professionals who work in diagnostic pathology laboratories performing diagnostic assays on all types of human biological samples. They provide test results and their interpretation to medical practitioners. The Laboratory Medicine course offered at Curtin University is one of 11 undergraduate degrees available in Australia and New Zealand that is accredited by the Australian Institute of Medical Scientists (<http://www.aims.gov.au/>).

One of the primary disciplines that students study in preparation for a career in diagnostic pathology is clinical microbiology (the study of microbial disease, the laboratory diagnosis of infection and treatment). The etiological agents of infection can be subdivided into four key areas; bacteriology, parasitology, virology and mycology. While students are introduced to all of these topics at Curtin the major emphasis at the undergraduate level is in the area of bacteriology. One of the most challenging aspects of

bacteriology, in the context of the laboratory diagnosis of infection, is acquiring the ability to recognise and differentiate the growth characteristics of potentially pathogenic bacteria from that of the non-pathogenic normal flora, from any given body site. This is made more complex by the fact that some members of the normal microbial flora, both from inside and outside of the body, can themselves, be pathogens when they acquire entry to sterile sites or are transferred to a body site that they normally don't inhabit. Add to this that a range of different agar culture media is used to ensure the recovery of various types of organisms from various body sites, then the process of bacterial recognition and differentiation is made more complex for the student because the growth characteristics of various bacteria can differ considerably from one type of agar to another. So not only do students have to differentiate pathogens from non-pathogens, based upon growth characteristics and taking into account the bodily site of collection, but they also have to develop the ability to do this across various culture media. The traditional approach that has been used to accomplish this training during the second year of the course is to initially provide *pure* cultures of known pathogens and non-pathogens growing on various culture media to individual students and get them to record a comprehensive set of growth characteristics and colony features. Over the course of 10 practical classes during a semester (one practical per week), the students could expect to encounter about 20 different organisms in this manner (i.e. two different organisms per week) with another 10-15 organisms provided as demonstration items. In the subsequent semester students would begin to process and examine cultures of these same organisms *mixed* together on various culture media according to specimen and body sites. The students would get to process and see most of these organisms for a second time during this semester. The areas of parasitology, virology and mycology were also introduced during this period. At the completion of second year those students wishing to major in clinical microbiology would then proceed to study for a further two semesters before the completion of their degree. For those not choosing microbiology as a subject major, this would be the end of their microbiology training.

In contrast to the traditional approach outlined above, recent changes to the structure and composition of the undergraduate degree have meant that second year students now only receive a very basic introduction to clinical bacteriology where they get to process and identify only five different pathogens. Those that choose to major in clinical microbiology at the end of second year, now only undertake one semester of intensive clinical microbiology training, in the first semester of third year, before commencing two semesters of laboratory-based work placement, including a six week placement in a microbiology laboratory. The present challenge is to cover as much of the traditional and essential bacteriology, together with the basic elements of parasitology and mycology condensed into a single semester, so that the students are adequately prepared to embark on their microbiology field placement.

The primary use of a blended learning approach in the current context of clinical microbiology education was to enhance student learning with respect to their ability to recognise colony morphologies of both pathogens and non-pathogens growing on

artificial culture media. These skills and competencies are normally acquired by repetition over a substantial time period, owing to the complexity of studying a large variety of micro-organisms, each of which may require a different set of skills (Sancho et al., 2006). Blended learning is particularly suited to this aspect of clinical microbiology education since the provision of online resources combined with the traditional face to face delivery is a strategy that reduces in class time in the face to face environment (Lorenzetti, 2011). Some of the repetition required to develop skills can be provided through the availability of online resources and/or exercises that can be accessed by the participants according to individual need, whenever required.

In practice, while it is relatively easy to provide uniform cultures of individual bacteria to every student in a clinical microbiology course, it is very difficult to provide consistently similar mixed cultures across a class or classes. Even though mixed culture plates are normally prepared from a single broth culture containing two or three bacteria, there are always a number of the replicate cultures where one organism outgrows the other or due to the ratio of the numbers of one organism to another, one or both of the colonies do not grow to their normal size. One of the recognised benefits of blended learning is the uniform delivery of the information to each student (HRWorkbench, 2011). The ability to display culture results to a whole group of students simultaneously was seen as a way to alleviate the problem of culture variation as well as promote group discussion about the reasons why culture variation occurs, even though all agar plates are inoculated from the same stock culture.

While the presumptive identification of some bacteria can be made based on their culture morphology, the presumptive identification of many others will require the correlation of their culture characteristics with their microscopic features. Therefore, an additional perceived benefit of introducing blended learning to the microbiology classroom was the ability to use the technologies to display and record microscopic images of the micro-organisms analysed during the laboratory sessions. While various authors have published articles concerning the use of virtual microscopy in the fields of pathology and histology (Grossman & Grossman, 2008; Maybury & Farah, 2010; Merk, Knuechel, & Perez-Bouza, 2010; Paulsen, Eichorn, & Brauer, 2010; Schmidt et al., 2011), to date no literature could be found describing the use of such technology with a focus on teaching the recognition of bacterial colony morphologies and their associated microscopic findings. In fact, the only reference to blended learning in clinical microbiology education that this author could identify was the successful application of virtual laboratory exercises to achieve learning outcomes in two microbiology units from a pharmacy course in Spain (Sancho et al., 2006).

