COMPARISON OF OPTICAL MICROSCOPY AND VIRTUAL MICROSCOPY FOR LEARNING HISTOLOGY

BY

DR. ANNA ALICIA SIMOK

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percentage
et al.	And others (Latin: *et alii*)
<	Less than
>	More than
=	Equal to
α	Significant level
d	Cohen effect size
p	*p*-value
r	Correlation Coefficient
n	Number of subject
df	Degree of freedom
x^2	Chi-Square
CI	Confidence Interval
SD	Standard deviation
IQR	Interquartile Range
OM	Optical Microscopy
VM	Virtual Microscopy
USM	Universiti Sains Malaysia
CAI	Computer Assisted Instruction
OSPE	Objective structured practical examination

PERBANDINGAN KESAN MIKROSKOP OPTIKAL DAN MIKROSKOP MAYA DALAM PEMBELAJARAN HISTOLOGI

ABSTRAK

Pengenalan: Histologi merupakan salah satu perkara utama dalam pendidikan perubatan. Ia juga merupakan sebahagian daripada modul sains asas. Histologi secara tradisional diajar menggunakan mikroskop optikal. Semenjak awal abad ke-21, pelbagai universiti yang telah mengintegrasikan atau telah menggantikan cara tradisional ini dengan mikroskop maya. Ini merupakan kesan daripada pengurangan masa pengajaran dan pembelajaran histologi selepas berlakunya reformasi di dalam pendidikan perubatan. Kajian ini bertujuan untuk membandingkan kesan penggunaan mikroskop optikal dan mikroskop maya dalam pembelajaran histologi di kalangan pelajar perubatan di Universiti Sains Malaysia.

Kaedah: Seramai 120 orang peserta yang terdiri daripada 53 orang pelajar perubatan tahun satu dan 67 orang pelajar perubatan tahun dua dari sesi pengajian 2017/2018 telah dipilih untuk kajian ini. Para peserta telah dibahagikan kepada dua kumpulan yang homogen iaitu kumpulan mikroskop maya dan kumpulan mikroskop optikal dengan menggunakan kaedah peruntukan rawak berstrata. Kajian ini telah dijalankan dalam masa sehari. Pada mulanya, semua peserta diminta untuk menghadiri kuliah 'Histologi Mata'. Kemudian, semua peserta menghadiri sesi demostrasi slaid di dalam makmal pelbagai guna. Sejurus itu, para peserta dibawa ke makmal masing-masing mengikut kumpulan yang telah ditetapkan. Kumpulan mikroskop maya telah diarahkan untuk menggunakan mikroskop maya sementara kumpulan mikroskop optikal diarahkan untuk menggunakan mikroskop optikal semasa sesi praktikal. Pemerolehan ilmu pengetahuan diukur menggunakan markah pos-praktikal, perubahan markah ujian iaitu dari ujian pra-praktikal sehingga ujian pos-praktikal, dan markah darjah pembelajaran. Pendapat para pelajar berkenaan pembelajaran histologi menggunakan kedua-dua jenis mikroskop telah dikumpul menggunakan borang kaji selidik tahap kepuasan dan inventori motivasi intrinsik.

Keputusan: Keputusan menunjukkan terdapat perbezaan ketara pada markah ujian (p<0.001) di antara kumpulan yang menggunakan mikroskop maya (min perbezaan=38.508) dengan mikroskop optikal (min perbezaan=35.079). Walau bagaimanapun, tiada perbezaan ketara antara kedua-dua kumpulan dalam tahap pemahaman (markah pos-praktikal) atau keupayaan belajar (markah darjah pembelajaran). Markah median (IQR) bagi tahap kepuasan bagi kumpulan mikroskop maya [5.00 (1)] lebih ketara berbanding kumpulan mikroskop optikal [4.00 (2)], p=0.008. Bagi motivasi intrinsik pula, hanya markah persepsi kompetensi kendiri kumpulan mikroskop maya lebih ketara berbanding kumpulan mikroskop optikal, p=0.037. Tiada perbezaan ketara antara markah kedua-dua kumpulan kajian bagi subskala minat, tekanan dan nilai.

Kesimpulan: Penggunaan mikroskop maya sebagai alat pembelajaran histologi memberikan kepuasan kepada para pelajar dan meningkatkan tahap kecekapan serta pemahaman terhadap ilmu histologi. Walau bagaimanapun, kajian lebih lanjut diperlukan untuk melihat kesan penggunaan mikroskop maya di dalam pembelajaran histologi yang lebih menyeluruh.

COMPARISON OF OPTICAL MICROSCOPY AND VIRTUAL MICROSCOPY FOR LEARNING HISTOLOGY

ABSTRACT

Background: Histology is one of the fundamentals in medical education and is part of the basic science module. Histology was traditionally taught using the optical microscope. Since early 21st century, the new virtual microscope has been integrated or has completely replaced the traditional method in various universities. This was a result of reduction in histology contact time after medical education reformation. This study aims to compare the effects of using a virtual microscope and an optical microscope for learning histology among medical students in Universiti Sains Malaysia.

Methodology: One hundred and twenty medical students from 2017/2018 academic session, comprising of 53 first year students and 67 second year students were recruited. The participants were divided into two homogenous groups which were the virtual microscopy group and the optical microscopy group, using stratified random allocation. This was a one day intervention. All participants attended a lecture on 'Histology of the Eye' and then attended a slide demonstration. Immediately after, the two groups were divided and attended the practical session at designated laboratories for an hour. The virtual microscopy group were exposed to the virtual microscope and the optical microscopy group exposed to the optical microscope. Knowledge acquisition was measured and compared between the study groups using the post-practical assessment score, changes in assessment scores from pre to post-practical assessment and learning quotient score. Student perceptions of learning histology using respective learning tool were collected at the end of the day by administering the satisfaction survey and Intrinsic Motivation Inventory.

Results: Results revealed that both study groups, the virtual microscopy group (mean difference=38.508) and the optical microscopy group (mean difference=35.079) had significant changes in assessment score, $p < 0.001$. However, there was no significant difference between study groups in terms of level of comprehension (post-practical assessment) and learning ability (learning quotient score). The median (IQR) of satisfaction score for the virtual microscopy group [5.00 (1)] was significantly higher compared to optical microscopy group [4.00 (2)], $p=0.008$. For the intrinsic motivation inventory, only the perceived competence score of virtual microscopy group was significantly higher compared to the virtual microscopy group, $p=0.037$. There were no significant differences between the two study groups in terms of interest, pressure and value score.

Conclusion: The use of virtual microscopy as a learning tool gives students great satisfaction and perceived competence while effectively enhancing their knowledge improvement in Histology. Further investigation is needed to assess the comprehensive effect of virtual microscope in learning histology.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Histology is the study of the cells and tissues of the body. Its teaching is mainly composed of lectures, practical sessions and utilizing workbooks. In the 21st century, technology is now widely used and developed in medical education to replace or improve the conventional ways of teaching. In teaching and learning histology, the virtual microscope was first introduced in 2002. It has since been adopted in many universities worldwide including Harvard University, United States of America and the Third Military University, China. In Malaysia, the virtual microscope is used in the field of histology as well as in the pathology.

Histology teaching and learning in Universiti Sains Malaysia, is based on both lectures and practical sessions. During the practical session, a demonstration is done using the virtual microscope by a qualified lecturer. After the demonstration, students have a hands-on session where groups of students share and take turns using the conventional optical microscope. Currently, an optical microscope is shared by 2 students during the practical session and a box of slides is shared among 12 to 16 students. Due to this condition, the optical microscopes need frequent maintenance and are costly to repair if any damage occurs. Furthermore, the glass slides also fade throughout time and once a slide is broken, a new one needs to be purchased.

Factors mentioned above make the virtual microscope financially more favourable in the long run. However, there is still a debate going on whether virtual microscopy is more effective as a learning tool as compared to the optical microscopy.

1.2 Justification of the study

This study is mainly to answer whether the virtual microscopy is more effective compared to the optical microscopy in terms of learning histology among medical undergraduates. There are limited well-controlled experimental studies on virtual microscopy as a learning tool compared to optical microscopy.

A study done in Ghent University, Belgium, showed non-significant differences between the post-intervention test results of students in both groups. Both groups were either exposed to an optical microscope or a virtual microscope during the first intervention then the tools were switched during the second intervention. Neither the nature of the medium nor the order of use seems to be important to transfer adequately the histology learning material (Mione *et al.*, 2013). Another study done in Third Military Medical University, China, showed a positive result. Test scores in the virtual microscope group showed a significant improvement compared to those in the optical microscope group ($p < 0.05$) (Tian *et al.*, 2014). As the previous studies showed variable results, a more systematic evaluation study should be done.

1.3 Objectives of the study

1.3.1 General objectives

To investigate the effects of using a virtual microscopy and an optical microscopy on learning histology among medical students

1.3.2 Specific Objectives

1.3.2.1 To compare the effects of using virtual microscopy and optical microscopy on students' histology knowledge acquisition by:

a) Comparing the difference between post-practical assessment score.
b) Comparing the changes in the assessment scores within each group.
c) Comparing the difference between learning quotient score.

1.3.2.2 To compare the students' satisfaction score between the optical microscopy and virtual microscopy groups.

1.3.2.3 To compare the students' intrinsic motivation towards using virtual microscopy or optical microscopy in learning histology by comparing the between group difference of:

a) Interest score
b) Perceived competence score
c) Pressure score
d) Value score

1.3.2.4 To determine the relationship between students' post-practical assessment score and satisfaction score.

1.3.2.5 To determine the relationship between students' learning quotient score and satisfaction score

1.4 Hypotheses of the study

1.4.1 The histology knowledge acquisition in terms of:

a) The post-practical assessment score in virtual microscopy group is higher than optical microscopy group.

b) The improvement of test score in virtual microscopy group is higher than optical microscopy group.

c) The learning quotient score of virtual microscopy group is higher than optical microscopy group.

1.4.2 The students' satisfaction score towards learning histology is higher in virtual microscopy group than optical microscopy group.

1.4.3 The virtual microscopy group compared to optical microscopy group has:

a) Higher interest score

b) Higher perceived competence score

c) Lower pressure score

d) Higher value score

1.4.4 There is a linear relationship between the students' post-practical assessment score and students' satisfaction score.

1.4.5 There is a linear relationship between the students' learning quotient score and students' satisfaction score.

CHAPTER 2

LITERATURE REVIEW

2.1 Study of histology

2.1.1 History of histology

Histology is the microscopic study of biological tissues such as animals, plants and humans. The study is done using special staining techniques combined with optical microscopy or electron microscopy. Histology is essential to understanding the intricacies of cell and tissue organization including its function. This includes understanding what cells are composed of and how different cells collectively form different tissues of the body with different actions respectively (Zaletel *et al.*, 2016). Currently, histology is widely used in archaeology, forensic investigations, autopsy, and in education. Furthermore, it is also used extensively in medicine especially in the study of diseased tissues to aid treatment and this field is better known as histopathology (Black, 2012).

Histology was initially brought to use in the 1700s by the French anatomist Marie François Xavier Bichat. Bichat is considered to be the father of modern histology and descriptive anatomy. He was given the honour based on his gross dissection discoveries from which he introduced 21 tissues as the basic elements of organs. However, Bichat's work was based on autopsy rather than the usage of microscope (Shoja *et al.*, 2008).

Marcello Malpighi was an Italian biologist and physician, who explored and described the histology of the lungs, kidneys, spleen and liver. In 1661, he was the first scientist to observe capillaries, hence he was considered to be the true "Father of Histology". His discovery was fundamental to our understanding of the vascular system in the brain and cord (Pearce, 2007). It was only until 1819 that Mayer coined the term "Histology". He combined two Greek root words that are *histos*, for tissues, and *logos*, for study (Hussein *et al.*, 2015).

2.1.2 Histology in medical education

In 1838, a German scientist named Johannes Muller was the first person to believe that microscopy can be of benefit to the medical profession. His book on specialization of histopathology techniques entitled "On the Nature and Structural Characteristic of Cancer" elaborated that microscopy proved to be a great technique to investigate various diseases by tracing back to their cellular and molecular malfunction. It was based on Muller's view that histology was integrated into medicine and thus histology became part of the medical curriculum (Hussein *et al*., 2015).

Histology has now become fundamental in medical education in many ways. It gives medical students the understanding of the arrangement and function of cells and tissues of normal organs. Moreover, it correlates the differentiation of tissue structure to their specific function. With this gained knowledge, medical students will have better cellular understanding and basis of anatomy as well as physiology. In addition, medical students must understand the normal to comprehend the abnormal, which makes histology essential to understanding pathology (Hussein *et al*., 2015).

Medical education has undergone reformation throughout the years since 1998 and major changes have been implemented including changes to histology teaching and learning (Cotter, 2001; Lawley *et al.*, 2005). In the traditional curriculum, histology was part of the basic science course usually given during first year of medical school. It previously consisted of lectures followed by practical sessions in the laboratory where students would explore histology glass slides using optical microscopes. Ample time was given to anatomists to teach each histology topics thoroughly and for students to absorb knowledge (Hussein *et al*., 2015).

Shifting towards the new curriculum, medical schools worldwide have focused on reduction in contact hours to decompress crowded programs and increase emphasis on independent learning, development of interpersonal skill and problem solving (Williams and Lau, 2004). As a result, basic science teaching time has been reduced and integrated with clinical medicine. The purpose of time reduction on basic science course was to accommodate more time for student self-learning and small group discussion. As a result, anatomists and histologists are left to adjust their teaching methods around these changes and many opt to rely on alternative tools (Hussein *et al*, 2015).

2.1.3 The role of laboratory in histology in medical school

Laboratory work is defined as a hands-on learning experience that instigates students to think of the world they live in (Woodley, 2009). One the other hand, a lecture is defined as an educational talk to a group of audience and in this context, students (Oxford, 2018). In medical schools, histology is taught by giving both lectures and providing practical sessions for students. A histology lecture is aimed to ‘transfer’ the lecturer’s knowledge into the minds of the students. However, transmission of abstract ideas alone simply does not work in helping a student’s understanding of the histology topic. This is where the histology practical session comes in and plays its role (Millar, 2004).

During histology practical sessions, students get hands-on experience by observing the histology slides themselves using the microscopes. While scoping the histology glass slides for example, students will come to think of how the small units of muscle fibers form a muscle bulk and consequently produce movement in union. As a consequence of this, students will try to form a bridge linking their acquired abstract ideas from lecture with their actual hands-on or observations during practical sessions and try to make sense of the whole histology topic (Millar, 2004).

An effective practical session is essential to build a bridge between what students see and handle, and the scientific ideas derived from their observations. When students are able to correlate what has been learnt theoretically with actual practice or experiment, this results in enhancement of students’ understanding of the subject and concepts introduced in other teaching sessions (Woodley, 2009; Millar, 2004). It also provides the opportunity for students to develop competence in experimental skills appropriate to their discipline (Lewis, 2014).

2.2 Issues in teaching and learning histology in medical school

As the new medical curriculum is slowly being implemented around the world, anatomists and students are faced with challenges brought by these changes. One major change was the time reduction in the basic science modules. Aside from reduction of lecture hours, histology practical sessions were also greatly reduced. In the University of Buffalo, 20% of histology course and 80% of the total practical hours were cut in total. As a result, the anatomists have shifted towards alternative teaching methodology, the virtual microscope, which is more time efficient and delivers the same amount of knowledge (Cotter, 2001, Hussein *et al*, 2015).

As practical session contact time is reduced, students are crammed in one or more laboratories for a session which may cover two to three topics of histology simultaneously. In such large group of students, the availability of light microscopy and histology slides becomes a problem. Small groups of students are made to share one microscope and a set of slides, limiting students to explore well each slide at their own pace during the already shortened practical hours (Blake *et al.*, 2003).

Although the new medical curriculum provided more time for student self-learning, optimization of this time depends on availability of learning resources, and in this context, the learning tool for histology. Availability of a learning tool outside the lecture halls and laboratories as well as access readiness was discussed in a study. It concluded that an available learning tool which is readily accessible will aid in the optimization of the self-learning period (Blake *et al.*, 2003).

While there are still issues in teaching and learning methods in histology, discussions of the decline in undergraduate knowledge of anatomy amongst the surgical community continues. It has been discussed whether the reduction in time, teaching staff or dissection had given adverse effects. It was difficult to objectively assess if the reduction in anatomy teaching has been excessive. However, a few studies conducted showed that the knowledge of anatomy amongst qualifying doctors has declined and is now below acceptable level (Turney, 2007).

2.3 Tools in teaching and learning histology

The light microscopy has been the primary laboratory instructional tool in histology for many years. From a one-lens, simple microscope to a two-convex-lenses microscope, the spectrum had advanced now to a virtual microscope and to what nowadays is known to be a 3-D microscope of moving cells (Hussein *et al*., 2015). The two most researched tools for both teaching and learning histology are the optical microscope and virtual microscope.

2.3.1 Optical microscope

The optical microscope, the primary tool for histology, has experienced great advancement since its creation. It was first created during the end of the 16th century, by Jannsen, a Dutch eyeglass dealer, who inserted lenses into a cylinder. He found out then that the objects were magnified, and that was the first prototype of modern microscopy. Jannsen later assembled the first microscope, which included two convex lenses.

In 1670, Dutch scientist Anthony van Leeuwenhoek developed a microscope with higher magnification and better image quality. Unlike the past where light from a candle flame was needed to illuminate the tissues, this developed microscope lenses were formed from beads and used natural light (Titford, 2009). During the 19th century, Ernst Abbe, Carl Zeiss, and Otto Schott worked on producing a high-quality microscope and thus providing a foundation of discoveries for scientists in histology and anatomy. (Hussein *et al.,* 2015).

One of the common microscope used for undergraduate histology learning is the compound microscope. It is essential to know its parts and functions to be able to use the microscope correctly. The two eyepieces at the top that you look through are called the ocular lenses. They are usually 10X or 15X power. Usually there are three or four objective lenses on a microscope, most commonly consisting of 4X, 10X, 40X and 100X powers. When coupled with a 10X eyepiece lens, the total magnifications is 40X (4X times 10X), 100X, 400X and 1000X. The shortest lens is the lowest power and the longest lens is the greatest power. The head connects the ocular lenses to the objective lenses. The arm supports the head and connects it to the base, which the bottom of the microscope used for support (MM, 2010-18).

The illuminator provides a steady light source (110 volts) used in place of a mirror. The flat platform where the slide is placed is called the stage. Stage clips hold the slides in place. There are two types of knobs on the microscope; the stage control knob and the focus knob. The stage control knob controls the slide movement left and right or up and down. There are two focus knobs which are the coarse focus and the fine focus. Coarse focus brings the specimen into general focus, whereas the fine focus allows fine-tuning the focus and increasing the details of the specimen. The revolving nosepiece is the part that holds two or more objective lenses and can be rotated to easily change power. The condenser gathers and focuses light from the illuminator onto the specimen being viewed (MM, 2010-18). Figure 2.1 shows a labelled compound microscope.