While the identification of micro-organisms did form one of the six virtual laboratory modules conducted at the University of Salamanca, there is no indication about how many of these micro-organisms were bacteria and there is no indication what role if any, colony morphology played in the identification process (Sancho et al., 2006). It can be

deduced that at least some of the micro-organisms in the course must have been bacteria because the students were required to interpret Gram staining results (a bacteria specific staining process) from microscopic images (Sancho et al., 2006). There is no mention of whether the students were required to interpret culture characteristics of the bacteria included in the course. However, this seems most unlikely given that none of the students performed any hands-on laboratory work as part of the identification module they engaged in. Therefore, an assessment of the likely beneficial role of blended learning in the identification and recognition of bacterial growth characteristics on common culture media remains unreported.

Photographic image collections of bacteria growing in culture do exist on the internet (e.g., <http://www.microbiologyinpictures.com/index.html> and <http://www.asm.org/Division/c/library.htm>), however these are limited in their detail and scope. The extent of the images available is limited to certain common bacteria and these are often only presented on limited types of culture media, like blood agar (e. g., <http://www.microbelibrary.org/component/resource/laboratory-test/2881-blood-agar-plates-and-hemolysis-streptococcus-and-other-catalase-negative-gram-positive-cocci>). In the current course of study, the students are expected to gain an understanding of what the various organisms look like on a variety of culture media including, but not limited to, blood agar (BA), BA with colistin/nalidixic acid (CNA), Mueller Hinton agar (MH), MacConkey agar (MAC) and chocolate agar (CHOC). Therefore, a course specific photographic collection was deemed essential and is one of the recognised benefits of blended learning (HRWorkbench, 2011).

A further limitation of photographic images, irrespective of their source, is their static nature. Unlike the examination of real culture plates where the viewer is able to tilt the plates in the ambient light, they do not allow the view of the three dimensional nature of the colonies. One of the intended benefits of our blended learning approach was to capture video footage of the plates being manipulated to reflect light from the surface of each culture, thus providing far more detail about the nature of the colony morphology compared with static images found in text books or on the internet. While video footage demonstrating particular bacterial colony morphologies may well exist on the internet, none could be found as individual files. Some such footage may exist as embedded material within more extensive microbiological education presentations.

With as many as 35 different bacterial organisms being presented either individually on different types of agar, or in combinations of two or three bacteria mixed together at a time on different agars, the complexity and the amount of detail that the ab-initio student has to grasp within a limited time frame is overwhelming, but essential. Within the limited time frame available, it is not possible for every student to obtain 'hands-on' experience with every organism. Therefore, the ability to simultaneously display and discuss colonial morphologies with an entire class during practical sessions will not only ensure uniform delivery of the information but will ensure that every student has

exposure to all of the organisms. In addition, the ability to capture the images and create an online reference library will allow the students the flexibility to 'practice' and review the material whenever required or desired. A further advantage of the latter is that the visual library created will be specific to the strains of bacteria and the working environment/conditions under which the students actually process them.

The over-arching aim of the current study was to incorporate appropriate audio visual technology into the clinical microbiology laboratory that would positively influence and assist in facilitating the learning of a content rich curriculum in a condensed period of time. The specific aims were: 1) to improve the ability of students to identify pathogenic bacteria from non-pathogenic bacteria, based upon colony morphology; 2) to determine if the laboratory video projection system positively enhanced student learning during the course, 3) to determine whether online resources prepared from recorded material from the laboratory sessions were a useful means of assisting with learning and preparing for the practical exam, and 4) to investigate student attitudes towards the use of traditional hands-on materials and virtual images.

The technology was implemented in time for the first cohort of students to undertake this new microbiology unit within the newly structured course during semester one of 2011.

Approach

Participants and unit structure

All of the laboratory medicine students enrolled in Medical Microbiology 331 (MM331) at Curtin University in the School of Biomedical Sciences during semester one of 2011 participated in the study (52 undergraduate students). Prior to commencing this microbiology unit, the students had to have achieved a pass in the prerequisite unit, Medical Microbiology 235, which they undertook during the first semester of 2010 (completed nine months previously).

The prerequisite unit of study only provides an introduction to the laboratory skills utilised in diagnostic clinical microbiology. As such, the timetable for the delivery of MM331 content was structured to accommodate an intensive lecture program during the first four weeks of semester. The first introductory laboratory class was not scheduled to commence until week two of semester, with the first detailed hands-on exercise scheduled for week three. This facilitated the presentation of three one hour lectures prior to the commencement of the first introductory practical exercise, the delivery of a total of six lectures prior to the commencement of the second practical and a total of nine lectures before practical three.

The lecture topics were arranged so as to provide essential background knowledge to the students before they encountered corresponding material in the practical classes. The topics presented during the first nine lectures in order of delivery included: an

introduction to antibacterial agents, fermentative Gram negative bacilli including extended spectrum beta lactamases, urinary tract infection and specimen processing, the processing of wound and pus swabs, catalase positive Gram positive cocci, catalase negative Gram positive cocci (two lectures), non-fermentative Gram negative bacilli and 'other Gram negative bacilli'. As far as possible, the lectures contained information about the growth characteristics and diagnostic features of all of the organisms discussed therein, including representative photographic images obtained from a variety of external sources (NB: images from this study were not yet available for inclusion in the lectures). The practice of introducing laboratory techniques and organism features during the lectures before the corresponding content was introduced in laboratory exercises was continued throughout the semester.

The total amount of time allocated for practical classes in MM331 during the semester was 30 contact hours or three hours per week for 10 weeks. In previous microbiology units that utilised this time allocation, the three hours of laboratory time was normally split over two consecutive days so that sub-cultures and diagnostic tests could be set up during the first session, incubated overnight and inspected the following day during the subsequent session. However, this format only allows the students to be provided with pre-prepared cultures on agar plates and does not allow sufficient time for the students to culture and perform identifying tests on bacteria contained within simulated clinical specimens. The latter requires laboratory sessions to be conducted over three consecutive days with two incubation periods (nights) in between. For this reason, the 30 hours of allocated practical time for this semester was divided into seven weekly exercises of four hours plus and an introductory exercise of two hours. The two hour introductory session was divided into two one hour sessions held over two consecutive days in week two of semester. The four hours of laboratory time per week was subdivided into a 1.5 hour, 2 hour and 0.5 hour sessions conducted over three consecutive days in weeks 3, 4, 6, 7, 8, 10 and 11. There was no practical scheduled in week five so that the lecture program would remain ahead of the practical program. Week nine was a designated student free week.

Technology

Two 65" high definition Panasonic Viera plasma television sets (model TH-P65S20A, Panasonic, Japan) were connected via two HDMI leads to the two output connections of a 4 x 2 HDMI Matrix Switcher (Model HDMX 0402 from www.ezyhd-cables.com.au/ - which permits 4 different input signals and 2 output signals). Using the matrix switcher, one input signal can be sent to both televisions simultaneously or two separate input signals can each be displayed individually (one per television). The televisions were placed on the side bench of the PC2 microbiology laboratory class approximately 10 metres apart. One of the cables was 15m long and the other was 1m long (both Monster Cable M1000 series - >14.96Gbps, USA). Two Canon Legria HFS21 high definition video cameras (Canon, Japan) were connected to two of the four input channels of the matrix switcher using two mini HDMI to HDMI cables. The video camera output was

of the mini HDMI plug type. One of the video cameras was mounted on a small photographic tripod and was positioned on the side bench of the laboratory so that objects of interest could be positioned underneath the lens (an objective lens distance of approximately 30 cm). The second video camera was mounted to the top of an Olympus BX41 microscope (Olympus, Japan) using a Canon specific MM99 adaptor tube (Martin Microscope Company S/N: 5026, USA). The microscope was fitted with phase contrast rings and the following objective lenses: x10, x20, x40, x100 (non-phase) and x10, x40 phase contrast. The HDMI matrix switcher not only permitted the easy selection of either camera's output as the input source for display on the televisions but also served to amplify and maintain the signal along the 15m length of HDMI cable to one of the plasma screens (a maximum of 25m was possible with the model purchased). The Canon digital video cameras were used to capture both still images (up to 3264 x 2456 pixels) and video footage (1920 x 1080 pixels) on a week by week basis during the practical classes as the semester progressed. Image and video data was directly recorded onto two Sandisk Extreme 32GB SDHC cards (one per camera). These were used to transfer material from the video cameras to a PC for manipulation and long term storage.

Still images (both macroscopic and microscopic) were edited using Microsoft Office Picture Manager on a PC running Microsoft Windows 7. Editing was limited to resizing, contrast, brightness and picture orientation. The images were then incorporated into a series of Microsoft PowerPoint presentations with annotated features and explanatory detail. These presentations were placed onto the unit web site within the Blackboard Learning Management System (version 8.0.494.5, release 8 service pack 7) as they were completed. Video footage was edited using Camtasia Studio 6 (TechSmith, USA). Owing to both limitations in the PC processing power available at the time of project and the time available to edit and process video footage during the concurrent teaching period in which it was obtained, the video footage was stored for future use and did not form part of this project.

Educational procedures with the technology

During the practical classes and on a daily basis, both microscopic and macroscopic footage was displayed in real time to the students as a means of standardising disseminated information. The macroscopic camera was initially used to display bacterial colony morphologies on various culture media. However, it became clear that the ability to display printed charts, tables and documents as well as being able to demonstrate certain laboratory skills was an additional and unforeseen benefit of this system. In the case of the former, the camera was used like a document viewer/projector. In the case of the latter, new laboratory techniques are normally explained with students crowding around a single bench location in the laboratory or they may only be explained in theory using diagrams on the whiteboard. Therefore, the principal benefit of using the camera system to demonstrate laboratory techniques was the unobstructed, close-up view of the procedures being carried out. Examples include the demonstration of the catalase test, the oxidase test, the spot indole test, inoculation techniques, Phadebact *Streptococcus*

grouping, latex agglutination for *Staphylococcus aureus*, bile solubility, interpretation of antimicrobial disc susceptibility testing (CDS and CLSI methods), interpretation of commercial biochemical test strips (API20E, Microgen GN-ID system), interpretation of urine colony counts (calibrated loop and filter foot), rapid tributyrin test, rapid PYR (L-pyroglutamic acid β -naphthylamide) and the rapid disc Cephinase test.

Initially, the camera attached to the microscope was used to provide assistance to the students in interpreting Gram stain results. This was especially useful when the students were first introduced to clinical smears containing very small or plump/short Gram negative bacilli such as organisms from the genus *Haemophilus*, *Bacteroides*, *Acinetobacter* and *Klebsiella*. Questions about the 'apparent' ambiguous appearance of these bacteria and the other microscopic elements often found in Gram smears were dealt with by displaying the microscopic appearance of the organisms/object of interest and halting class activities for 1-2 minutes to provide instruction, explanation and guidance. This reduced the need for students to raise their hands and wait for demonstrator assistance (2 demonstrators per 40 students) before being able to progress with the rest of the prescribed practical activities. As a result, this generally improved the efficiency of the laboratory sessions for the students whilst improving staff availability to assist/answer other questions.