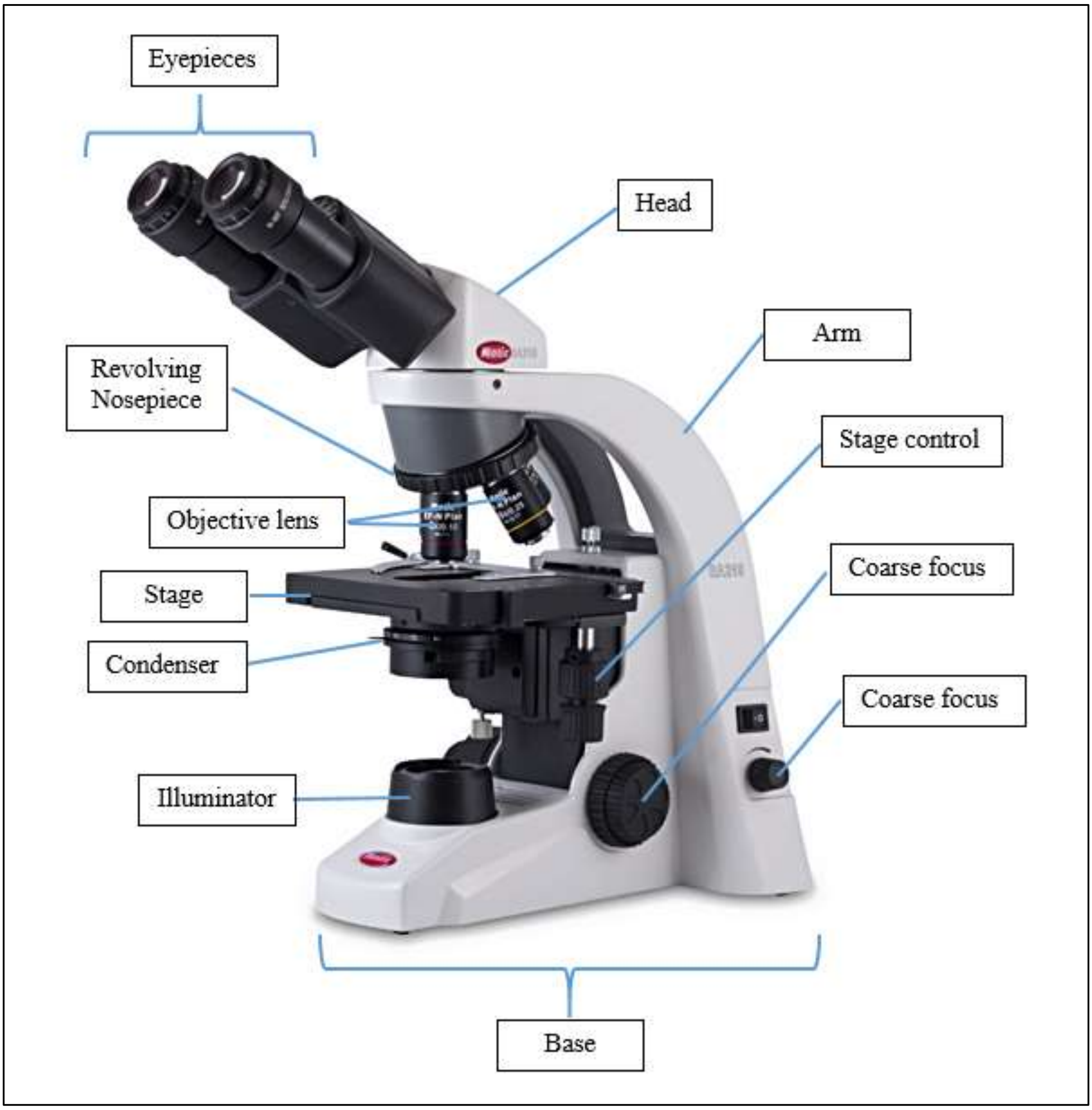

Figure 2.1: A compound microscope.

(Image taken from www.motic-microscope.com/popup.aspx?src=/images/product)

Schmidt (2013) reported that the correct use of the microscope is a prerequisite for the course of histopathology. The author commented that an individual cannot adopt these abilities virtually, without any practical experience. Therefore if students do not learn to use an optical microscope correctly during pre-clinical years, they must learn it during their clinical phase. A study showed that 25% of the students found that it was necessary or desirable to use both the optical microscopy and virtual microscopy (Blake *et al.*, 2003). In another study, a student commented that optical microscopy gave the hands-on experience during practical sessions and without it, there was lack of motivation to study histology (Husmann *et al.*, 2009).

2.3.1.1 Advantages and disadvantages of optical microscope

One great advantage of the optical microscope is the ability to observe not only dead but also living cells. It is possible to observe a wide range of biological activities, such as the uptake of food, cell division and movement. Additionally, it is possible to use in-vivo staining techniques to observe the uptake of colored pigments by the cells (Microbehunter, 2018). Another advantage was that the optical microscope gave a three dimensional feeling to observers.

As compared to the virtual microscopy, the optical microscopy's disadvantages outweighs the advantages. An example is the massive cost of purchasing and regularly maintaining or repairing an optical microscope. As optical microscopes and glass slides are needed in large amounts to accommodate all student needs for teaching and learning, a huge storage space is also required to store these equipment (Blake *et al.*, 2003).

As aforementioned, the actual cost must also include purchasing student slide sets, which are rendered for replacement if broken (Blake *et al.*, 2003; Kumar *et al.*, 2006). Furthermore, the glass slides are not only costly and hard to find but also difficult to be identical. Thus, it was reported that there was a discrepancy between students and their slides (Bloodgood and Ogilvie, 2006).

2.3.2 Virtual microscopy

Since the beginning of 21st century, the virtual microscopy has been vastly debated for its role in teaching and learning histology as well as pathology. It is rapidly replacing the traditional optical microscopy in many universities. Numerous medical schools have either opted for virtual microscopy or integrated both the virtual microscopy and optical microscopy as teaching tools for histology (Hussein *et al*., 2015).

Virtual microscopy image acquisition involves photographing tissue sections on microscopic slides at high magnification using a slide scanner. These captured images are then stored in a multi-resolution file format. These files can then be viewed with a specialized software mimicking the optical microscope. With a click of the computer mouse, magnification and focus can be easily adjusted (Kumar *et al.*, 2006). Figure 2.2 shows a slide scanner and Figure 2.3 shows a labelled display from a virtual microscope software.

Figure 2.2: The Pannoramic Desk, slide scanner.
(Image was taken from https://diamedica.lv/images/PRODUKCIJA/mikroskopi/Pannoramic-DESK-3DHISTECH.png)

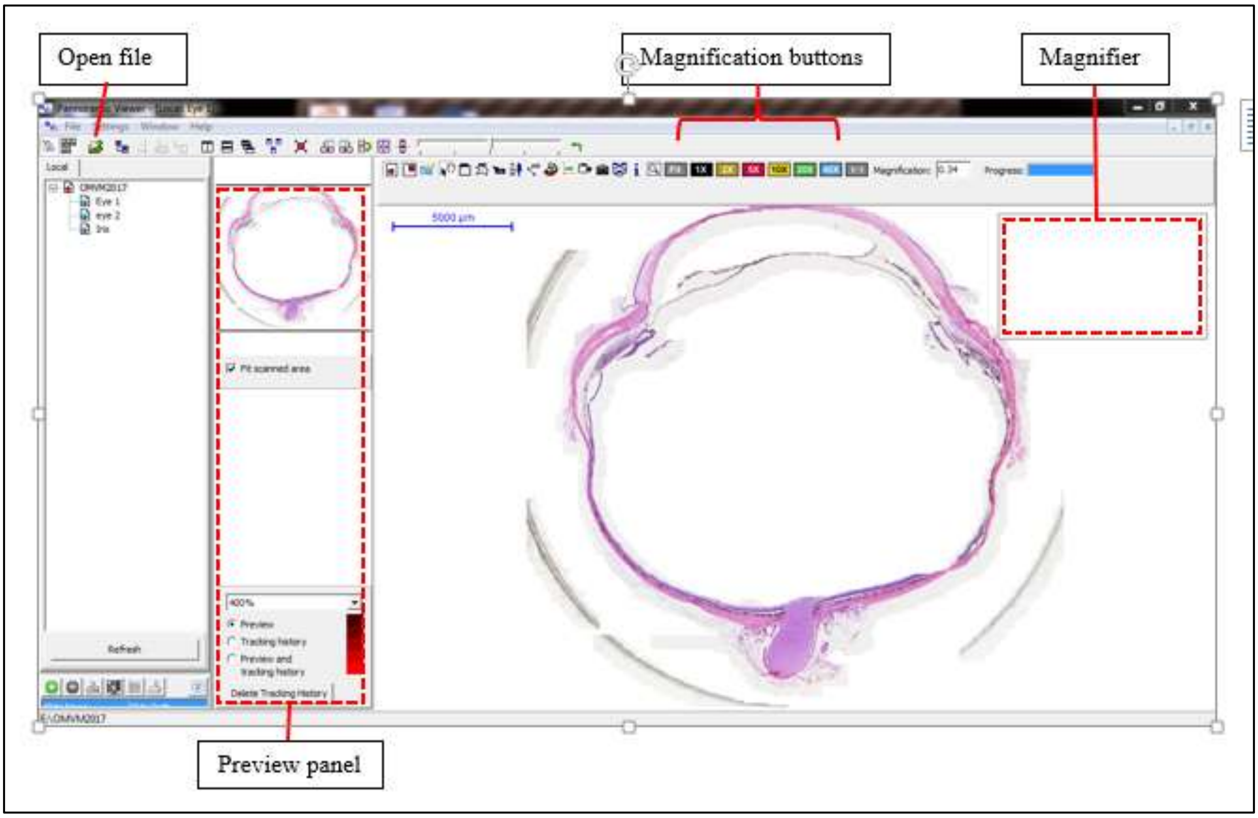

Figure 2.3: Screenshot of the Pannoramic Viewer by 3DHISTECH Ltd.

(Image was taken from the Computer Assisted Instruction (CAI) laboratory, School of Medical Sciences, USM.)

2.3.2.1 Advantages and disadvantages of the virtual microscope

Advantages of using the virtual microscope in histology teaching and learning have been reported in many studies. In the University of Buffalo, the study of histology in its School of Medicine was reformed after curriculum changes were made in 2001. It was reported that histology contact-time was halved as virtual slides have replaced the traditional optical microscope. The reduction in time and transition to virtual slides did not reduce the amount of valuable information delivered to students (Cotter, 2001).

Two studies reported that one of the virtues of virtual microscopy was the virtual slide images are always in focus with optimized contrast (Kumar *et al.*, 2006; Ordi *et al.*, 2015). Another study, reported that the virtual microscope facilitates collaborative learning. More than one student can examine specimens at the same time on the same monitor thus solving the large group discussion issue (Braun and Kearns, 2008; Kumar *et al.*, 2006).

Furthermore, according to Kumar *et al*. (2006), virtual microscopy solved the problems related to tissue section variability and slide maintenance issues as aforementioned. Unlike the optical microscope, the best quality slides are easily captured by the slide scanner and duplicated. Thus, every student will have identical virtual slides of best quality and these slides will not fade or break (Dee, 2009; Ordi *et al.*, 2015).

The use of virtual microscopy in large groups may prove to be financially desirable when compared with the cost of maintaining a large number of optical microscopes and student histology slide sets (Husmann *et al.*, 2009). In addition, the virtual microscope was shown to help prevent the motion sickness and eye fatigue issue reported by some students when using the optical microscope (Braun and Kearns, 2008). The virtual microscopy is also easily portable and accessible anywhere where computer is available. Students preferred to be able to access the learning tool from their lecture halls to their bedrooms (Dee, 2009; Ordi *et al.*, 2015).

As with every other teaching tool, the virtual microscopy has its drawbacks. Unlike optical microscopes, it lacks the 3-dimensionality where students move from different focus planes by changing their focus knobs. Hence, students lose the sense of dimension pertaining to the slides they were viewing. Other reported drawbacks included low magnification having less resolution when viewed on a standard computer screen and original glass slide tissue artifact as well as imperfections are difficult to scan (Dee, 2009). The digital scanning will only produce great images if the quality of the original slide is excellent. Hence, it is crucial to select the best quality sections, showing good staining, mounted flat and free of artefacts (Morales, 2012).

Moreover, the virtual microscope software used requires the ability to provide access to a large group of students simultaneously. Hence, a good server with appropriate software is required to support the large quantity of data (Hortsch, 2013; Hussein *et al.*, 2015). Another limitation of the virtual microscopy is that the virtual slides consume a huge amount of memory and therefore requires a large storage system (Morales, 2012).

2.3.3 Student satisfaction level towards the learning tool in histology

Students' satisfaction can be defined as a short-term attitude resulting from an evaluation of students' educational experience, services and facilities. Earlier it was assessed by common satisfaction frameworks but later higher education specify satisfaction models were developed (Weerasinghe *et al.*, 2017). A study in Allama Iqbal University, Pakistan revealed that satisfaction of students can be determined from their level of contentment as well as the effectiveness of the education that they experienced. In this regard, satisfaction can be considered as the act of fulfilling the desire in achieving a planned goal (Dhaqane *et al.*, 2016).

A study showed that there was a strong relationship between satisfaction of students and academic performance (Dhaqane *et al.*, 2016). It further revealed that satisfaction promotes both academic achievement and retention of the student. Hence, students' satisfaction towards a learning tool is an important point to consider when deliberating on the optimal learning tool in histology.

A study on student satisfaction level towards virtual microscopy and optical microscopy done showed that overall, 87.61% of the students strongly agreed that the virtual microscopy was useful as a practically oriented teaching–learning tool and shows enhanced learning (Hande *et al.*, 2017). While many studies reporting students' opinion on histology learning tools has been published, there is limited student satisfaction level reported (Blake *et al.*, 2003; Krippendorf and Lough, 2005).

CHAPTER 3

METHODOLOGY

3.1 Research design

This is a randomised controlled study on the comparison of optical microscopy and virtual microscopy for learning histology.

3.2 Ethical consideration

The study was conducted after acquiring ethical approval from Universiti Sains Malaysia (USM) Human Ethic Research Committee (JEPeM) (JEPeM Code: USM/JEPeM/15100338). Please refer to Appendix A.

3.2.1 Potential risks to subjects

The study has the risk of interfering with the students' academic activity, study week and exam periods. Hence, to avoid this risk, this study was done during the weekend and not during their academic activity, study week or exam periods. Furthermore, the students have risk of not receiving equal learning opportunities. Students of the optical microscopy group were not be exposed to virtual microscopy during this study. To guarantee that students receive equal learning opportunities, the students in the optical microscopy group were invited for a virtual microscopy practical session after the study.

3.2.2 Direct and indirect benefits to subjects

Students gained new knowledge on histology of the eye, which is not in their syllabus. Furthermore, students obtained the opportunity to experience a practical on histology of the eye using a virtual microscope. In addition, students were also be given an honorarium.

3.3 Study population

The sample was taken from the first and second year medical students of academic session 2017/2018 from the School of Medical Sciences, Universiti Sains Malaysia, Health Campus in Kubang Kerian, Kelantan, Malaysia.

3.3.1 Inclusion Criteria

a. Candidate must be a first year or second year medical student who enrolled in the Doctor of Medicine Program, School of Medical Sciences at USM, Health Campus on September 2017.

b. The age of the participant must not be below 18 years old and not exceed 25 years old on the first of September 2017.

3.3.2 Exclusion Criteria

a. Repeat students are excluded to assure that no prior knowledge influences the study result.

3.4 Sample size

The calculation for sample size was made based on Cohen Statistical Power Analysis (behavioral sciences). According to Cappelleri and Darlington, (1994), Cohen Statistical Power Analysis is one of the most popular approaches in the behavioral sciences in calculating the required sampling size. A sample size calculator (available online: https://www.danielsoper.com/statcalc/calculator.aspx) was used to aid with calculation taking into consideration the following; significance level (α) set at 0.05, medium effect size and power of study of 80%. The calculated sample size was 64 subjects per group.

Sample size was readjusted to address the non-response rate for personal invitation. The non-response rate for an email invitation was 40% (Fincham, 2008) and according to the National Student Survey, London (2016), having a lecturer or staff personally explain to students regarding the study increases the response rate. Therefore, a non-response rate of 20% was readjusted to the sample size. Hence, sample size including 20% non-response rate amounted to 80 subjects per group. The following formula was used to calculate the adjusted sample size:

If n is the sample size required as per formula and if d is the non-response rate then adjusted sample size N1 is obtained as

$$N1 = n/ (1-d).$$

The total sample size calculated was 160 students.

3.5 Sampling method and participants' recruitment

Purposive sampling method was used in this study due to small population cohort. A purposive sampling is a non-probability sampling method, where the sample is selected based on predefined criteria or objective of the study (Crossman, 2018). The subjects were from first year and second year students in Doctor of Medicine Program, School of Medical Sciences of academic session 2017/2018. A personal invitation was given to all students to attend a briefing session.

Direct recruitment was applied in this study, where a briefing session to each of the first year and second year medical students was done in their respective lecture halls to explain the purpose, methodology, participation criteria, risks and benefits of the study. In addition, each participant was given a file containing the consent form and a handout on the study details.

Students who were willing to participate were given a written consent form to sign after the briefing session. Out of 240 students who attended the briefing sessions, 157 students agreed to participate in this study. Each participant was given a copy of the consent form.

3.6 Stratified random allocation

Group allocation was performed using stratified random method to control confounding factors that may affect the study results (Figure 3.1). The confounding factors are gender and year of study. The consented participants (n=157) were divided into four name lists, which were the first year male students (n=24), first year female students (n=65), second year male students (n=26) and second year female students (n=42). The group allocation was performed by an independent research assistant using random number generator software (available online: https://www.calculatorsoup.com/calculators/statistics/number-generator.php). From each list, using the random number generator, participants were randomly selected to represent the optical microscopy group and the remaining unselected participants to represent the virtual microscopy group with a one to one ratio. The participants were blinded until the actual research day.

Gender is an important factor to control due to its strong relationship with working memory capabilities. In general, women have a higher level of performance on the auditory episodic memory and men have a higher level visual episodic memory performance (Herlitz *et al.*, 1997; Pauls *et al.*, 2013). Therefore, gender was included in the stratification. Previous studies have demonstrated that visual working memory increases with age (Amundsen *et al.*, 2014). Hence, year of study was also included in the stratification.

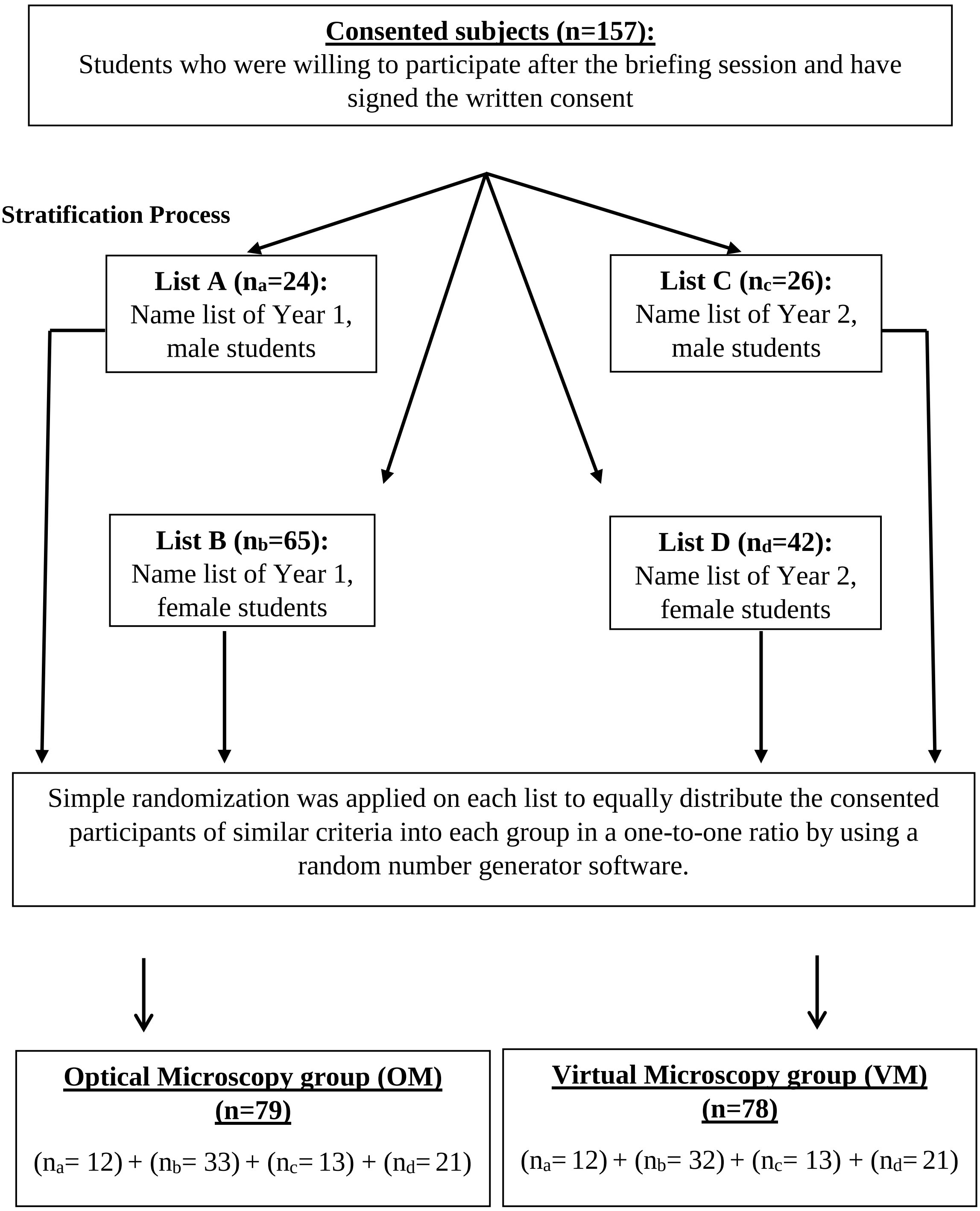

Figure 3.1: Group allocation through stratified random allocation

3.7 The intervention study

3.7.1 The histology topic

To eliminate the prior knowledge factor, a topic that was not in the undergraduate syllabus, which was histology of the eye was chosen. The learning outcomes of this topic are as follows:

1) Identify sclera and state its characteristic histological features
2) Identify cornea and its layers: a) Corneal epithelium, b) Corneal stroma, c) Corneal endothelium
3) Identify choroid and state its characteristic histological features
4) Identify ciliary body and its components: a) Ciliary process, b) Ciliary epithelium, c) Ciliary stroma, d) Ciliary muscle
5) Identify iris and its components: a) Anterior surface of the iris, b) Posterior surface of the iris, c) Iris stroma, d) Sphincter pupillae muscle
6) Identify retina and the different layers in retina: a) Retinal pigment epithelium, b) Layer of rod & cones, c) Outer nuclear layer, d) Outer plexiform layer, e) Inner nuclear layer, f) Inner plexiform layer, g) Ganglion cell layer, h) Optic nerve fibre layer
7) Identify the three chambers within the eye: a) Anterior chamber, b) Posterior chamber, c) Vitreous chamber

3.7.2 Practical preparation

This study used commercially available histology glass slides of the eyeball and iris obtained from GinkgoMed Company, Taiwan. A total of ninety slides of the eyeball and forty-five slides of the iris were selected after screening and meeting the criteria needed to fulfill the learning outcomes aforementioned. These were then packed into forty-five slide boxes containing three slides, which consisted of two slides of the eyeball and one slide of the iris to be used by the optical microscopy group. Two best eyeball slides and one best iris slide were chosen to be photographed at high magnification (40x) using a slide scanner (Zeiss Mirax Desk, Germany) available at the School of Dental Sciences, USM. The captured images were then stored in a multiresolution file format and uploaded into ninety computer desktops at the Computer Assisted Instruction (CAI) Lab of the School of Medical Sciences and School of Dental Sciences, USM. These virtual slides were prepared for the virtual microscopy group.

A total of ninety standard optical microscopes (Motic, China) were prepared at the multipurpose labs of both centres. Each microscope was carefully tested by viewing one histology eye slide to determine its state of function. Each microscope has a maximum magnification of 1000x using the 100x objective lens. However, participants were only allowed to use up to 400x magnification, using the 40x objective lens during the practical session of the optical microscopy group. The virtual microscope software was installed into ninety computer desktops at the CAI lab of both centres. The Pannoramic viewer software (Figure 2.3) was downloaded online from https://www.3dhistech.com/pannoramic_viewer. Examples of images of the virtual slides as viewed via the Pannoramic viewer software are shown in Figure 3.2 and Figure 3.3.

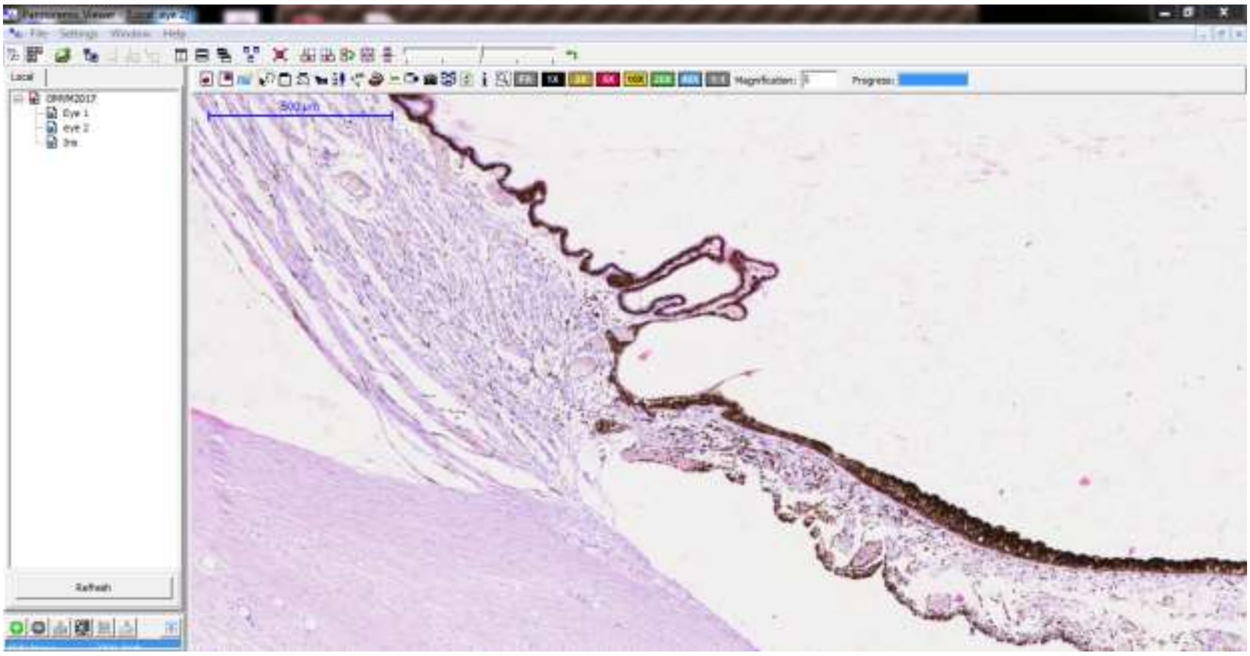

Figure 3.2: Virtual slide image of the eye. X5. (Image was taken from the Computer Assisted Instruction (CAI) laboratory, School of Medical Sciences, USM.)

Figure 3.3: Virtual slide image of the eye. X20. (Image was taken from the Computer Assisted Instruction (CAI) laboratory, School of Medical Sciences, USM.)

3.7.3 Method of intervention

This was a one-day intervention and it was carried out on a weekend. Registration of the participants started at 7.30 am, during which each participant was given a file containing stationaries, histology of the eye workbook, a note book, a few sheets of plain A4 papers and most importantly, one participant profile sheet which states the participants name and research identification number. Initially, all participants attended a one-hour lecture on histology of the eye delivered by a qualified anatomist with 7 years of experience in the lecture hall (Figure 3.4). The learning outcomes of the lecture is as aforementioned.

Figure 3.4: Participants attending a lecture on 'Histology of the eye'

All participants were then assembled in the laboratories to sit for a thirty minutes pre-practical assessment. Immediately after, a slide demonstration session was given by the same anatomist for 30 minutes. Afterwards, a short briefing was given regarding the practical session. All participants were forbidden to bring along any textbook into respective lab, to study other than during the allocated practical session and they were also asked to switch off their hand phones. Students were then called out according to their allocated intervention group; the optical microscopy group and the virtual microscopy group were ushered to their designated laboratories for their respective practical session.

During the one hour practical session (Figure 3.5), the participants from the virtual microscopy group were given individual computers and they were instructed to explore and identify histological structures of three different virtual slides using the virtual microscope software. A short briefing was given to them on using the virtual microscope before starting their practical session. Participants from the optical microscopy group were also given individual optical microscopes to use. However, there were not enough slides to accommodate a one-to-one ratio of participant and glass slide. Therefore, two students were made to share a set of slides and each set had three different histology slides similar to the virtual slides used by the virtual microscopy group. Throughout the practical session, a lecturer accompanied each group in their respective labs.

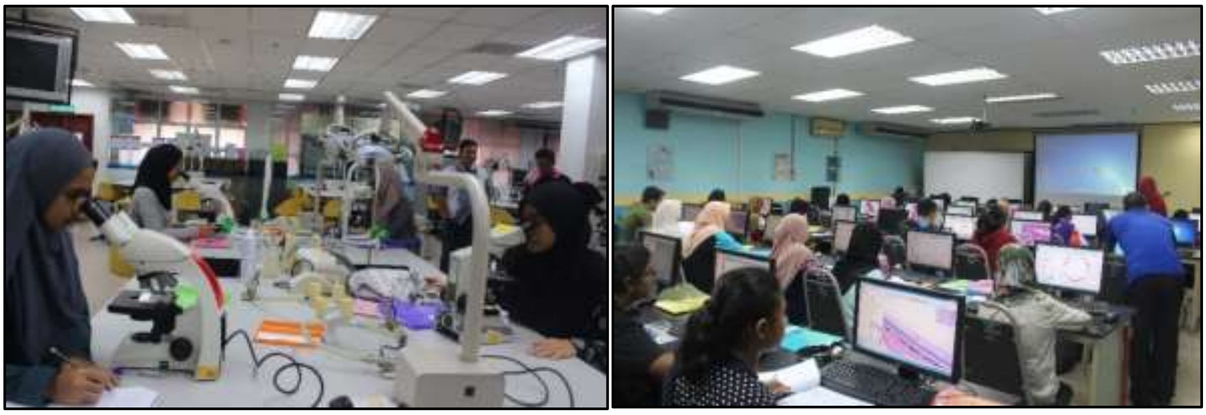

Figure 3.5: (Left) The practical session of the optical microscopy group. (Right) Practical session of the virtual microscopy group.

After the practical session, students reassembled at the initial laboratories and sat for a thirty minute post-practical assessment (Figure 3.6) and answered the survey questionnaire. After completing the survey, students were then dismissed.

Figure 3.6: Participants answering the post-practical assessment questions.

3.7.4 Time and venue of the study

This study was a one-day intervention and was held during the weekend on a Saturday, 2nd December 2017 from 7.30am to 3.00pm to avoid students' busy academic schedule. The whole intervention was held within the School of Medical Sciences and School of Dental Sciences, USM. The lecture session was held in Lecture Hall 2, School of Medical Sciences and the lecture content was prepared by a qualified anatomist, who delivered both the lecture and slide demonstration session. The practical session was done in two centres but with comparable environment. The practical session for virtual microscopy was held at the computer-assisted instruction laboratories (CAI-Lab) of the two centers. Whereas for the optical microscopy practical session, it was held at the multipurpose laboratories of the two centers. The pre-practical, post-practical assessments, histology slide demonstration and evaluation survey were held at the multipurpose laboratories of USM Medical School.

3.8 Data collection technique and measurement of variables

Data collection was done throughout the intervention day. To ensure anonymity of participants, all data were identified by participants' identification number. The summary of data construct, variables measured and the measurement tool used is presented in Table 3.1.

Table 3.1: Data construct, variables and measurement tools

Data construct	Variables measured	Measurement tool
Knowledge acquisition	1) Pre-practical assessment score	5-vetted pre-practical OSPE questions.
	2) Post-practical assessment score	5-vetted post-practical OSPE questions.
	3) Learning quotient score	5-vetted pre- and post-practical OSPE questions.
Students' satisfaction towards the learning tool in learning histology	4) Student's satisfaction score	Student's satisfaction survey
Students' intrinsic motivation towards the learning tool in learning histology	5) Students' intrinsic motivation score	Validated intrinsic motivation inventory

OSPE= objective structured practical examination

3.9 Variables & measurement tools

3.9.1 Variables

The five variables measured in this study (Table 3.1) were:

i. **Pre-practical assessment score**: This score was calculated to determine the baseline knowledge of the participants prior to the practical session. The score was determined by calculating the percentage of correct answers from five vetted objective structured practical examination (OSPE) questions of the pre-practical assessment. Normal marking system (without negative marking) was used for marking the answer sheets.

ii. **Post-practical assessment score**: This score is one of the knowledge acquisition measures of this study. The score was calculated as per previously mentioned pre-practical assessment. Likewise, normal marking system (without negative marking) was used for marking the answer sheets.

iii. **Learning quotient score**: Learning quotient is defined as an individual's learning potential or his/her ability to learn something new (Taylor et. al., 2005). This score is one of the knowledge acquisition measures of the study. This score was calculated using the learning quotient equation (Noda *et. al.,* 2009). In this equation, 'a' denotes the percentage of correct answers in the pre-practical assessment and 'b' indicates the percentage of correct answers in the post-practical assessment respectively.

Learning quotient (LQ) = [(b-a) / (100-a)] X 100

iv. **Students' satisfaction towards the learning tool score**: This score was used to determine students' overall satisfaction towards the learning tool given either the optical microscope or virtual microscope in learning histology.

v. **Students' intrinsic motivation towards the learning tool score**: The score was determined by calculating the mean score for each subscale, which are interest, perceived competence, pressure and value.

3.9.2 Measurement tools

The four measurement tools used in this study (Table 3.1) were:

i. **Pre-practical OSPE questions**: The pre-practical assessment included five test items or OSPE questions. Each item consisted of one printed photomicrograph and questions which included identification and stating characteristic histological features. The five OSPE questions were vetted by four qualified histologists and one medical educationist. The OSPE questions are as attached as Appendix C.

ii. **Post-practical OSPE questions**: The post-practical assessment was adapted from pre-practical assessment questions mentioned previously. The question sets were the same but labels and sequence arrangement were shuffled to avoid students memorizing the questions from prior pre-practical assessment. The OSPE questions are as attached as Appendix D.

iii. **Student's satisfaction survey**: The survey was a single item questionnaire requiring students to score their satisfaction from very dissatisfied, dissatisfied, neutral, satisfied to very satisfied. This was then converted to a range of numbers with very dissatisfied denoted by one to very satisfied represented by five. The satisfaction survey is as attached as Appendix E.

iv. **Intrinsic motivation inventory**: This survey was adapted from the validated Intrinsic Motivation Inventory (Ryan & Deci, 2000). The Intrinsic Motivation Inventory (IMI) is a multidimensional measurement tool designed to assess participants' subjective experience in regards to the activity or intervention during an experiment. It has been used in several studies related to intrinsic motivation and self-regulation (Ryan, 1982; Ryan, Koestner & Deci, 1991; Deci *et al.*, 1994). The survey consisted of four subscales; interest, perceived competence, pressure and value with a total of twenty-five items. Participants are requested to answer each item based on a five Likert scale; 1= Strongly disagree; 2= Disagree; 3=Unsure; 4=Agree; and 5=Strongly Agree. The interest subscale assess the participant's interest or enjoyment with regards to learning histology by using the learning tool. This subscale is considered to be a self-report measurement of the intrinsic motivation. Learning tool here refers to either virtual or optical microscope according to their respective groups. There are seven items in the interest subscale in which five are positive statements and two are negative statements. The perceived competence subscale assess the participant's perception on how well they performed the task given using the learning tool. The task here refers to identifying histological structures seen from their glass slides or virtual slides. This subscale had six items in which five are positive statements and one is a negative statement. For the pressure subscale, it measures how burdensome or anxious the participant felt while trying to identify histological features using either the virtual or optical microscope. There are three positive statements and two negative statements in this subscale. Lastly, the value subscale is to assess how much the participant appreciates and values learning histology using their respective learning tool either the virtual microscope or optical microscope. The Intrinsic Motivational Inventory of this study is as attached as Appendix E.

3.9 Data analysis

(a) Descriptive data study

Descriptive data analysis was performed using Statistical Package for the Social Sciences (SPSS) software, version 22 (IBM Corp., Armonk, NY) to calculate the demographic distribution of participants according to confounding factors.

(b) Inferential statistical analysis

The inferential statistical analysis was performed using SPSS version 22. The data was entered, checked for data entry error and missing values, explored and cleaned. Prior running the statistical test, assumptions for each were checked and significance level (α) was set at 0.05 with confidence interval of 95%.