Later in the semester, the ability to display microscopic findings was of particular benefit when the students were introduced to the areas of parasitology and mycology. The diagnosis and identification of many infections in these two disciplines are primarily based on the microscopic morphology and features of the causative organisms. The features of a select number of fungi were displayed and discussed as a group before the students embarked on preparing and analysing various cultures of fungal growth individually. In the case of parasitology, there are limitations on the availability of fixed clinical samples containing known parasites, especially the more exotic organisms not endemic to Australia. The camera system permitted all of the students to see real examples of the diagnostic forms of some parasites where only a single stool sample of limited volume containing an organism was available. It was also beneficial to be able to display and discuss the morphology of faecal elements that often resemble parasitic ova but are artefacts.

Microscopic analysis of urine specimens using phase contrast microscopy was also taught using the video display system. The ability to identify, differentiate and enumerate white blood cells, red blood cells, squamous cells, crystals, bacteria and amorphous deposits was achieved using the technology.

Evaluation tools

To determine the effectiveness of the blended learning approach to laboratory learning, the students voluntarily and anonymously completed a pen and paper questionnaire about their perceptions of the audio visual system. The questionnaire was administered

prior to their laboratory practical exam at the end of the semester. The instrument was based on previously published statements (Farah et al. 2010; Maybury & Farah, 2010; Sancho et al. 2006) with adaptations and additional questions related to the specific application of the technology (Table 1). There were 22 questions where the students were invited to provide responses using a 6 point Likert response scale (SA = Strongly Agree, A = Agree, U = undecided, D = Disagree, SD = Strongly Disagree, N/A = Not Applicable). For reasons of clarity, the six point rating scale was merged into a four point rating scale by combining the responses for 'Strongly Agree' with 'Agree' and the responses for 'Strongly Disagree' with 'Disagree' (Table 1). There were two qualitative questions at the end of the survey as follows:

1. I enjoyed learning with the video projection system because....
2. Do you have any other comments you would like to make about the video projection system?

As an indirect measure of the perceived popularity/usefulness of the online image resources (those recorded in the laboratory and placed on the unit Blackboard site), the content usage statistics for the number of 'hits' made to the file containing images of Gram negative organisms during the semester up to and including the date of the practical exam was analysed. This file was available and accessible for most of the semester whereas, the other image files were only compiled closer to the end of the study period. Since all of these files could be downloaded onto private computers for future use, a single hit by an individual student could be just as significant as multiple hits by one individual. The usage statistics for the Gram negative file were categorised as follows: the number of students who made five or more hits, the number of students who made between two and four hits, the number of students who made only one hit and the number of students who did not access the file at any time.

The study and questionnaire was approved by the Human Research Ethics Committee at Curtin University.

Findings

One hundred per cent of the 52 students enrolled in the Medical Microbiology 331 unit during 2011 completed the survey. The responses obtained have been summarised in Table 1. There was overwhelming agreement with most of the statements concerning the benefits and quality of the images obtained using the video system. Four of the 22 questions received responses with 100% agreement (Q1, 2, 4, 20) and 11 questions received responses with between 88 and 98% agreement. These results indicate the video projection system was a very positive addition to the microbiology laboratory (100% agreement) and that the overall quality and resolution of the images was sufficient for the learning of the material (100% agreement). The system positively enhanced the learning of the material in the course (100% agreement) and there was a high level of student satisfaction with the approach used.

Colonial morphology

There were three questions that specifically dealt with the recognition of colonial morphologies on agar culture media (Table 1, Q8-10). The importance of colonial morphology as a means of fast tracking the identification of an unknown pathogen was affirmed with 88% of respondents agreeing that the ability to recognise particular colony morphologies reduced the time taken to determine an identity. Only 6% disagreed with an equal number being undecided. When asked if the images improved their ability to recognise potential pathogenic bacteria, 94% agreed with the remaining 6% undecided. In contrast, when asked if the images improved their ability to differentiate pathogenic bacteria from normal flora, only 79% agreed, 19% were undecided and 2% disagreed.

Table 1: Questionnaire addressing the student's perceptions about the laboratory audio visual system

Item	Agree %	Undecided %	Disagree %	N/A%
1. I feel that using the video projection system in the practical classes positively enhanced my learning of the material in this course?	100	0	0	0
2. Overall, I found the quality of the images and video materials to be sufficient for the learning of the material?	100	0	0	0
3. The resolution of the microscopic images was sufficient for the learning of the material?	98	2	0	0
4. The resolution of the macroscopic images (agar plates, colony morphologies, demonstration items etc.) was sufficient for the learning of the material?	100	0	0	0
5. I feel that the video projection system will positively affect my grade for this course?	96	4	0	0
6. It was <i>often</i> necessary to use both the projected/virtual images together with actual hands-on laboratory materials during the semester to understand the material?	88	10	2	0
7. I preferred looking at the actual hands-on laboratory materials to the projected/virtual images?	54	23	23	0
8. The ability to recognise particular colony morphologies reduces the time taken to determine the final identification of an unknown organism growing in culture?	88	6	6	0
9. I feel that the images of colony morphologies improved my ability to recognise potential pathogenic bacteria growing on agar media?	94	6	0	0
10. I feel that the images of colony morphologies improved my ability to differentiate between potential pathogenic bacteria and normal flora growing on agar media?	79	19	2	0