Mann-Whitney test was applied to test the between group difference of the aforementioned variables. A non-parametric test was used because assumptions of the independent t-test were not met. The outcome variable were not normally distributed in each group. The changes in the assessment scores within the study group was analyzed using paired t-test after meeting all assumptions.

The correlation between students' post-practical assessment score and satisfaction score as well as learning quotient score and satisfaction score were analyzed using Spearman correlation test. This test was used because the assumption of bivariate normal distribution was not met. The scatterplots are shown as Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 in Chapter 4.

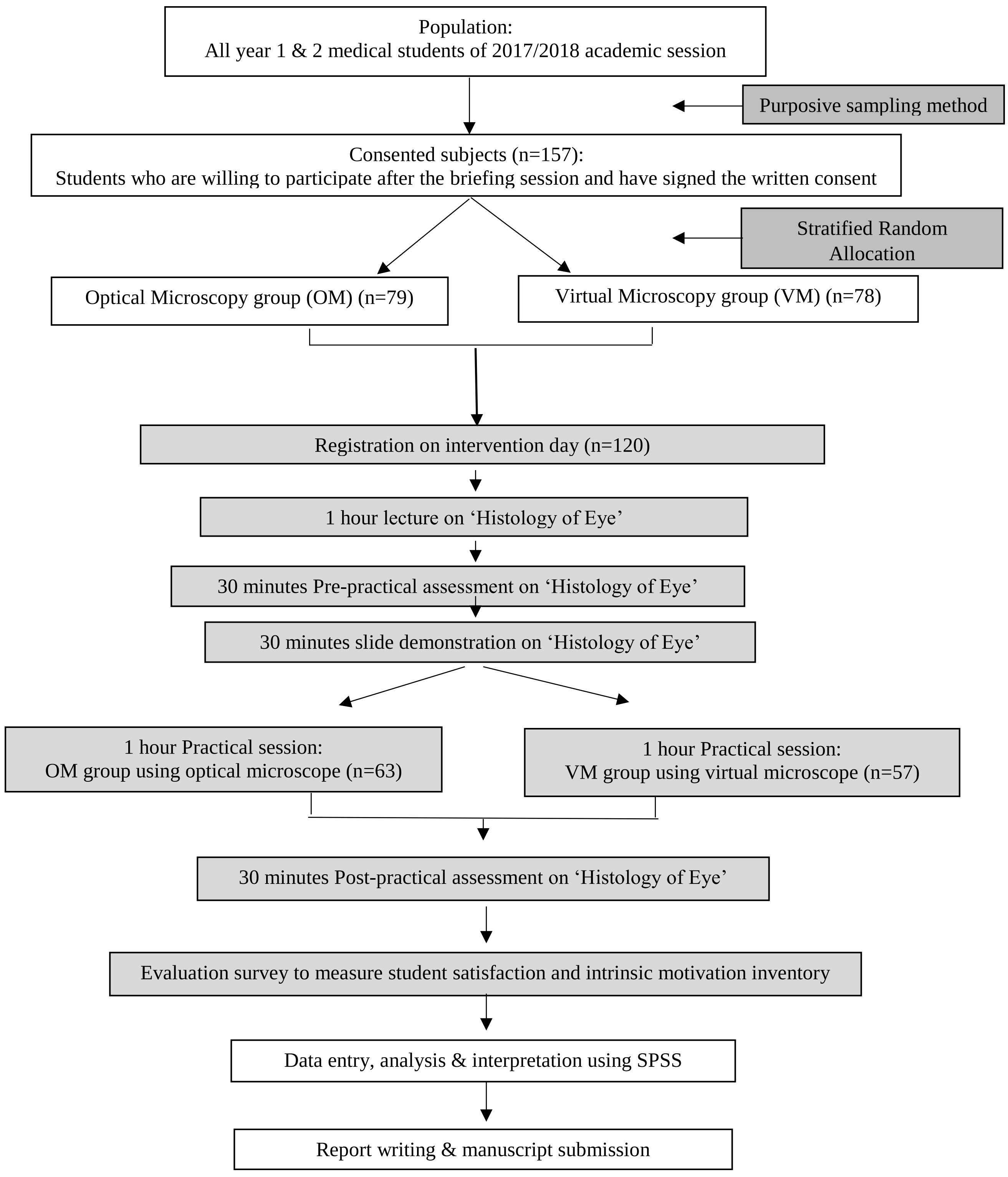

Figure 3.7: Research flowchart

CHAPTER 4

RESULTS

4.1 Descriptive analysis

4.1.1 Demographic profile of consented participants

A total of 157 consented participants were divided into the virtual microscopy group and the optical microscopy group using stratified random allocation. The two confounding factors controlled in this process were gender and year of study as shown in Table 4.1.

Table 4.1: Confounding factor profile distribution of the consented participants after stratified random allocation

Variables	Study group, Frequency (%)			X^2- statistic (df)	*p*-value
	Virtual Microscopy Group	Optical Microscopy Group	Total		
Gender:					
Male	25 (32.1%)	25 (31.6%)	50 (31.8%)	0.003 (1)	0.956
Female	53 (67.9%)	54 (68.4%)	107 (68.2%)		
Year of study:					
First year	44 (56.4%)	45 (57%)	89 (56.7%)	0.005 (1)	0.944
Second year	34 (43.6%)	34 (43.0%)	68 (43.3%)		

Pearson Chi-square test; Expected count less than 5 was 0%.

The Pearson chi-square test revealed no significant difference of the confounding variable profiles between the groups, and thus indicates that the stratified randomization had successfully distributed the participants into two homogenous groups.

4.1.2 Participation rate

From the 157 consented students, only 120 students registered and took part on the actual intervention day. The calculated participation rate was 76.43%. The sample size of this study lacked another eight participants to meet the estimated minimum sample size, which is 64 participants per group and 128 participants in total.

4.2 Knowledge acquisition measure:

4.2.1 Comparison of the pre-practical assessment score between study group

The pre-practical assessment score of the two study groups were compared to determine the students' baseline knowledge regarding 'Histology of the eye' topic prior to the practical session as shown in Table 4.2.

Table 4.2: Comparison of the pre-practical assessment score between the study groups

Variable	Mean (SD)		t- statistics (df)	*p*-value	Mean difference (95% CI)	Cohen effect size (*d*)
	Virtual Microscopy Group (n=57)	Optical Microscopy Group (n=63)				
Pre-practical assessment score	43.789 (22.584)	38.714 (23.199)	-1.212 (118)	**0.228**	5.075 (-13.368,3.217)	0.16

Independent t-test was applied to determine mean difference between study groups. Significance level was set at 0.05. SD= standard deviation; df = degree of freedom; CI= confidence interval. Cohen effect size was calculated using effect size calculator for t-test, (Statistics, 2015). Cohen effect size threshold: Small = 0.20, medium = 0.50 and large = 0.80, very large = 1.13 (Cohen, 1988).

The analysis revealed no significant difference in the pre-practical assessment score between the study groups, indicating that students in both groups have similar baseline knowledge on the histology topic.

4.2.2 Comparison of the post-practical assessment score between study group

The post-practical assessment score were compared between the study groups to evaluate student's knowledge after the practical session and results are shown in Table 4.3.

Table 4.3: Comparison of the post-practical assessment score between the study groups

Variable	Median (IQR)		z- statistics	*p*-value	Cohen effect size (*d*)
	Virtual Microscopy Group (n=57)	Optical Microscopy group (n=63)			
Post-practical assessment score	86 (18.5)	81 (29)	-1.935	0.053	0.43

Mann-Whitney test was applied to determine difference between study groups. Significance level was set at 0.05. IQR = Interquartile range. Cohen effect size was calculated using effect size calculator for t-test, (Statistics, 2015). Cohen effect size threshold: Small = 0.20, medium = 0.50 and large = 0.80, very large = 1.13 (Cohen, 1988).

We accept the null hypothesis, suggesting that no difference exists between the post-practical assessment score of the virtual microscopy group and optical microscopy group. The median (IQR) of score for the virtual microscopy group [86 (18.5)] was not significantly higher compared to the optical microscopy group [81 (29)], p=0.053. This result indicates that both study groups performed equally well in the post-practical assessment, reflecting improvement in their understanding of 'Histology of the Eye' after attending respective practical sessions.

4.2.2 Changes in assessment scores within each study group

Changes in the assessment scores were evaluated to determine the improvement in the assessment performance within each group as shown in Table 4.4.

Table 4.4: Changes in the assessment scores within group.

Group (n)	Assessment score Mean (SD)		Mean difference (95% CI)	t- statistics (df)	*p*-value	Cohen effect size (*d*)
	Pre	Post				
Virtual Microscopy Group (n=57)	43.789 (22.583)	82.298 (16.368)	38.508 (32.926, 44.091)	13.818 (56)	**>0.001**	1.83
Optical Microscopy Group (n=63)	38.714 (23.198)	73.793 (22.621)	35.079 (30.035,40.123)	13.902 (62)	**>0.001**	1.75

Paired t-test was applied to determine the change in assessment score within groups. Significance level was set at 0.05. SD= standard deviation; df = degree of freedom; CI= confidence interval. Cohen effect size was calculated using effect size calculator for t-test, (Statistics, 2015). Cohen effect size threshold: Small = 0.20, medium = 0.50 and large = 0.80, very large = 1.13 (Cohen, 1988).

The analysis revealed that both intervention and control group have significant improvement in assessment scores following the practical sessions. The mean assessment score of the virtual microscopy group improved from 43.789% to 82.298% and the mean assessment score for optical microscopy group improved from 38.714% to 73. 793%. The mean difference of the virtual microscopy group (38.508) is higher than the optical microscopy group (35.079).

4.2.3 Comparison of the learning quotient score between study groups

Using the pre-practical and post-practical assessment scores, the learning quotient score was calculated by applying the learning quotient equation as aforementioned. The result is shown in Table 4.5.

Table 4.5: Comparison of the learning quotient score between study groups.

Variables	Median (IQR)		z- statistics	*p*-value	Cohen effect size (*d*)
	Virtual Microscopy Group (n=57)	Optical Microscopy Group (n=63)			
Learning quotient score	76.812 (37.624)	68.421 (43.902)	-1.613	0.107	0.292

Mann-Whitney test was applied to determine the difference between study groups. Significance level was set at 0.05. IQR = Interquartile range. Cohen effect size was calculated using effect size calculator for t-test, (Statistics, 2015). Cohen effect size threshold: Small = 0.20, medium = 0.50 and large = 0.80, very large = 1.13 (Cohen, 1988).

The analysis showed no significant difference of learning quotient score between the study groups. The median (IQR) score for the virtual microscopy group [76 (37.624)] was not significantly higher compared to the optical microscopy group [68.421 (43.902)], p=0.107. Both the virtual microscopy group and the optical microscopy group have similar understanding of the histology topic after attending their respective practical session.

4.3 Satisfaction score

Table 4.6 shows the comparison of satisfaction score between the virtual microscopy group and the optical microscopy group.

Table 4.6: Comparison of satisfaction score between study groups.

Variable	Median (IQR)		z- statistics	*p*-value	Cohen effect size (*d*)
	Virtual Microscopy Group (n=57)	Optical Microscopy Group (n=63)			
Satisfaction score	5.00 (1)	4.00 (2)	-2.654	**0.008**	0.50

Mann-Whitney test was applied to determine the difference between study groups. Significance level was set at 0.05. IQR = Interquartile range. Cohen effect size was calculated using effect size calculator for t-test, (Statistics, 2015). Cohen effect size threshold: Small = 0.20, medium = 0.50 and large = 0.80, very large = 1.13 (Cohen, 1988).

We reject the null hypothesis, suggesting that a real difference exists between the satisfaction score of the virtual microscopy group and optical microscopy group. The median (IQR) of score for the virtual microscopy group [5.00 (1)] was significantly higher compared to optical microscopy group [4.00 (2)], p=0.008. This indicates students were significantly satisfied with the virtual microscope as a learning tool for histology.

4.4 Intrinsic motivation measures

The intrinsic motivation score was evaluated based on each subscale; interest; perceived competence; pressure; and value; and compared between the study groups. This is to determine whether the learning tool used had an effect on students' self-motivation to learn.

Table 4.7: Comparison of intrinsic motivation scores between study groups.

Variables	Median (IQR)		z- statistics	*p*-value	Cohen effect size (*d*)
	Virtual Microscopy Group (n=57)	Optical Microscopy Group (n=63)			
Interest score	29 (5.50)	27 (5.00)	-1.527	0.127	0.344
Perceived competence score	23 (4.50)	22 (6.00)	-2.085	**0.037**	0.474
Pressure score	10 (4.00)	11 (7.00)	-0.657	0.511	0.224
Value score	33 (4.00)	32 (7.00)	-1.505	0.132	0.341

Mann-Whitney test was applied to determine the difference between study groups. Significance level was set at 0.05. IQR = Interquartile range. Cohen effect size was calculated using effect size calculator for t-test, (Statistics, 2015). Cohen effect size threshold: Small = 0.20, medium = 0.50 and large = 0.80, very large = 1.13 (Cohen, 1988).

Table 4.7 shows that only the subscale of perceived competence showed a significant difference between the study groups. The median (IQR) of perceived competence score for the virtual microscopy group [23(4.50)] was significantly higher compared to optical microscopy group [22(6.00)], *p*=0.037. This indicates that the participants of virtual microscopy group felt they learned histology very well using the virtual microscope during practical session. For other subscales, there were no significant difference between the study groups. Hence, participants from both virtual and optical microscopy group were similar in terms of interest and pressure while using the learning tool. Furthermore, both study groups felt their respective learning tool were useful in learning histology.

4.5 Correlation between post-practical assessment score and satisfaction score

The correlation between post-practical assessment score and students' satisfaction score within each study group was evaluated. The scatterplot of both study groups are shown in Figure 4.1 and Figure 4.2. The results are shown in Table 4.8.

Figure 4.1: Scatterplot showing correlation between post-practical assessment score and satisfaction score of the virtual microscopy group.

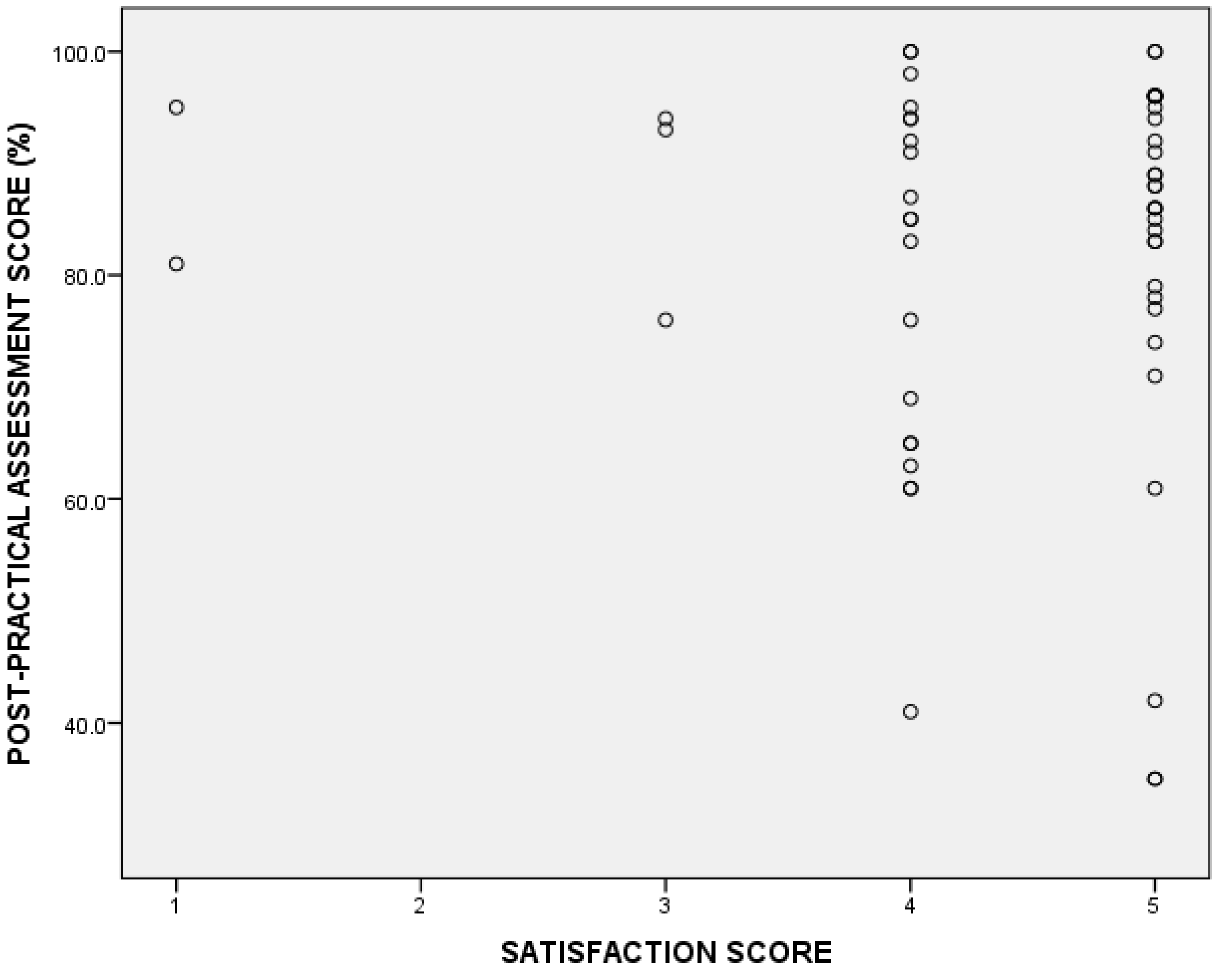

Figure 4.2: Scatterplot showing correlation between post-practical assessment score and satisfaction score of the optical microscopy group.

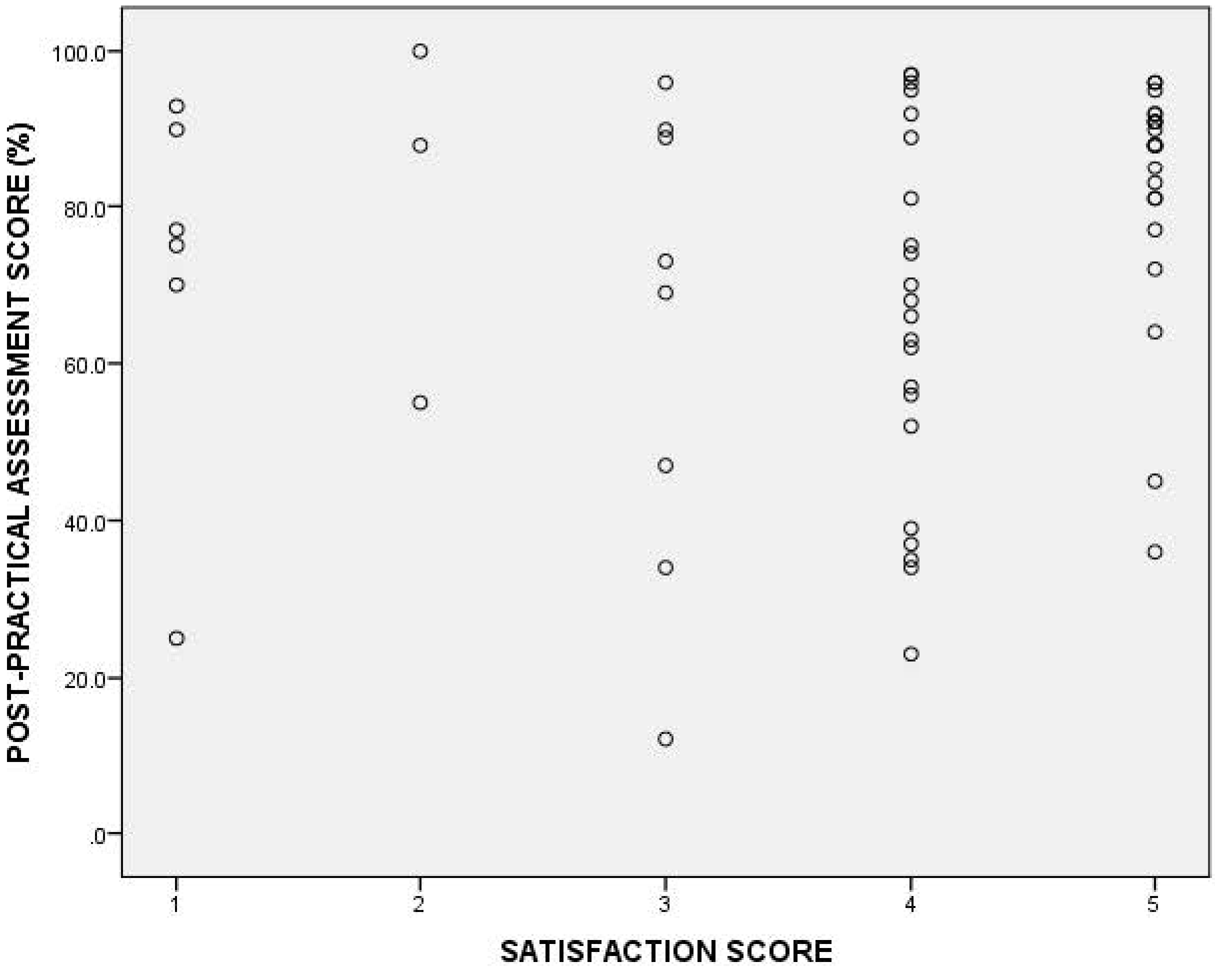

Table 4.8: Correlation between satisfaction score and post-practical assessment score

	Correlation coefficient (r_s)	
	Satisfaction[a]	Satisfaction[b]
Post-practical score	0.049	0.2
p-value	0.716	0.122

[a]Virtual Microscopy Group (n=57), [b]Optical Microscopy Group (n=63)
Spearman correlation was used to determine the strength of relationship. Significance level set at 0.05

The analysis shows that there is no significant correlation between students' satisfaction score and their post-practical assessment score in both study groups. This indicates that students' satisfaction towards the learning tool has no relation to their performance during post-practical assessment.

4.6 Correlation between learning quotient score and satisfaction score

The correlation between students' satisfaction score and learning quotient score within each study group was evaluated. The scatterplot of both study groups are shown in Figure 4.3 and Figure 4.4. The results are shown in Table 4.9.

Figure 4.3: Scatterplot showing correlation between learning quotient score and satisfaction score of the virtual microscopy group.

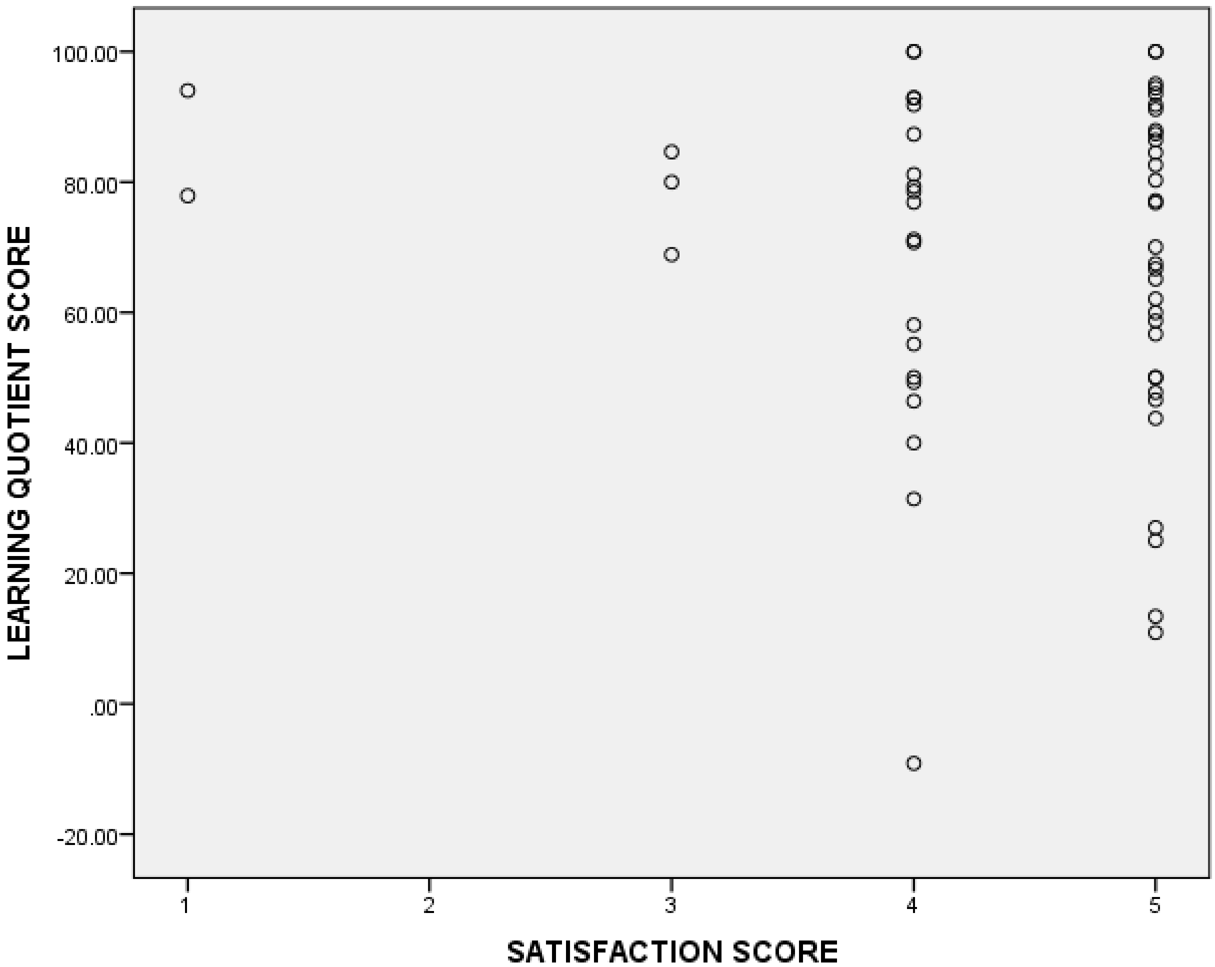

Figure 4.4: Scatterplot showing correlation between learning quotient score and satisfaction score of the optical microscopy group.

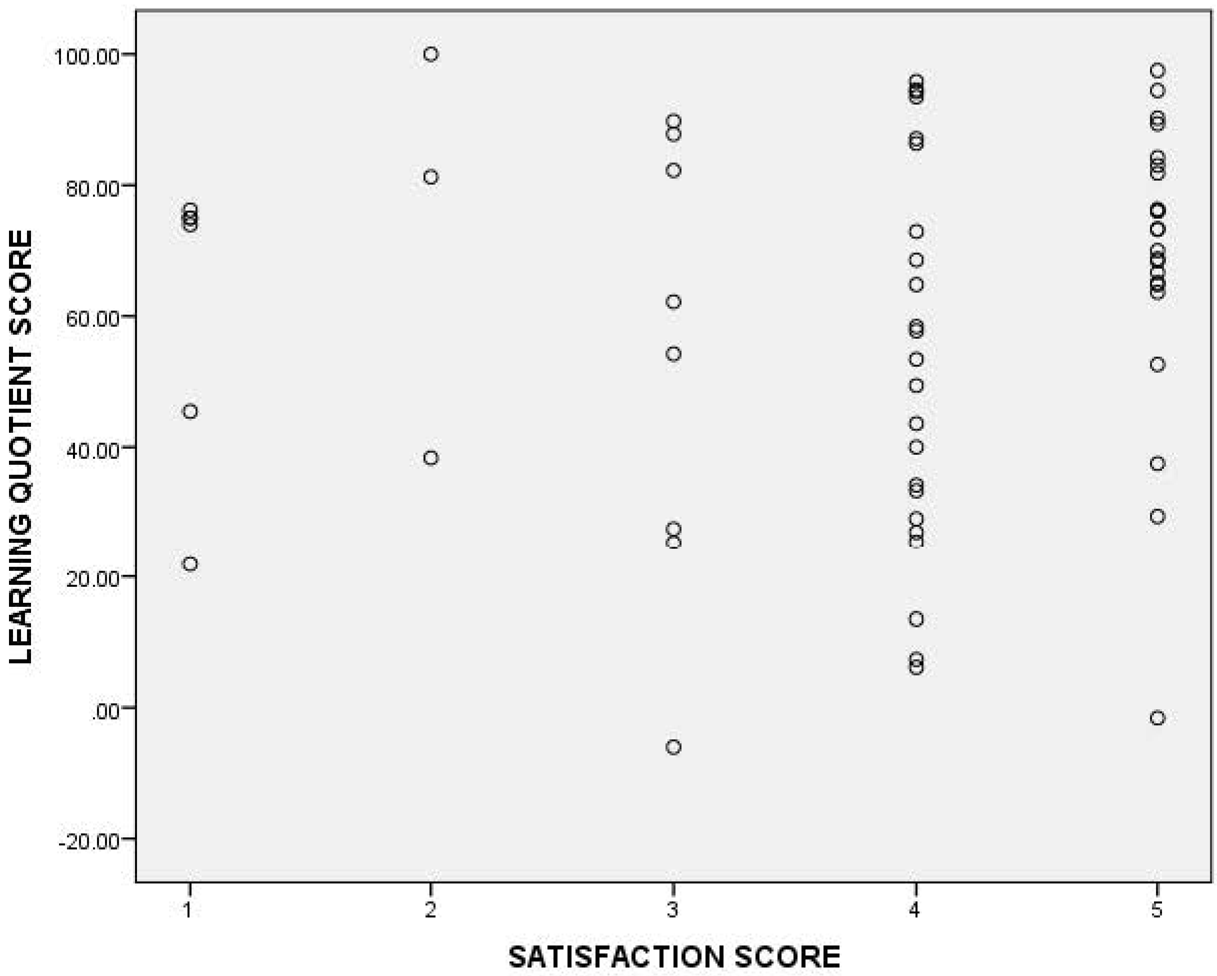

Table 4.9: Correlation between satisfaction score and learning quotient score

	Correlation coefficient (r_s)	
	Satisfaction[a]	Satisfaction[b]
Learning quotient score	-0.087	0.131
p-value	0.519	0.306

[a]Virtual Microscopy Group (n=57), [b]Optical Microscopy Group (n=63)
Spearman correlation was used to determine the strength of relationship. Significance level set at 0.05

The analysis shows that there is no significant correlation between students' satisfaction score and their learning quotient score in both study groups. This indicates that students' satisfaction towards the learning tool has no relation to the students' understanding of the histology topic.

4.7 Summary of the results

In summary, the findings yield were;

1. The number of sample size did not meet the estimated minimum sample size, which is 64 subjects per group.
2. The non-response rate, 23.57% was larger than the anticipated non-response rate.
3. The stratified random allocation had successfully distributed the study subjects into two homogenous groups.
4. Three outcome measures were found to be significant as summarized in Table 4.10.

Table 4.10: The results according to hypothesis outcomes.

Hypothesis	Findings	Null hypothesis outcome
1(a)	There is no significance difference in the post-practical assessment score between the study groups.	Accepted
1(b)	The changes in assessment score in the virtual microscopy group is higher compared to optical microscopy group	Rejected
1(c)	There is no significant difference in the learning quotient score between the study groups.	Accepted
2	The virtual microscopy group has significantly higher satisfaction score than the optical microscopy group.	Rejected
3(a)	There is no significant difference of interest score between the study groups	Accepted
3(b)	The virtual microscopy group has a significantly higher perceived competence score than the optical microscopy group.	Rejected
3(c)	There is no significant difference of the pressure score between the study groups	Accepted
3(d)	There is no significant difference of the value score between the study groups	Accepted
4	There is no significant correlation between the satisfaction score and the post-practical assessment score within both study groups	Accepted
5	There is no significant correlation between the satisfaction score and the learning quotient score within both study groups	Accepted

5. The effect of virtual microscopy on the outcome variables are highly evident through small to very large Cohen effect size as summarized in Table 4.11

Table 4.11: The effects of virtual microscopy on the outcome variables

Outcome measures	Variables	Cohen effect size (*d*)	Interpretation of Cohen effect size
Knowledge acquisition	1. Post-practical assessment score 2. Learning quotient score 3. Pre to post-practical assessment score	0.43 0.29 1.83	Small to very large effects
Satisfaction level	1. Satisfaction score	0.50	Medium effects
Intrinsic motivation	1. Interest score 2. Perceived competence 3. Pressure score 4. Value score	0.344 0.474 0.341 0.224	Small to medium effects

Cohen effect size was calculated using effect size calculator for t-test, (Statistics, 2015). Cohen effect size threshold: Small = 0.20, medium = 0.50 and large = 0.80, very large = 1.13 (Cohen, 1988).

CHAPTER 5

DISCUSSION

5.1 Introduction

In this chapter, the findings of this study are discussed and limitations, implications of the virtual microscopy as well as recommendations are also elaborated.

5.2 Descriptive analysis of participant's profile distribution

Descriptive analysis of participants' profile distribution was done to ensure that the factors between the two study groups are comparable from the beginning until the end of the study. The participation rate was calculated to ensure that the accuracy of the findings and prevent misleading results due to sample size. The discussion of this section is grouped under 2 subheadings: i) Participation rate and ii) Demographic profile of the participants.

5.2.1 Participation rate

As mentioned in the previous chapter, the participation rate for this study was less than 80% which was lower than expected. The minimum estimated sample size was not met. The main reason for the high non-participation rate was due to a conflict in the schedule. Some of the first year and second year students had other academic activities on the same day of the research. Furthermore, these academic activities were compulsory. Due to this scheduling conflict, students opted out from volunteering for this study.

The research day was initially postponed a few times due to the same reason above. Eventually due to time constraint, we decided to proceed with the best date that had the most response from students. However, some academic activities were arranged by respective lecturers in short notice. Attempts to negotiate with the lecturer in-charge was considered, however it was abandoned due to the ethical conflict in this study in which, stated that this study must not interfere with students' academic activities.

Therefore due to the small sample size, the power of study for significant results in this study were recalculated to determine its reliability using the G*Power calculator, a statistical power analysis program for the social and behavioral sciences (Faul *et al.*, 2007). Results will be shown accordingly in the following subheadings in this chapter.

5.2.2 Demographic profile of the participants

The demographic profile of the participants was re-evaluated due to the high non-participation rate aforementioned. This study's total sample size was 120; 57 subjects in the virtual microscopy group and 63 subjects in the optical microscopy group. To ensure the validity of results of this study, the demographic profile of participants was re-analyzed and the result is shown in Table 5.1.

Table 5.1: Confounding factor profile distribution of the actual participants

Variables	Study group, Frequency (%)			X^2- statistic (df)	*p* - value
	Virtual Microscopy	Optical Microscopy	Total		
Gender:					
Male	17 (29.8%)	20(31.7%)	37 (30.8%)	0.052 (1)	0.82
Female	40 (70.2%)	43(68.3%)	83 (69.2%)		
Year of study:					
First year	23 (40.4%)	30 (47.6%)	53 (44.2%)	0.641 (1)	0.423
Second year	34 (59.6%)	33 (52.4%)	67 (55.8%)		

Pearson Chi-square test; Expected count less than 5 was 0%.

The Pearson chi-square test revealed no significant difference in the confounding factor profile between the study groups. This indicates that the stratified random allocation had successfully distributed the participants into two homogenous groups despite the high non-participation rate. Therefore, we can confidently report that the outcomes of this study are not due to gender or age bias.

5.3 Outcome measures

5.3.1 Knowledge acquisition

The students' knowledge acquisition is better when using the virtual microscope as a histology learning tool. The virtual microscopy group outperformed the optical microscopy in terms of improvement in assessment score. However, the virtual microscopy group performed similarly well with the optical microscopy group in regards to comprehension and learning ability.

5.3.1.1 Level of comprehension

The analysis showed that there was no significant difference of post-practical assessment score between the virtual microscopy group and the optical microscopy group (Table 4.3). The post-practical assessment reflects how much the students understand regarding the histology topic after attending their respective practical sessions. Hence based on the result, the virtual microscope and optical microscope have similarly enhanced the students' understanding of the histology topic.

The Cohen effect size was calculated to determine the magnitude effect of the virtual microscopy on this result. The calculated Cohen effect size was 0.43, indicating that this result is probably due to the effect of virtual microscope. The students' level of comprehension was similar when using either the virtual microscope or the optical microscope.

Our result is in keeping with a few previous studies which showed no significant difference in post test scores between the virtual microscopy and optical microscopy groups (Helle *et al.*, 2011; Mione *et al.*, 2013; Ordi *et al.*, 2015). The authors concluded that although virtual microscopy was not significantly better, it is comparable and can effectively replace optical microscopy. Another study showed significant difference in post-test score between the study groups (Hande *et al.*, 2017). In this study, three groups were compared. The first group used the optical microscope, second group used the virtual microscope and the last group used both microscopes. The result revealed that the virtual microscopy outperformed the other two groups in terms of comprehension. The author reported that the enhanced understanding may be due to the many benefits of the virtual microscopy. The mentioned benefits were that the virtual slides could easily be annotated and that virtual microscopy made discussion among students easier. In contrast, the present study did not use annotations and participants were not allowed to discuss during the practical session. Therefore, this could be a factor resulting in contrasting study results.