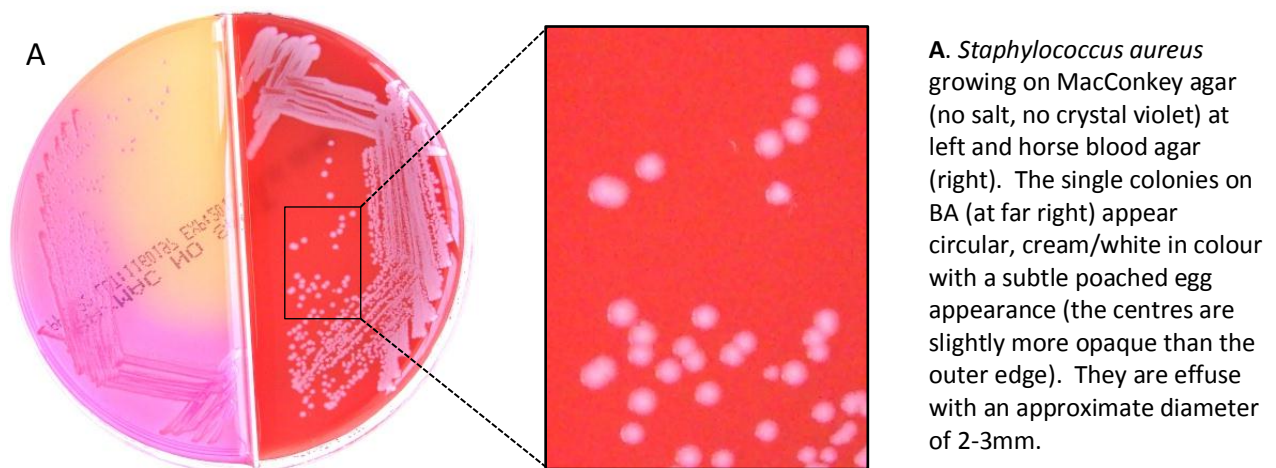
Item	Agree %	Undecided %	Disagree %	N/A%
11. The ability to share results and observations with the whole class using the video projection system enhanced my learning of the material in this course?	90	2	2	6
12. The ability to share results and observations with the whole class in practical sessions, allowed for greater collaboration with other students?	77	19	0	4
13. The <i>microscopic</i> images were more useful than the <i>macroscopic</i> images of agar plates, colony morphologies, demonstration items etc.?	37	38	25	0
14. The <i>macroscopic</i> images of agar plates, colony morphologies, demonstration items etc. were more useful compared with the <i>microscopic</i> images?	54	29	17	0
15. The online resources in Blackboard positively enhanced my learning of the material in this course?	98	0	0	2
16. It was relatively simple to use Blackboard to interface with the resources derived from the video projection system?	90	6	2	2
17. Using the materials from the video projection system OUTSIDE scheduled laboratory class time helped me to understand the material?	75	6	4	15
18. Using the video projection system DURING scheduled laboratory class time helped me to understand the material?	98	2	0	0
19. I found the online resources useful for preparing for the practical examination in this course?	96	4	0	0
20. I feel that the video projection system was a positive addition to the microbiology classroom?	100	0	0	0
21. I feel that the video projection system would be useful in other microbiological courses that I have studied?	90	8	0	2
22. I consider the online images from the video projection system of little use unless supported by the hands-on materials and exercises in the laboratory sessions?	54	29	17	0

These latter results indicate that the majority of students were generally able to differentiate pathogenic bacteria from non-pathogenic organisms that were mixed together on semi solid culture media. Of the 21% of students that did not 'agree', the fact that 90% of these students were 'undecided' suggests that these students may not

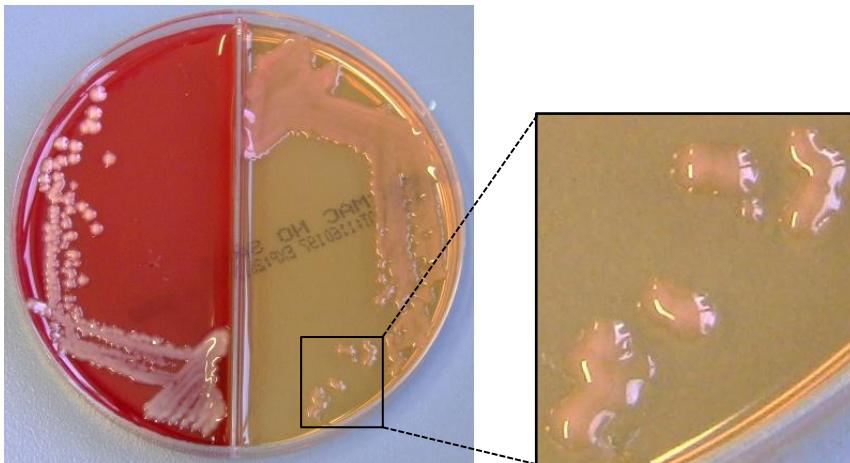
have fully identified or connected the question with the particular laboratory exercises that were conducted to facilitate this outcome. Alternatively, while they could recognise this learning outcome embedded within the laboratory exercises, the exercises themselves were either insufficient in frequency or insufficient in clarity to fully achieve the learning outcome. Overall, the video system was very effective in conveying the importance of colonial morphology in the laboratory identification process and it greatly improved the ability of the students to recognise potential pathogens.