In the study done by Helle *et al.* (2011) which had a similar result with the present study, all participants of this study were never exposed to virtual microscopy prior to the study. During the study, they were exposed to the tool in a short one week period. The author mentioned that integration of modern technology into the traditional teaching method does not occur overnight. Similarly in this present study, the 1 hour practical session was the virtual microscopy participants' first encounter with the virtual microscope. Students require time to adapt to the new virtual microscope to be able to benefit from it optimally. Hence, to have students of the virtual microscopy group score similarly to the optical microscopy group with only an hour of exposure reflects the efficiency of the virtual microscopy.

Furthermore, the participants of the optical microscopy group had deliberate practice using the optical microscope during regular histology practical sessions especially for the second year students. This condition gave the optical microscopy group an upper hand. This is supported by a study done on the effects of deliberate practice of music instruments on professional performance. The study revealed that deliberate practice enhances an individual's performance (Ericsson *et al*., 1993). Therefore in the present study, deliberate practice enhances students' academic performance. Hence, the result of the current study could be due to this factor.

5.3.1.2 Improvement of knowledge

The results showed that both study groups have statistically significant changes in assessment score from pre-practical to post-practical assessment as shown in Table 4.4. However, the virtual microscopy showed a higher mean difference score than the optical microscopy group. Changes in assessment scores reflects the students' improvement of knowledge from prior to attending the practical session until after attending the session.

The calculated Cohen effect size of both the virtual and optical microscopy group, 1.83 and 1.75 respectively were very large, indicating that the significant improvement in the assessment score was most likely due to the intervention itself. The recalculated power of study was 100% for the changes in assessment score for the virtual microscopy group and likewise for the optical microscopy group. Therefore, these results are reliable.

There were limited previous studies done on the changes in assessment score within the virtual microscopy and optical microscopy groups. One study reported that there was a significant difference between the students' first examination and second examination scores. This study's finding was in keeping with our findings. However, in this study all students were exposed to virtual microscopy (Husmann *et al.*, 2009). Therefore, no comparison can be made to the optical microscopy as only the virtual microscope was tested in the study. The author concluded that the virtual microscopy required less time for students to master the handling of the software. This resulted in students being able to improve their knowledge at a much faster rate.

As aforementioned in the previous subheading, Hande *et al.* (2017) reported a significant difference in score improvement within three study group. The first group used the optical microscope, second group used the virtual microscope and the last group used both microscopes. The study group that used both the virtual and optical microscope outperformed the other two study groups. Furthermore, the study group that used the virtual microscopy alone outperformed the optical microscopy group. The author reported that the findings could be due to the increased effectiveness of the learning method when using the virtual microscopy and the optimal efficiency was achieved when the two tools were used in combination. Both studies above reflect the efficiency of virtual microscopy in reducing the amount of time needed to understand technology and thus indirectly obtaining information at a faster pace. As for the present study, it cannot be concluded that the virtual microscopy group's improvement in knowledge was significantly higher than the optical microscopy group. Further test is needed to control other hidden factors such as time.

5.3.1.3 Learner's learning ability

The analysis showed no significant difference in the learning quotient score between the study groups (Table 4.5). As aforementioned, learning quotient score reflects an individual's ability to learn new things (Taylor *et al*., 2005) and in this study, the participant's ability to learn about histology of the eye. Based on the result, the learning ability of both the virtual microscopy and optical microscopy groups equipped with their respective learning tools were similar. Based on the calculated Cohen effect size, the impact of the intervention on learning quotient score was small to medium (d=0.29). Therefore, this result is probably due to the effects of their respective tools.

No previous study was found to have measured learning quotient score in comparing the effects of virtual microscopy and the optical microscopy. However, a study by Ericsson *et al.* (1993) as aforementioned, revealed that deliberate practice enhances not only individual performance but also enhances an individual's learning ability. The result showed that repetitive purposeful practice on the learning tool helps the learner to adapt better to the learning environment. In this present study, participants from the optical microscopy have previously been using the optical microscope during their regular histology practical sessions. The optical microscopy group were already accustomed to their learning tool and this was an advantage to them. In contrast, the virtual microscope was a new learning tool to the participants of the virtual microscopy group. Although having the disadvantage, the virtual microscope still proved to similarly enhance students' learning ability as compared to the accustomed optical microscope.

5.3.2 Satisfaction level

The analysis revealed there was a significant difference of satisfaction score between the study groups as shown in Table 4.6. The analysis showed that the median satisfaction score for the virtual microscopy group was significantly higher than the median satisfaction score of the optical microscopy group. The calculated Cohen effect size was medium, 0.50 therefore indicating that the result was most probably due to the intervention. The recalculated power of study was 57%. Hence, it is suggested that this result to be used with caution.

While there were several studies that reported on students' opinion, there were limited studies done specifically on satisfaction level towards virtual microscopy or optical microscopy. One study showed students' high acceptance towards virtual microscope. In the study, there were three study groups; group A used the optical microscope, group B used the virtual microscope and group C used both virtual and optical microscopes. The study groups were compared in terms of their satisfaction level. Result of the study showed 87.61% of the students from group B and C strongly agreed that the virtual microscopy was useful as a practical learning tool. Group A was not exposed to the virtual microscope and hence was not asked regarding their satisfaction towards the virtual microscopy (Hande *et al.*, 2017).

A few other studies have reported on students' opinion and revealed that students are in favor of virtual microscope (Blake *et al.*, 2003; Helle *et al.*, 2011; Krippendorf and Lough, 2005). The authors further elaborated that their findings were due to the many virtues of the virtual microscopy as mentioned before in Chapter 2 including the virtual microscopy having excellent resolution.

5.3.3 Intrinsic motivation

Under this subheading, the intrinsic motivation will be elaborated according to each subscale; i) interest score; ii) perceived competence, iii) pressure score, and iv) value score.

5.3.3.1 Interest score

The result of this study showed no significant difference in interest score between the study groups (Table 4.7). The virtual microscopy group and the optical microscopy group similarly found learning histology to be interesting using their respective tools. The calculated Cohen effect size was 0.344, indicating that this result was probably due to effects of the intervention itself. There were very limited studies which reported the effects of virtual microscopy on intrinsic motivation. One of which was conducted by Helle *et al*. (2010) and showed similar result on interest score. Her study revealed that there were no significant difference in interest score between the virtual microscopy group and optical microscopy group. She mentioned that the short one-week period of exposure to the virtual microscopy could be a factor of the result. Students of the virtual microscopy group have only begun to familiarize their selves with the learning tool. They require more time to adapt to the new tool to be able to enjoy learning histology with it. This was a similar condition to the present study in which participants were only exposed to the virtual microscope for an hour period.

One previous research by Granito and Chernobilsky (2012), investigated on the effect of technology on a student's motivation. This study revealed that when given the option between completing a paper-based project and completing a computer-based project, the students were equally divided in terms of their preference. The study also revealed that students who chose to complete their projects using provided technology scored significantly higher than students who were forced to use the provided technology. The authors reported that a student's background, personal preference, previous experience using technology and availability of technology at home could be factors affecting a student's interest as well as motivation to learn. Therefore, these factors could also be affecting participants of the virtual microscopy group.

Furthermore, the interest subscale is considered the self-report measure of the intrinsic motivation inventory (Monteiro *et al*., 2015). Like other self-report measures, the interest subscale alone cannot be simply interpreted. Many factors must be considered such as ego-involvements, self-presentation styles and other psychological dynamics. Hence, the non-significant difference in interest score between the virtual microscopy group and the optical microscopy group of this present study could possibly be due to the above factors as well.

5.3.3.2 Perceived competence score

Out of the four measured subscales, perceived competence was the only one that showed a significant difference between the two study groups (Table 4.7). The virtual microscopy group had a significantly higher perceived competence score than the optical microscopy group. The calculated Cohen effect size was medium (d=0.47), therefore indicating that this result was most probably due to the effect of the virtual microscopy. However, the recalculated power of study was 73%, therefore the use of this result should be with caution.

The result was in keeping with previous studies which reported that students commented that the virtual microscopy was user-friendly (Hande *et al.*, 2017; Ordi *et al.*, 2015). In contrast to a previous study by Helle *et al.* (2010), the study revealed no significant difference in perceived competence between the virtual microscopy and the optical microscopy group. The virtual microscopy group commented that they had difficulty in terms of viewing and creating annotations. This could be a factor that had affected students' perceived competence in the study done by Helle *et al.* (2010). In contrast, the annotation feature was not used in the present study and this could probably explain the differing results.

In the current study, participants of the virtual microscopy group perceived that they learned histology better. They perceived that they could identify histological features of the eye well when using the virtual microscope. This could be possibly be due to that participants of the virtual microscopy group obtained a clear and focused image of the cell structure faster as compared to the optical microscopy group. This is further supported by previous studies which reported that the images of the virtual microscopy were always in focus with optimized contrast (Kumar *et al.*, 2006; Ordi *et al.*, 2015).

On the other hand, the optical microscopy group of the present study felt that they were less competent in learning histology of the eye. This is most likely because the optical microscope requires participants to adjust focus and illumination before obtaining a clear focused image of the histology slides. Hence, the difficulty in obtaining a clear and focused image gave the participants an impression that they were less competent. Glass slide variability is also one factor that could have given the optical microscopy participants the perception of being less competent in learning as reported by Bloodgood and Ogilvie (2006). If a student was given a good quality tissue section, he or she would be able to identify the histological features of the tissue well enough and perceive himself or herself to be competent. Whereas if another student was given a tissue section of less quality, he or she would have slight difficulty in identifying the histological features and this student would perceive himself or herself as less competent. In the present study, the quality of the slides in terms of sectioning and staining were carefully screened. However, the discrepancy between the glass slides cannot be eliminated. Dissimilar to the glass slides, the virtual slides were produced after selecting the single best quality section and were identical. Hence, all participants of the virtual microscopy group received identical virtual slides of the best quality.

5.3.3.3 Pressure score

The analysis as shown in Table 4.7, revealed no significant difference of pressure score between both study groups. Both the virtual microscopy and optical microscopy group felt less pressured when using their respective learning tools. Supported by the small effect size of 0.224, this result was due to the effects of the intervention.

This result was in contrast to a study done using the Intrinsic Motivation Inventory, which revealed that the virtual microscopy had a significant lower pressure score (Helle *et al.*, 2011). However, in this study students in the virtual microscopy group were allowed to self-study in their rooms and they were provided with homework besides attending the lab demonstrations. The optical microscopy group had to attend the regular demonstration led by their lecturer only. The freedom to study at student's own place, pace and time with an easily accessible virtual microscope might have reduced their anxiety and stress level in learning histology. Participants in the present study were not exposed to the virtual microscope outside the allocated practical session. Hence, this could possibly explain the dissimilarity of the results.

In this current study, the students of the optical microscopy group had deliberate practice using the tool since early first year. Having already developed the basic skills of using the optical microscopy, they were comfortable with their tool and felt less pressured learning histology of the eye. As for the virtual microscopy group, participants were comfortable using their learning tool despite being new to them. The virtual microscope is easily accessible on the computer, the virtual slides were easy to open from files and when the slide images appeared they were already in focus. The participants only have to drag the cursor to change fields and select the magnification buttons to reduce or increase magnification of the image. The above conditions could probably be the reason as to why both study groups scored similarly in the pressure subscale.

5.3.3.4 Value score

Result from Table 4.7 showed that there was no significant difference in the value score between the study groups. Both groups rated similarly on this subscale and the calculated Cohen effect size was small to medium, 0.341 indicating that the result of this measurement was probably due to the effects of the intervention. This result was in contrast with the study done by Helle *et al.* (2010), which revealed that the value score of the optical microscopy was significantly higher than the virtual microscopy. In this study again, the virtual microscopy group had their first encounter with the tool and was only exposed to it for one week. As aforementioned, the integration of modern technology into the conventional teaching method does not occur overnight (Helle *et al.*, 2011). Students could not appreciate the new virtual microscope as compared to their accustomed optical microscope. Another study revealed that even after successful transition to the virtual microscope, there were still 25% of the medical students who found it useful to use both the virtual and optical microscopes (Blake *et al.*, 2003).

Based on the result of the present study, the virtual microscopy group felt the tool was very useful in learning histology despite it being new to them. They valued the many advantages of the learning tool, which had effectively assist them in learning histology. As for the optical microscopy participants, they too valued their learning tool in which they were accustomed to. Getting accustomed to the optical microscopy would especially be beneficial for those interested in pursuing pathology as a career.

5.3.4 Association between satisfaction score and: a) post-practical assessment score, b) learning quotient score.

The results as shown in Table 4.8 and Table 4.9, showed that there were no significant association between the post-practical assessment score and satisfaction score likewise the learning quotient score with satisfaction score. No previous study had reported any investigation into the relationship between similar variables of this present study. However as aforementioned, a comparable study was done in the University of Benadir, Somalia. The study showed that there is a strong relationship between satisfaction of students and academic performance (Dhaqane, 2016). The author concluded that students' satisfaction promotes their academic achievement. In contrast to Dhaqane's study, no significant association between students' academic performances when using the virtual microscope with their satisfaction towards using virtual microscope in learning histology was found. Similarly, no significant association was found between the above variables of the optical microscopy group. This could probably be because Dhaqane (2016) assessed students' satisfaction not only towards their learning method but also assessed students' satisfaction towards the university services and facilities as a whole. The university services and facilities could be an affecting factor of student's academic achievement which was not assessed in the present study.

Another study conducted by Oja (2011) also reported that student performance was statistically related to satisfaction ratings. In this study, the satisfaction was measured using the Noel-Levitz Student Satisfaction Inventory (SSI) which measures student satisfaction in 12 different areas relevant for academic institutions such as student services and academic counseling. The study showed that students with lower grades were found to be less satisfied in several areas that they rated as important such as academic counseling, efficiency of registration, service excellence, and campus climate. Similar to the aforementioned study by Dhaqane (2016), the contrasting results of the current study with the study done by Oja (2011) are probably due to the difference in the assessed areas of student satisfaction. The present study measured satisfaction using a single item satisfaction survey and assessed student satisfaction towards the learning methodology alone.

Another comparable study reported that student satisfaction is not related to actual learning behaviour and academic performance (Rienties and Toetenel, 2016). In the study, results showed that the learning design instead had a significant correlation with learning behaviour and academic performance. Furthermore, the author reported that the best predictor for student academic performance was whether there were collaborative learning activities, such as group discussions and online tuition sessions in the learning module. This supports the present study findings that students' satisfaction does not relate to students' academic performance.

Moreover, the non-significant findings of this study were maybe due to the small sample size of the present study. Besides that, it is possible that the lack of variability in the satisfaction score variable affected the strength between the two variables. This is supported by a study which reported that the value of correlation coefficient (r) will be greater if there is more variability in the data as compared to if there is less variability. Variability here refers to the range value in variable x or y (Goodwin and Leech, 2006). Looking at this present study, x represented the satisfaction score and y represented either post-practical assessment score or learning quotient score. While the y variables had more variability ranging from 0 to 100, the satisfaction score variable had less variability which ranged from 1 to 5.

Furthermore, looking at the scatterplot in Figure 4.2 and Figure 4.4, there were no obvious pattern of linear relationship between the satisfaction score and post-practical score as well as between the satisfaction score and learning quotient score of the optical microscopy group. Whereas the scatterplot in Figure 4.1 and Figure 4.3, show there were little data distributed over satisfaction score of 1 to 3 of the virtual microscopy group and data distribution appears to be more crowded over the higher satisfaction score and post-practical assessment score. This probably shows that some isolated factors had affected a small number of participants in the virtual microscopy group.

5.4 Limitations of the present work

In this study, there were a few limitations. One of which is regarding the small sample size. As aforementioned, it was mainly due to the scheduling conflict. It was difficult to find a suitable time during the students' weekend. It was more difficult to find time which matched both the first year and second year medical students' schedule. Small sample size affected some of the results in this study such as the results of the association between satisfaction score and post-practical score.

Secondly, the satisfaction survey was based on a simple framework. It generally assessed participants overall satisfaction using their respective tools in learning histology based on a 5 Likert scale. Another limitation was that we lacked computers in our labs and could not accommodate all the participants in one computer lab. Therefore, both the virtual and optical microscopy groups were further divided into two small groups. One small group of the virtual microscopy and one small group of the optical microscopy had their practical session at the nearby School of Dental Sciences, Computer Laboratory and Multipurpose Biology

Laboratory. However, these laboratories were all a comparable environment for the participants.

Thirdly, the student's prior experience of using the optical microscope was an overlooked factor. Having deliberate practice not only affected the student's knowledge acquisition, but the intrinsic motivation too as discussed in the previous subheadings.

5.5 Recommendation for future research

5.5.1 Methodology

Addressing the limitations in this present research, it is suggested for the future research to increase the sample size in the future study and the target population should be first year medical students only excluding repeating students. This condition will minimize the possibility of prior experience using the optical microscope. Furthermore, it would be great to integrate the study into the official academic program structure addressing the limitation of the short intervention period, minimize scheduling conflict and increase sample size by allowing all students to participate. The intervention period can be prolonged and more follow up study can be done. Lastly, the usage of repeated measure ANOVA is suggested to minimize hidden factors that could affect the result. As for the present study, application of repeated measure ANOVA is suggested to clarify any hidden factors that were missed such as time.

5.5.2 Study settings

Firstly, it is suggested that a study be done on the efficacy of virtual microscopy resolving large group discussion issue which was one of the concerned issues. Large groups of students should be formed and each group be made to share one virtual microscope. The efficacy of the virtual microscopy can be measured using pre- and post-large group discussion scores. The relevance of comparing to a large group discussion using an optical microscope should be further discussed. Next suggestion is a study be done to investigate whether virtual microscopy effectively reduces laboratory hours and still delivers the same amount of knowledge compared to optical microscopy as reported by previous study (Cotter, 2001). Lastly, to thoroughly compare the benefits of the virtual microscopy and optical microscopy, it is suggested that an investigation on the cost of purchasing, repairing and maintaining respective tools be done.

5.6 Implications of the present work

Proven by the result of this study, the virtual microscope can be beneficial if used as a collaborative learning tool together with the optical microscope. These two tools can be used aligned with the respective lecture or practical learning outcome. When the learning outcome requires more focus on skills of handling an optical microscope, students may use the optical microscope. Likewise, when the learning outcomes are cognitively heavy, students may use the virtual microscope. The successful learning of histology requires a balance between virtual microscopy and optical microscopy.

Many studies have reported successful transition to the virtual microscopy (Blake *et al.,* 2003, Husmann *et. al.,* 2009, Krippendorf and Lough, 2005, Ordi *et al.,* 2014). However, there are also those who opt to integrate both learning tools. The virtual microscope has advantages that the optical microscope lacks hence, may serve as a complimentary tool to each other (Granito and Chernobilsky, 2012, Hande *et al*., 2017, Hussein *et al*., 2015, Scoville and Buskirk, 2007). This innovative learning method can have a big impact on the field of self-directed learning (Granito and Chernobilsky, 2012).

5.7 Conclusion

Firstly, the virtual microscopy group's knowledge acquisition was better than that of the optical microscopy group. The virtual microscopy group outperformed the optical microscopy group in regards to improvement in knowledge. However in terms of understanding and learning ability, both study group were comparably effective. Considering that deliberate practice of optical microscopy among the participants prior to this study exists, it cannot be concluded that the effectiveness of the virtual microscopy in regards to the students' comprehension level and learning ability. As aforementioned, an author concluded that the virtual microscope if not better, is equivalent to the optical microscope in terms of knowledge acquisition (Mione *et al.,* 2013). However, in this study only the level of comprehension was tested. Furthermore, there could be hidden factors which were not controlled well during the analysis of the present study such as time.

Secondly, the satisfaction score was significantly higher in the virtual microscopy group. The students were very satisfied learning histology by using the virtual microscope. However, students' satisfaction was found to be statistically unrelated to the students' academic performance.

As for the intrinsic motivation, the interest subscale is considered the self-report measure of intrinsic motivation (Monteiro *et al*., 2015). Thus, saying the intrinsic motivation of the virtual microscopy and optical microscopy groups were comparable is fair. However, other factors must be considered to properly interpret the interest score alone such as students' background and psychological dynamic. Furthermore, the perceived competence subscale is theorized to be the positive predictors of intrinsic motivation and the pressure subscale as the negative predictor (Monteiro *et al*., 2015). Hence, if the positive predictors are significantly high and there is no significant negative predictor, it is expected that there should be a significant difference in the interest subscale. Therefore as a whole, it cannot be concluded that the effects of virtual microscopy on students' intrinsic motivation. Many factors need to be taken into consideration including this study's limitations such as the prior deliberate practice of optical microscope and the short exposure to the virtual microscope. Nonetheless, virtual microscopy had a statistically significant effect on student's perceived competence in learning histology.

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APPENDIX A: ETHICAL APPROVAL

UNIVERSITI SAINS MALAYSIA
JAWATANKUASA ETIKA PENYELIDIKAN MANUSIA

Jawatankuasa Etika
Penyelidikan Manusia USM (JEPeM)
Human Research Ethics Committee USM (HREC)

Universiti Sains Malaysia
Kampus Kesihatan,
16150 Kubang Kerian, Kelantan, Malaysia
T : (609-767 3000/2354/2362
F : (609-767 2351
E : jepem@usm.my
L : www.jepem.kk.usm.my
www.usm.my

31st July 2017

Dr. Fazlina Kasim
Department of Anatomy
School of Medical Sciences
Universiti Sains Malaysia
16150 Kubang Kerian, Kelantan

JEPeM USM Code: USM/JEPeM/15100338

Study Protocol Title: Comparison of Optical Microscopy and Virtual Microscopy for Teaching Histology.

Dear Dr:

We wish to inform you that the Jawatankuasa Etika Penyelidikan Manusia, Universiti Sains Malaysia (JEPeM-USM) acknowledged receipt of Continuing Review Application dated 6th July 2017.

Upon review of JEPeM-USM Form 3(B) 2015: Continuing Review Application Form, the committee's decision for the **EXTENSION OF APPROVAL IS APPROVED (start from 1st August 2017 till 31st July 2018)**.

JEPeM USM has noted that there is no research activity took place during the period of 31st January 2017 until 31st July 2017. The report is noted and has been included in the protocol file.

Principle Investigator (PI) should aware and concern about the ethical expiration of the study in the future.

Thank you for your continuing compliance with the requirements of the JEPeM-USM.

"ENSURING A SUSTAINABLE TOMORROW"

Very truly yours,

(PROF. DR. HANS AMIN VAN ROSTENBERGHE)
Chairperson
Jawatankuasa Etika Penyelidikan (Manusia), JEPeM
Universiti Sains Malaysia

c.c Secretary
Jawatankuasa Etika Penyelidikan (Manusia), JEPeM
Universiti Sains Malaysia

UNIVERSITI SAINS MALAYSIA

JAWATANKUASA ETIKA PENYELIDIKAN MANUSIA

Jawatankuasa Etika
Penyelidikan Manusia USM (JEPeM)
Human Research Ethics Committee USM (HREC)

Universiti Sains Malaysia
Kampus Kesihatan,
16150 Kubang Kerian, Kelantan, Malaysia
T [illegible]
F [illegible]
E [illegible]
L www.jepem.kk.usm.my
www.usm.my

Date of meeting : 23rd July 2017
Venue : Meeting Room, Division of Research & Innovation, USM Kampus Kesihatan.
Time : 9.00 a.m – 2.00 p.m
Meeting No : 366

Members of Committee of the Jawatankuasa Etika Penyelidikan (Manusia), JEPeM Universiti Sains Malaysia who reviewed the protocol/documents are as follows:

Member (Title and Name)		Occupation (Designation)	Male/ Female (M/F)	Tick (✓) if present when above items, were reviewed
Chairperson: Professor Dr. Hans Amin Van Rostenberghe		Chairperson of Jawatankuasa Etika Penyelidikan (Manusia), JEPeM USM	M	✓ (Chairperson)
Deputy Chairperson: Professor Dr. Mohd Shukri Othman		Deputy Chairperson of Jawatankuasa Etika Penyelidikan (Manusia), JEPeM USM	M	✓ (Deputy Chairperson)
Deputy Chairperson: Professor Dr. Narazah Mohd Yusoff		Deputy Chairperson of Jawatankuasa Etika Penyelidikan (Manusia), JEPeM USM	F	✓ (Deputy Chairperson)
Secretary: Mr. Mohd Bazlan Hafidz Mukrim		Science Officer	M	✓
Members:				
1.	Associate Professor Dr. Azlan Husin	Lecturer, School of Medical Sciences	M	✓
2.	Mr. Harry Mulder	Community Representative	M	✓
3.	Professor Dr. Nik Hazlina Nik Hussain	Lecturer, School of Medical Sciences	F	✓
4.	Mr. Sadasivam Ramiah	Community Representative	M	✓
5.	Dr. Soon Lean Keng	Lecturer, School of Health Sciences	F	✓
6.	Dr. Surini Yusoff	Lecturer, School of Medical Sciences	F	✓
7.	Professor Dr. Zeehaida Mohamed	Lecturer, School of Medical Sciences	F	✓

Jawatankuasa Etika Penyelidikan (Manusia), JEPeM-USM is in compliance with the Declaration of Helsinki, International Conference on Harmonization (ICH) Guidelines, Good Clinical Practice (GCP) Standards, Council for International Organizations of Medical Sciences (CIOMS) Guidelines, World Health Organization (WHO) Standards and Operational Guidance for Ethics Review of Health-Related Research and Surveying and Evaluating Ethical Review Practices, EC/IRB Standard Operating Procedures (SOPs), and Local Regulations and Standards in Ethical Review.

PROFESSOR DR. HANS AMIN VAN ROSTENBERGHE
Chairperson
Jawatankuasa Etika Penyelidikan (Manusia), JEPeM
Universiti Sains Malaysia

National Pharmaceutical Regulatory Agency (NPRA)

Forum for Ethical Review Committees in Asia & Western Pacific Region

APPENDIX B: RESEARCH INFORMATION SHEET AND CONSENT FORM

RESEARCH INFORMATION

Research Title: **Comparison of Optical Microscopy and Virtual Microscopy for Learning Histology.**

Researchers Name:

Dr. Fazlina Binti Kasim (MMC: 40732)
Dr. Siti Nurma Hanim Binti Hadie@Haji (MMC: 43634)
Dr. Husnaida Binti Abdul Manan@Sulong (MMC: 46730)
Dr. Nor Farid Bin Mohd Noor (MMC: MPM41819)

INTRODUCTION

You are invited to take part voluntarily in an interventional research study to compare the effects of using an optical microscope (light microscope) and a virtual microscope on learning histology. Virtual microscopy is a method of digitizing microscope slides and viewing the produced virtual slides on a computer screen. This study requires you to attend a histology lecture and a histology practical, two examination sessions and a survey session. Before agreeing to participate in this research study, it is important that you read and understand this form. If you participate, you will receive a copy of this form to keep for your records.

Your participation in this study is expected to last for 8 hours. The lecture, practical, examination and survey sessions will be conducted on the very same day. An estimated of 222 first and second year students from the Doctor of Medicine Programme, School of Medical Sciences, Universiti Sains Malaysia will participate in this study. This study is supported by the Universiti Sains Malaysia Short Term Grant.

PURPOSE OF THE STUDY

The purpose of this study is to compare the effects of using an optical microscope and a virtual microscope on learning histology in medical students. A comparison will be made in the aspects of:

1) knowledge acquisition
2) the level of student satisfaction with the learning tools used in the practical sessions

QUALIFICATION TO PARTICIPATE

The researcher in charge or a staff of this study will elaborate on the requirements for participation in this study. You should not participate in this study if you do not meet all of the requirements.

The requirements for participation in this study are:

1) Participants must be a first or second year medical student, whom had enrolled in the Doctor of Medicine Programme, School of Medical Sciences at the Universiti Sains Malaysia, 2017/2018 academic session.
2) The age of the participants must not be below 18 years old and should not exceed 25 years old.

You cannot participate in this study if you are a repeat student.

STUDY PROCEDURES

If you agree to participate in this study, you will need to attend several sessions which include lecture, practical, examination and survey sessions (see Attachment 1). You will also be given an identification code that you will use in the examination and survey sessions.

This study will last up to about 8 hours. It will be completed in one day on a weekend. In this study there will be an hour session of histology lecture, a 2 hours session of histology practical and two sessions of examination and a survey session lasting for half an hour each.

After attending a histology lecture, you are required to attend an examination session and answer a few objective structured practical examination (OSPE) questions.

After the examination session, you are required to attend a practical session which will be preceded by a demonstration of histology slides. Students will then be divided into two groups and you will continue your practical session in your designated group. The practical will last for two hours. You will also need to attend another session of examination after the practical and answer a few OSPE questions. After completing the examination session, you are required to complete a survey that assesses your satisfaction level towards the learning tool that you have used in the practical session earlier.

RISKS

If you agreed to participate in this study, your participation will not in any way affect your semester and professional examination marks and grades in the Doctor of Medicine Programme. The results obtained from this study will only be used for the purpose of this study. Your name will not be stated on the examination and survey paper. The risk that you may experience if you agree to participate in this study is that your time that can be spent for revising, socializing, or recreation on that day will be reduced. Some students have the risk of not receiving equal learning opportunities, however these students will be invited to use the virtual microscope in a practical session after the study. If any important new information is found during this study that may affect you wanting to continue to be part of this study, you will be informed about it right away.

PARTICIPATION IN THE STUDY

Your participation in this study is entirely voluntary. You may refuse to take part in this study. You may also stop participating in this study at any time, without a penalty or loss of benefits to which you are otherwise entitled. Your participation also may be stopped by the researcher or sponsor without your consent if certain circumstances and reasons occur.

POSSIBLE BENEFITS [Benefits to Individual, Community, University]

The study procedures will be provided to you at no cost. You may receive information about your performance in the examination sessions. You will receive an incentive payment of honorarium and meals will be provided. You can also increase your knowledge related to histology from your participation in this study. The outcome of this study is expected to benefit in improving the teaching and learning of histology in the future. Hence, in the long run help to produce more knowledgeable and competent graduates. All your needs related to the sessions in this study will be supplied by the researchers.

QUESTIONS

If you have any questions about this study or your rights, please contact;

Dr. Fazlina Kasim (MMC number: 40732)
Department of Anatomy
School of Medical Sciences
USM Health Campus
09-767 6952 (office), 013-9401230 (handphone)

If you have any questions regarding the Ethical Approval or any issue or problem related to this study, please contact;

Mr. Mohd Bazlan Hazif Mukrim
Secretary of Human Research Ethic Committee USM
Centre for Research Initiative, Clinical & Health Sciences
USM Health Campus
Tel. No. 09-767 2354 / 09-767 2362
Email : bazlan@usm.my/jepem@usm.my

CONFIDENTIALITY

Information obtained from this study will be kept confidential by the researchers and staff involved. It will not be made publicly available unless disclosure is required by the law. Data obtained from this study that does not identify you individually will be published for knowledge purposes and it may be reviewed by the researcher, the Ethical Review Board for this study, and regulatory authorities for the purpose of verifying the research procedure and/or data. The information that is obtained from this study may be held and processed on a computer. By signing this consent form, you authorize the record review, information storage and data transfer as described above.

SIGNATURES

To be entered into this study, you or a legal representative must sign and date the signature page **[ATTACHMENT S and ATTACHMENT P]**

ATTACHMENT S

Subject Consent Form
(Signature Page)

Research Title: **Comparison of Optical Microscopy and Virtual Microscopy for Learning Histology**

Researcher's Name: **Dr. Fazlina binti Kasim, Dr. Siti Nurma Hanim binti Hadie@Haji, Dr. Husnaida binti Abdul Manan@Sulong and Dr. Nor Farid Bin Mohd Noor**

To become a part of this study, you or your legal representative must sign this page.

By signing this page, I am confirming the following:

- I have read all of the information in this Research Information and Consent Form **including any information regarding the risk involved in this study** and I have had time to think about it.
- All of my questions have been answered to my satisfaction.
- I voluntarily agree to be part in this research study, follow the study procedures, and to provide necessary information to the researchers or research staff members, as requested.
- I may freely choose to stop being a part of this study at any time.
- I have received a copy of this Research Information Sheet and Consent Form to keep for myself.

Subject's Name (print or type**)**

Subject's Initials and Number

Subject's I.C No (New)

Subject's I.C No. (Old)

Signature of Subject or Legal Representative

Date (dd/MM/yy)
(Add time if applicable)

Name of Individual Conducting Consent Discussion
(printed or typed)

Signature of Individual Conducting Consent Discussion

Date (dd/MM/yy)

Name & Signature of Witness

Date (dd/MM/yy)

Note: 1) All subjects who are involved in this study will not be covered by insurance.

ATTACHMENT P

Publication Related to Subject Consent Form

Signature Page

Research Title: **Comparison of Optical Microscopy and Virtual Microscopy for Learning Histology**

Researcher's Name: **Dr. Fazlina binti Kasim, Dr. Siti Nurma Hanim binti Hadie@Haji, Dr. Husnaida binti Abdul Manan@Sulong and Dr. Nor Farid Bin Mohd Noor**

To become a part of this study, you or your legal representative must sign this page.

By signing this page, I am confirming the following:

- I understood that my name will not appear on the materials published and there have been efforts to make sure that the privacy of my name is kept confidential although the confidentiality is not completely guaranteed due to unexpected circumstances.
- I have read the materials or general description of what the material contains and reviewed all photographs and figures in which I am included that could be published.
- I have been offered the opportunity to read the manuscript and to see all materials in which I am included, but have waived my right to do so.
- All the published materials will be shared among the medical practitioners, scientists and journalist worldwide.
- The materials will also be used in local publications, book publications and accessed by many local and international doctors worldwide.
- I hereby agree and allow the materials to be used in other publications required by other publishers with these conditions:
- The materials will not be used as advertisement purposes nor as packaging materials.
- The materials will not be used out of contex – i.e.: Sample pictures will not be used in an article which is unrelated subject to the picture.

Subject's Name (print or type) **Subject's Initials or Number**

Subject's I.C. No (New) **Subject's Signature** **Date** (dd/MM/yy)

Name and Signature of Individual Conducting Consent Discussion **Date** (dd/MM/yy**)**

Note: 1) All subjects who are involved in this study will not be covered by insurance.

APPENDIX C: PRE-PRACTICAL ASSESSMENT SHEET

Question 1

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

PRE-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph P1, showing layers in an eyeball.

a) Identify the layers labelled A, B, C, D, E, F, G and H (8 marks)

b) State the contents in C (1 mark)

c) Identify structure X (1 mark)

ANSWERS:

a) Layer A ____________________
   Layer B ____________________
   Layer C ____________________
   Layer D ____________________
   Layer E ____________________
   Layer F ____________________
   Layer G ____________________
   Layer H ____________________

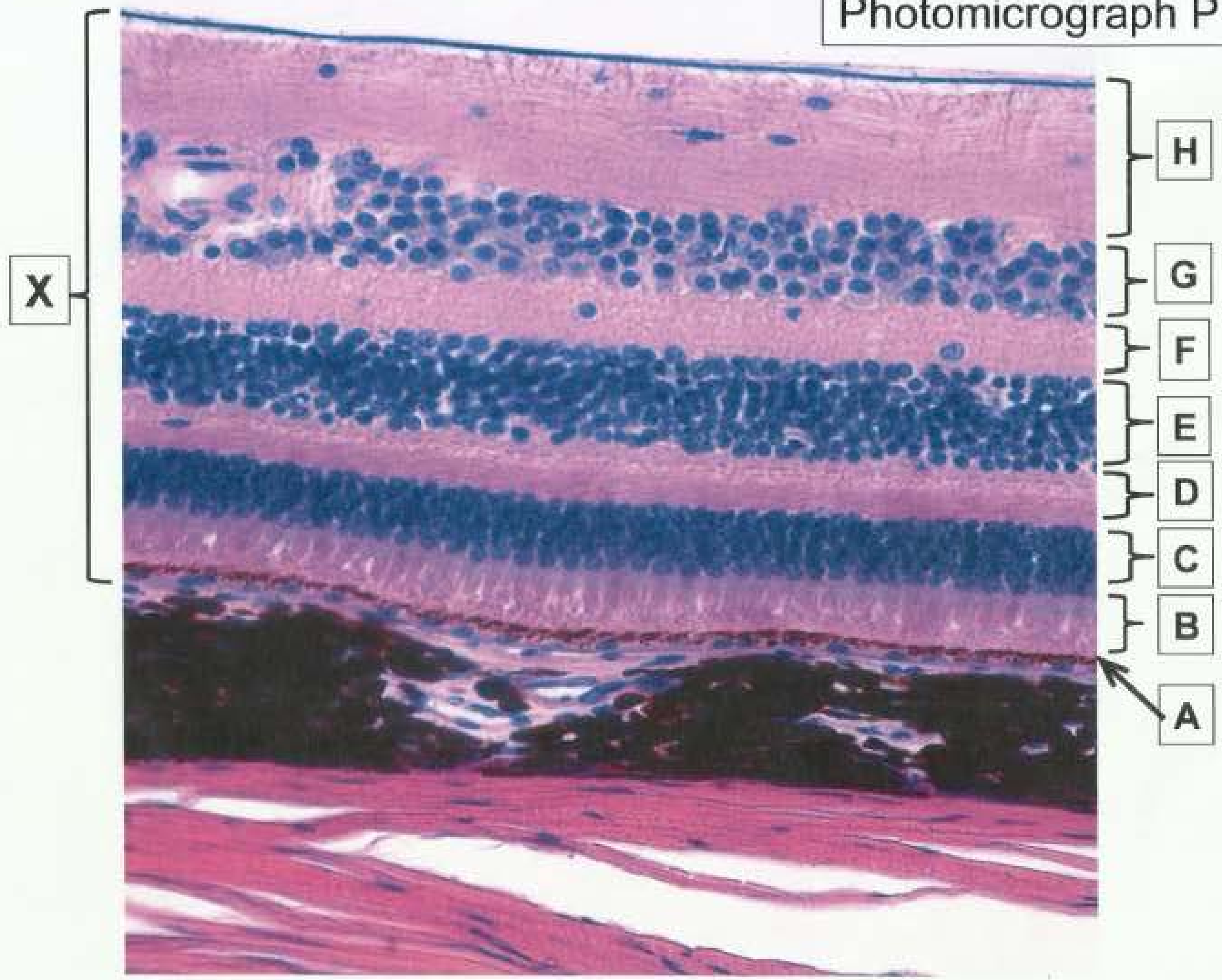
b) Contents of C

____

____

c) Structure X ____________________

Photomicrograph P1



Question 2

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

PRE-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph P2, showing layers in an eyeball.