Image and video quality

Four questions within the questionnaire dealt with the student's perceptions of the quality of the images (Q3, 4) and the relative merits of the two cameras used in the imaging system (one for microscopy and one for culture plates and other macroscopic materials, Q13, 14). There was 98% and 100% agreement respectively that the resolution of the microscopic and macroscopic images were of sufficient quality for the learning of the material. Examples of the colony morphology detail and information regarding the image sizes being displayed are shown in Figure 1. When asked if the microscopic images were more useful than the macroscopic ones, 37% agreed, 38% were undecided and 25% disagreed. Similarly, when asked if the macroscopic images were more useful than the microscopic images, the responses were divided (54% agreed, 29% were undecided, 17% disagreed). This suggests that both types of images play an important role in the learning of the material with the macroscopic camera judged slightly more useful than the microscopic system. This finding is in agreement with this author's observations of the two cameras. Although both camera systems were utilised during the laboratory sessions, the macroscopic camera system was definitely used more frequently than the microscopic system. The macroscopic camera was not only useful for displaying colonial morphologies of bacteria growing on culture media (as intended), but was found to be extremely useful for displaying all manner of objects, for demonstrating rapid test procedures, reading biochemical test results (Figure 2) and for displaying printed tabulated data (similarly to a document reader/display). Based on these results it is reasonable to assume that regardless of a student's seating position within the laboratory, relative to the two plasma screens, the image quality was of a sufficiently high standard.



B



B. *Klebsiella pneumoniae* growing on BA/MAC as above. The single colonies on MAC (at far right) appear pale pink in colour with a shiny, wet, mucoid appearance (pink means the organism ferments lactose in the media). They are convex and have a very sticky consistency. Individual colonies are circular and have an approximate diameter of 3-5 mm. However, they often coalesce with surrounding colonies to produce large irregular areas of growth.

Figure 1: Examples of the colony morphology detail that can be displayed/captured using the video display camera system. The petri dishes measure about 9cm across (actual size). In photographic mode, the native resolution on the cameras produces a static image where the petri dish is about 50cm in diameter allowing close-up detail to be shown. In the laboratory, the petri dish fills the entire screen of each of the 65" plasma screens.

Figure 2: Photographic image of two agar slopes (triple sugar iron agar – left, urea slope – right) that were inoculated and incubated as part of screening a faecal specimen for the presence of *Salmonella sp.* and *Shigella sp.* The actual tubes are approximately 10cm long and 12mm wide. The native resolution of this image was 2277x925 pixels and produced tubes that were about 70cm long. When orientated sideways, they can be displayed in real time using video mode to completely fill the screen of the 65" plasma screens in the laboratory.



Using the resources in and out of class

Given that the video display system was used primarily in laboratory classes to display materials in real time and that there were also static images placed online as study resources, a series of questions were posed to determine the students' perceptions of the relative usefulness of the online materials compared with those displayed during laboratory classes. Firstly, 90% of the students agreed that the online resources were easily accessed/utilised (2% disagreed, with the remaining 8% either undecided or nominating 'N/A'). Ninety eight per cent of the respondents agreed that the online resources positively enhanced the learning of the material in the course. The remaining 2% nominated 'N/A' to this question. Ninety six per cent of the students found the online material useful in preparing for the practical exam (the remaining 4% were undecided). Interestingly, when asked 'if using the materials from the video system outside of laboratory classes helped to understand the

material', the number of students who agreed dropped to 75% with 15% nominating 'N/A', and 6% undecided. The reference to 'outside' of laboratory classes was meant to imply the use of 'the online material' as opposed to students having free access to the laboratory video system for their own study purposes. It is unclear if this question was misunderstood. The question was intended to identify whether there were more people who found the online material more useful than the material presented during the laboratory classes. The latter is certainly not true, given that 98% of the respondents agreed that using the system during class helped them to understand the material with only 2% undecided. While the overall positive feedback from these questions supports the use of supplemental online resources derived from the laboratory video system for private study, it is equally clear that using the laboratory system during class is an integral part of the student's learning experience. Ninety per cent of the students agreed that sharing laboratory results and real time observations with the class, using the video display, enhanced the learning of the materials, while 77% agreed that it allowed greater collaboration with other students.

Hands-on materials and virtual images

It is this author's opinion that virtual images and recorded video could never fully replace hands-on learning in clinical microbiology at the level being taught. Nevertheless, three questions were included in the questionnaire to investigate the students' attitudes towards using the virtual images compared with using real life hands-on resources (Table 1). Two of these questions invoked reasonably split responses (Q7 and 22). When asked if the 'hands-on' materials were preferred to the virtual images, 54% agreed, 23% disagreed and 23% were undecided. Similarly, 54% agreed that the online images were of little use unless supported by the 'hands-on' materials, 17% disagreed and 29% were undecided. In each case, the majority agreed that the 'hands-on' materials were important. What is interesting is the relatively high number of students that were undecided on whether one system was more useful than the other. It is tempting to interpret these 'undecided' responses as being from those students who place an equivalent emphasis on both 'hands-on', face to face teaching together with the utilisation of virtual resources. When asked 'if it was often necessary to use both types of resources during the semester to understand the material', 88% of the students agreed (Table 1, Q6). Therefore, it is clear there is a role for both approaches in clinical microbiology education and that the utilisation of virtual resources could not be fully substituted for the 'hands-on' laboratory training.

Blackboard usage statistics for online resources

Although the students were asked about their perceptions regarding the usefulness of the online resources in the questionnaire (as described above), the actual number of times each individual student accessed the 'Gram negative bacteria' file on Blackboard was examined. This group of bacteria represents a very large component of the course and the online file summarising all of these organisms was made available as soon as the

material was compiled, following the first two to three weeks of semester. The total number of times the file was accessed on a day by day basis from the time it was first made available (March 14th, 2011) until the end of June, 2011 is shown in Figure 3. There was a total of 76 ‘hits’ during the first 7 days of availability. As expected, there was quite a bit of activity in the 7 days up to and including the practical exam (26th May, 2011). There was 164 ‘hits’ during this time frame with only 10 of these on the actual day of the prac exam. Between the first day of availability and the practical exam, a total of 356 ‘hits’ were made to this file. Given that 4 of the total of 52 students did not access the file at all during this time, this equates to 7.4 ‘hits’ for each of the remaining 48 students. A breakdown of the frequency with which students accessed this file is shown in Table 2. The majority of students accessed the file 5 or more times each (61.5%) with 17.3% accessing it between 2 and 4 times each. Clearly the students’ positive perceptions regarding the online material, as indicated in the questionnaire, were based on actual and repeated use of the resources. Even though the file could have been downloaded to a personal computer by any of the students (constituting a single hit), it would seem that most preferred to access the file from Blackboard, on demand, when required.

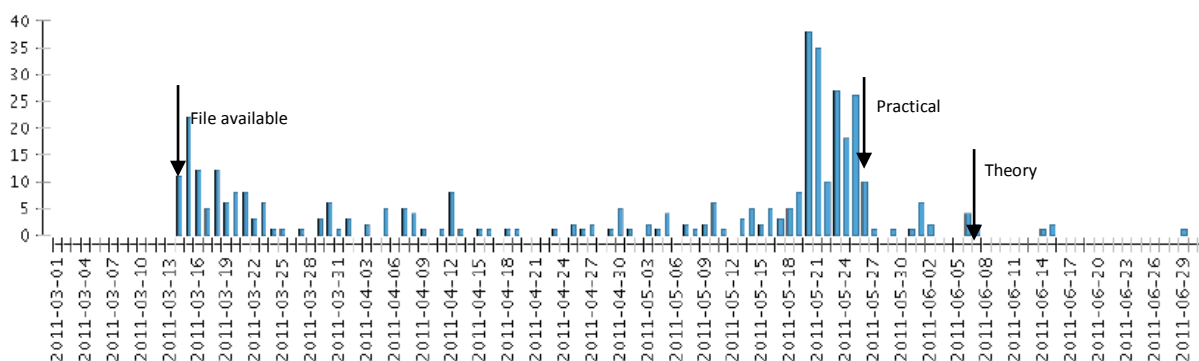


Figure 3: Graphical representation of the number of ‘hits’ (y axis) made by students to the Gram Negative file located on the unit’s learning management system website (Blackboard) versus the date (x axis). The file was first made available on Blackboard on the 14th March. The practical exam was held on the 26th May and the final theory exam was held on the 7th June. There were 356 ‘hits’ made to this file from the 14th March, up to and including the day of the practical exam. There were 17 ‘hits’ made to this file from the day after the practical exam, up to and including the day of the theory exam. Four ‘hits’ were made after the final theory exam

Table 2: The frequency with which individual students accessed the image file of Gram negative bacteria on Blackboard between the 14th March and the 26th May, 2011

Number of students with 5 or more ‘hits’	32	61.5%
Number of students with 2-4 ‘hits’	9	17.3%
Number of students with 1 ‘hit’	7	13.5%
Number of students with 0 ‘hits’	4	7.7%
Total number of students	52	100%

Student comments

There were two questions at the end of the survey that permitted the students to offer further feedback about the video imaging system. Most respondents recorded a comment to at least one of the questions. The following are some of the statements made.

'It allowed us to see good quality images inside and outside of class, and made recognising different types of bacteria easier

'It allowed me to view different types of organisms without necessarily having to have done the lab. work on every one'

'I viewed every organism made available to the class even though I didn't physically see all of them'

'Easier to show results when viewing macroscopic cultures'

'All bacteria culture plates could be seen without having to crowd around a bench'

'I got to see all the colony morphologies with the demonstrator explaining the defining features'

'Easier to see' 'Very productive' 'You could see more organisms'

'Easy to see colony morphologies which are an essential part of this course'

'Gives a greater learning opportunity, better understanding of the material'

'It enabled the class to view many species of bacteria in the limited amount of time available'

'Even if I didn't get a particular pathogen or bacteria, I was able to see it on the screen'

'It allowed everyone to observe the same thing at the same time, rather than bunching and crowding around an item waiting for other students to finish looking at it or pass it around'

'It saved time and the group learnt as one. We were all able to see the images and identify morphologies'

'It's really great to have the video projection system because it makes learning easier and exciting'

'The university should fund this to be used in all microbiology units, as it would hugely enhance the learning of the material in all classes and aspects of microbiology'

'I can see what organisms other students had'

'It provided better resolution images and demonstrations than that of a text book. Was engaging as well'

'The images are clearer than on a data projector'

'It made a lot of the pathogens clearer and easier to identify'

'It was new and awesome!!'

It is very clear from these comments that the students liked the video projection system. There were no negative comments received. A recurring theme throughout the feedback was that the system allowed for a greater number of organisms to be covered during the course and that the system adequately allowed colony morphology features to be shown, discussed and learnt. It is also clear that the students did not feel disadvantaged if they did not see or process a particular organism first hand. Instead, using the system in the laboratory classes together with the online resources adequately compensated for not having physically manipulated a particular bacterial culture. From a demonstrator's point of view, I concur with many of these comments. The system adequately displayed the necessary information and the students readily embraced it.

Conclusion

The feedback and findings concerning the implementation of the video projection system into the clinical microbiology laboratory were overwhelmingly positive. As many of the students' comments indicate, the system allowed for a large number of organisms to be covered during a limited amount of laboratory class time. All of the aims of the project were successfully achieved. In short, the system successfully allowed the students to understand and appreciate the subtle differences in colony morphologies between various different organisms, and this in turn, has improved the efficiency with which students can move from a hypothesis about the likely identity of an unknown pathogen, to selecting the most appropriate rapid/minimal confirmatory tests for confirmation of their suspicions. This is the principal skill of any medical laboratory scientist working in the field of diagnostic clinical microbiology. Therefore the video projection system successfully addressed this learning outcome.

From a laboratory demonstrator's point of view, the system greatly improved 'in class' time management. Frequently, if a student requires demonstrator assistance at their work bench, the question or problem is usually one that the rest of the students will probably also experience or need to ask. By using each of these different occurrences as an opportunity to explain a concept or provide guidance to the whole class simultaneously (via the video projection system), the practical classes ran more efficiently. In many cases, a short interruption to class activity to explain something meant that many of the students then didn't require demonstrator assistance before being able to continue with their exercises independently. This noticeably reduced the number of requests for hands-on assistance and also reduced the student wait time when assistance was required. As a consequence, the demonstrator was generally more available to assist the students in other ways (i.e., replenishing reagents and consumables, providing assistance with microscopy and laboratory techniques, answering theoretical questions) or just being free to talk about microbiology or the lecture content. The ability to place any document,

diagram or table under the camera and have it displayed also saved time during the laboratory sessions. Instead of asking and waiting for the students to turn to a particular page in their manuals, the page could be displayed and the information contained therein discussed immediately. As one of the student comments of the system states, *“it saved time.”*

In this study, 100% of the students felt that the video projection system was a positive addition to the microbiology classroom and 90% agreed that it would be useful in other microbiology courses. Since the equipment is located in a laboratory that is used by other microbiology units, that is now possible. According to the scientific staff (who prepare the materials for the various practical classes), there have been several situations where students who have experienced the system with a different supervisor, have requested that their current laboratory demonstrator turn it on and use it. Obviously, the students have come to appreciate the benefits of its use and now expect it to be used. It is hoped that together with the findings presented here, this sentiment will encourage the investment and implementation of a similar system in the second microbiology laboratory located in the School of Biomedical Sciences.

In addition to the positive feedback reported here, there has been extremely positive and unsolicited feedback from some of the students from this study, who at the time of writing, are currently undertaking their clinical laboratory work placement. They have reported through their work placement supervisors that the Clinical Microbiology 331 unit, in which the camera system was first utilised, has prepared them very well for working in a routine microbiology (bacteriology) laboratory.

The only thing I would have done differently would be to have invested more time investigating AV hardware, their connectivity and compatibility during the planning processes of the project. By the time I began investigating the mechanisms by which a computer could be placed between the camera output and the signal amplifier/plasma screens, the semester was well underway. A computer would have allowed real time editing/capture of video footage and would have solved a minor problem which none of the students have commented about. From a demonstrator's view point, the one notable disadvantage of the current system occurred when microscopy images were displayed. When images from the microscope were displayed on the two plasma screens, the only way for the demonstrator to point out a feature of interest, was to physically walk between the two television screens and motion at the screen. A computer interfaced between the camera and screens would allow the mouse cursor to be used as a pointer. An order for an Apple Mini Mac (has high definition digital input and output connectors as standard) was placed, but the computer did not arrive until the end of semester.

The addition of online video resources should be viewed as the next logical step in developing the blended learning approach in the clinical microbiology classroom. The real time display of colony morphologies during laboratory classes has one major

advantage over viewing the static images made available as online resources. The real bacterial cultures can be tilted to reflect the ambient light from their surface whereas a static image only captures one 'view' of the growth characteristics. Often, tilting the culture in the light reveals far more detail than can be seen in a static image. For this reason, each organism should be filmed on each of the different culture media (at least 30 seconds on each culture plate) and the videos annotated together with narration. Additionally, the demonstration of certain laboratory protocols and methods could be recorded and uploaded for both classroom use and student revision.

According to Grando (2010), one of the benefits of blended learning is that, "when learning environments combine face to face and online delivery, the resulting learning outcomes can be greater than the sum of each form of delivery." It is this author's opinion that based on the students' feedback, this is exactly what has been achieved and demonstrated during this study.

Acknowledgements

The author is grateful to Curtin Teaching and Learning at Curtin University for the opportunity to positively impact the learning of the undergraduate students undertaking clinical microbiology training in the School of Biomedical Sciences. I also thank Diana Taylor from eLearning and Design for her continued, enthusiastic support and guidance throughout the duration of the project. Special thanks to Mr Alain Delhaize, Scientific Officer in the Microbiology Department in the School of Biomedical Sciences at Curtin University, for his work in helping to solve equipment connectivity and signal amplification issues.

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Citation:

Costantino, P. (2012). A blended approach to supporting student learning in clinical microbiology laboratory classes. In A. Herrington, J. Schrape, K. Singh (Eds.), *Engaging students with learning technologies* (pp. 15-34). Perth, Australia: Curtin University.



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