a) Identify the layers labelled Y and Z (4 marks)

b) State TWO (2) characteristic histological features for Y (3 marks)

c) State TWO (2) characteristic histological features for Z (3 marks)

ANSWERS:

a) Layer Y ____________________

Layer Z ____________________

b) TWO (2) characteristic histological features for Y

____

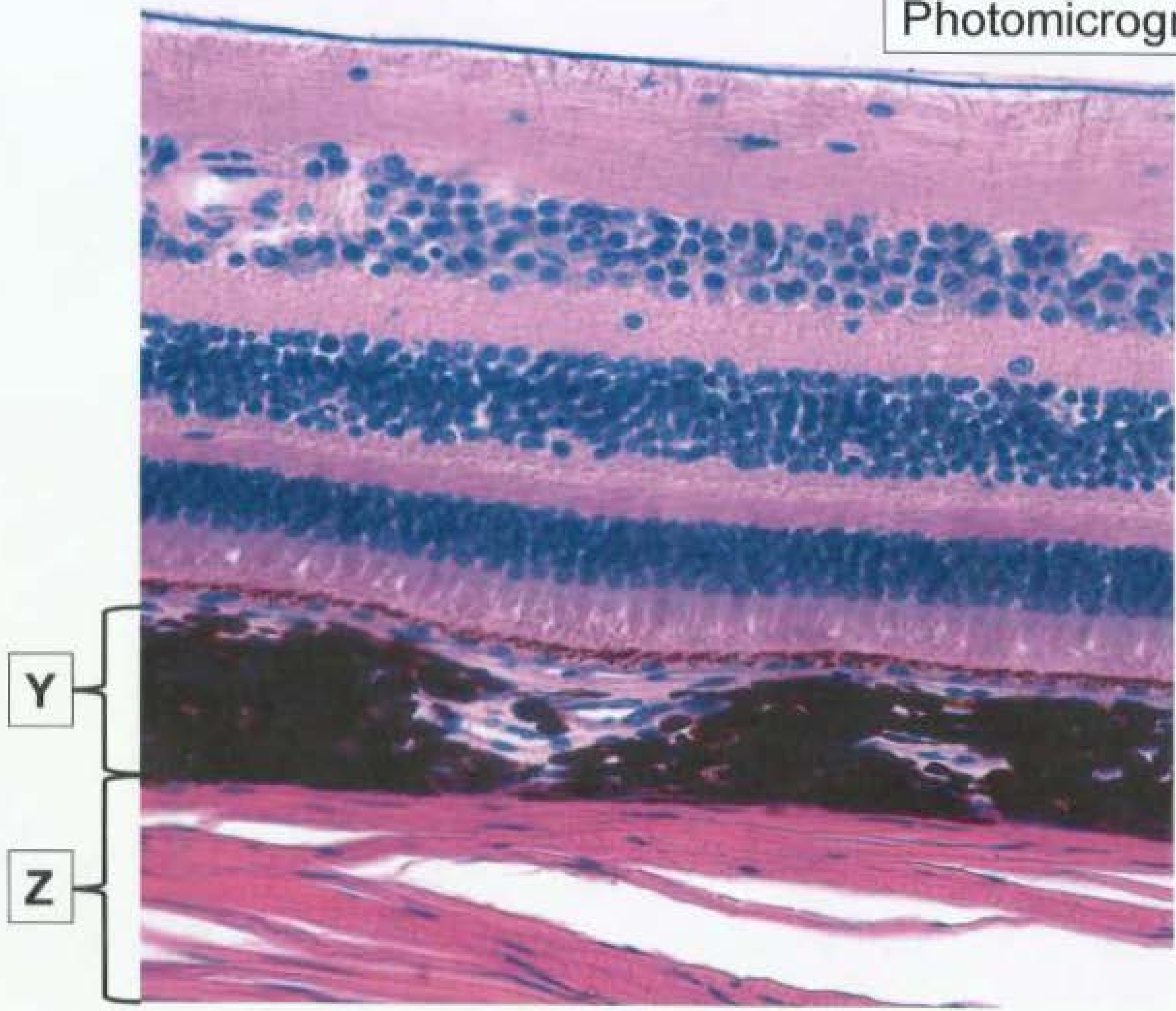
____

c) TWO (2) characteristic histological features for Z

____

____

Photomicrograph P2



Question 3

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

PRE-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph Q, showing structures in an eyeball.

a) Identify the structures/area labelled A, B, C and D (8 marks)

b) Identify chambers Y and Z (1 mark)

c) State the tissue type of D (1 mark)

ANSWERS:

a) A ____________________

B ____________________

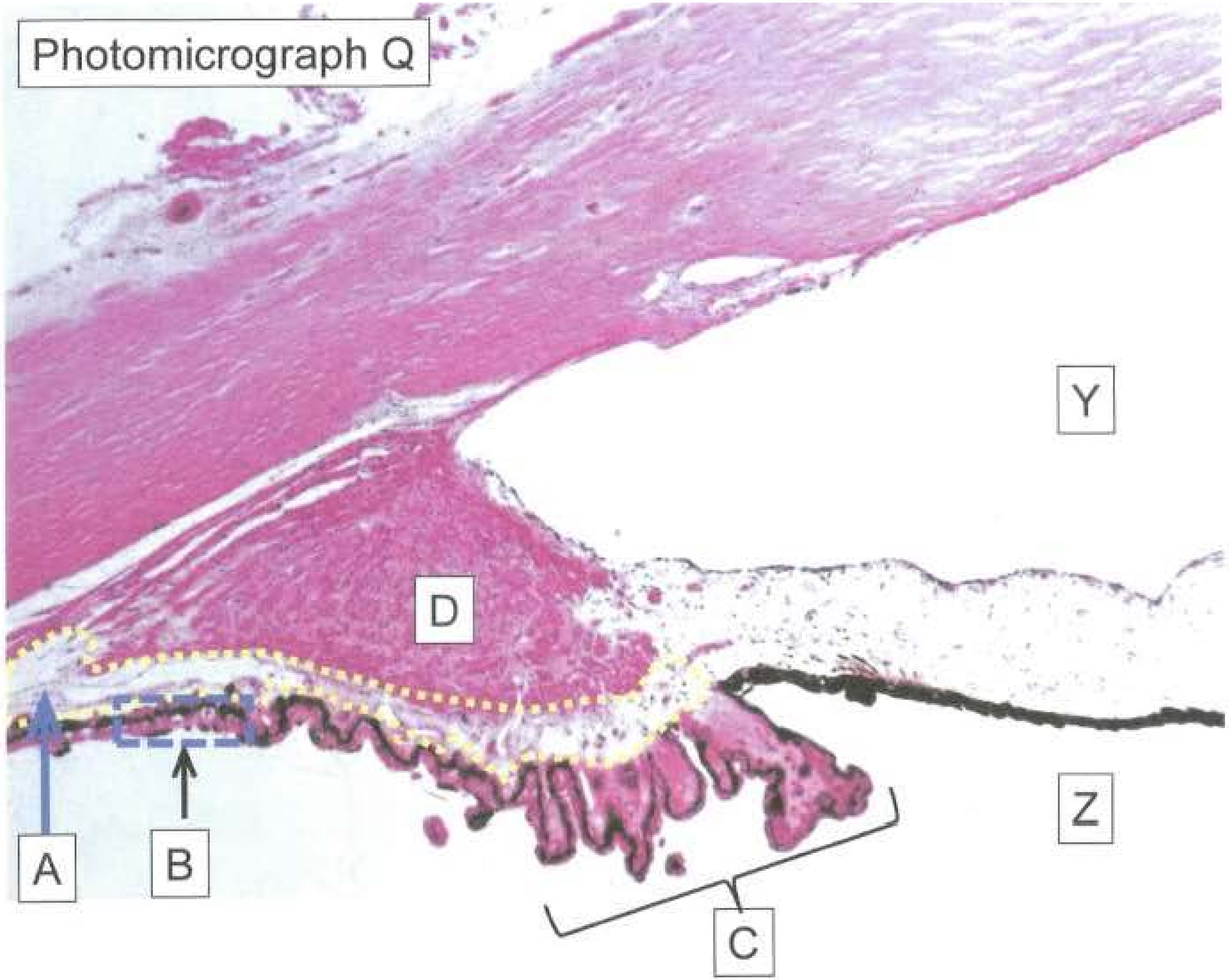
C ____________________

D ____________________

b) Chamber Y ____________________

Chamber Z ____________________

c) Tissue type of D ____________________


Photomicrograph Q
Y
D
Z
A
B
C

Question 4

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

PRE-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph R, showing a structure in an eyeball.

a) Identify the layers labelled A, B and C (6 marks)

b) State the type of epithelium A (1 mark)

c) State the type of epithelium C (1 mark)

d) Identify the structure shown in this photomicrograph (2 marks)

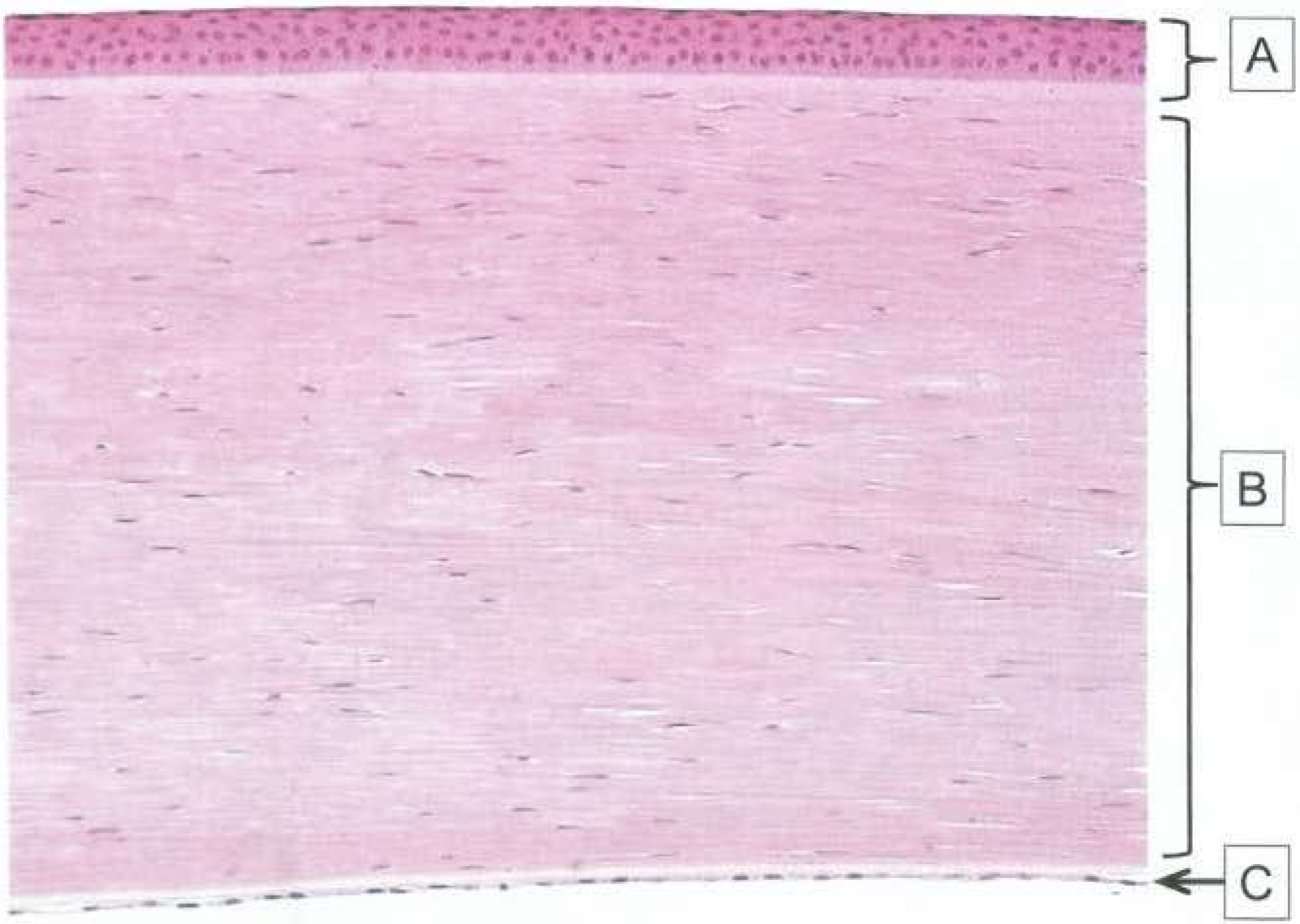
ANSWERS:

a) Layer A ____________________
   Layer B ____________________
   Layer C ____________________

b) Type of epithelium A ____________________

c) Type of epithelium C ____________________

d) Structure shown in this photomicrograph ____________________



Photomicrograph R

Question 5

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

PRE-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph S, showing structures in an eyeball.

a) Identify the structures labelled A and B (4 marks)

b) Identify the surfaces labelled Y and Z (4 marks)

c) State the tissue type of B (1 mark)

d) Identify the structure shown in this photomicrograph (1 mark)

ANSWERS:

a) A ____________________

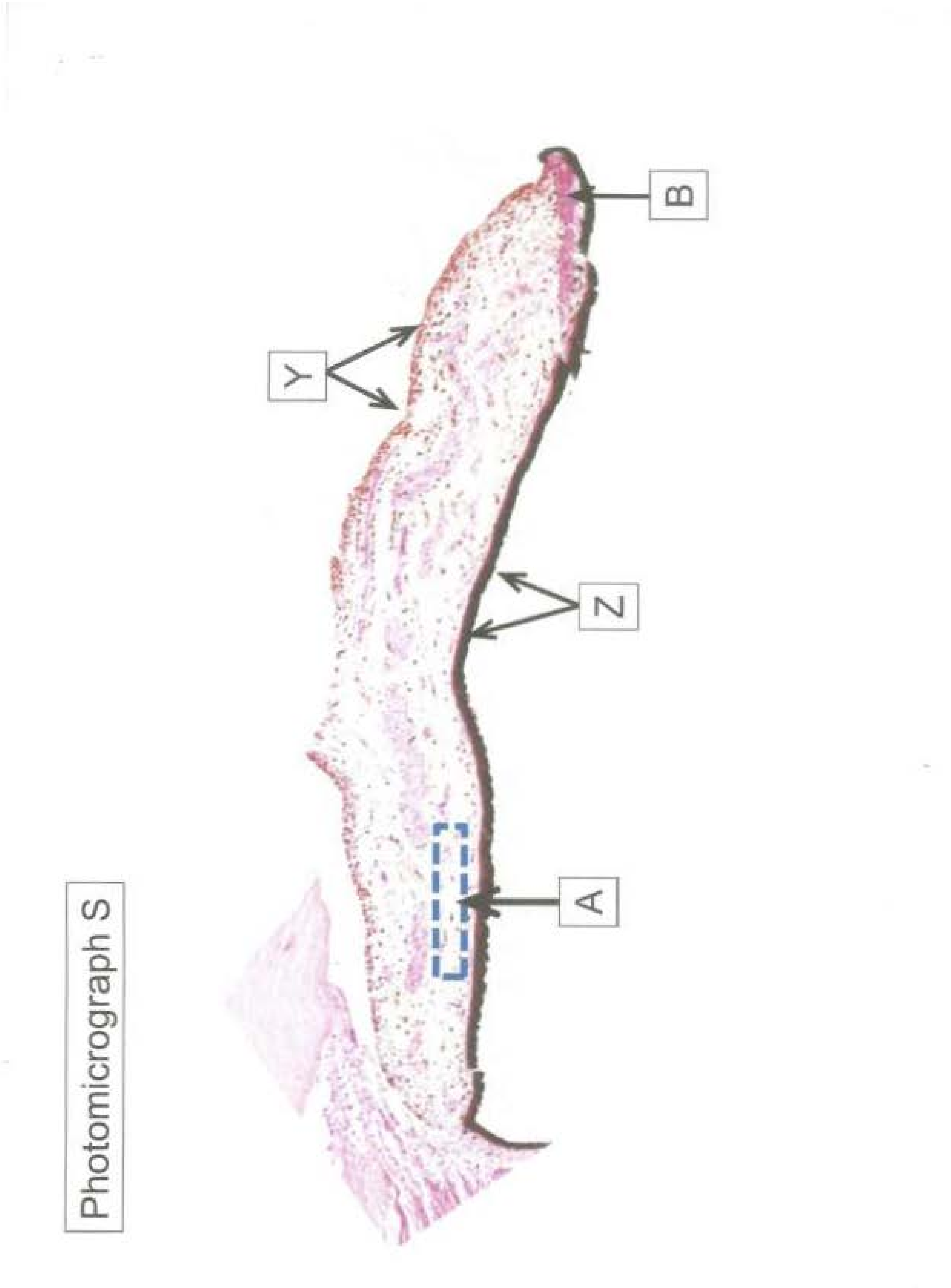
B ____________________

b) Surface Y ____________________

Surface Z ____________________

c) Tissue type of B ____________________

d) Structure shown in this photomicrograph ____________________



APPENDIX D: POST-PRACTICAL ASSESSMENT SHEET

Question 1

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

POST-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph P, showing a structure in an eyeball.

a) Identify the layers labelled X, Y and Z (6 marks)

b) State the type of epithelium X (1 mark)

c) State the type of epithelium Z (1 mark)

d) Identify the structure shown in this photomicrograph (2 marks)

ANSWERS:

a) Layer X ____________________

Layer Y ____________________

Layer Z ____________________

b) Type of epithelium X

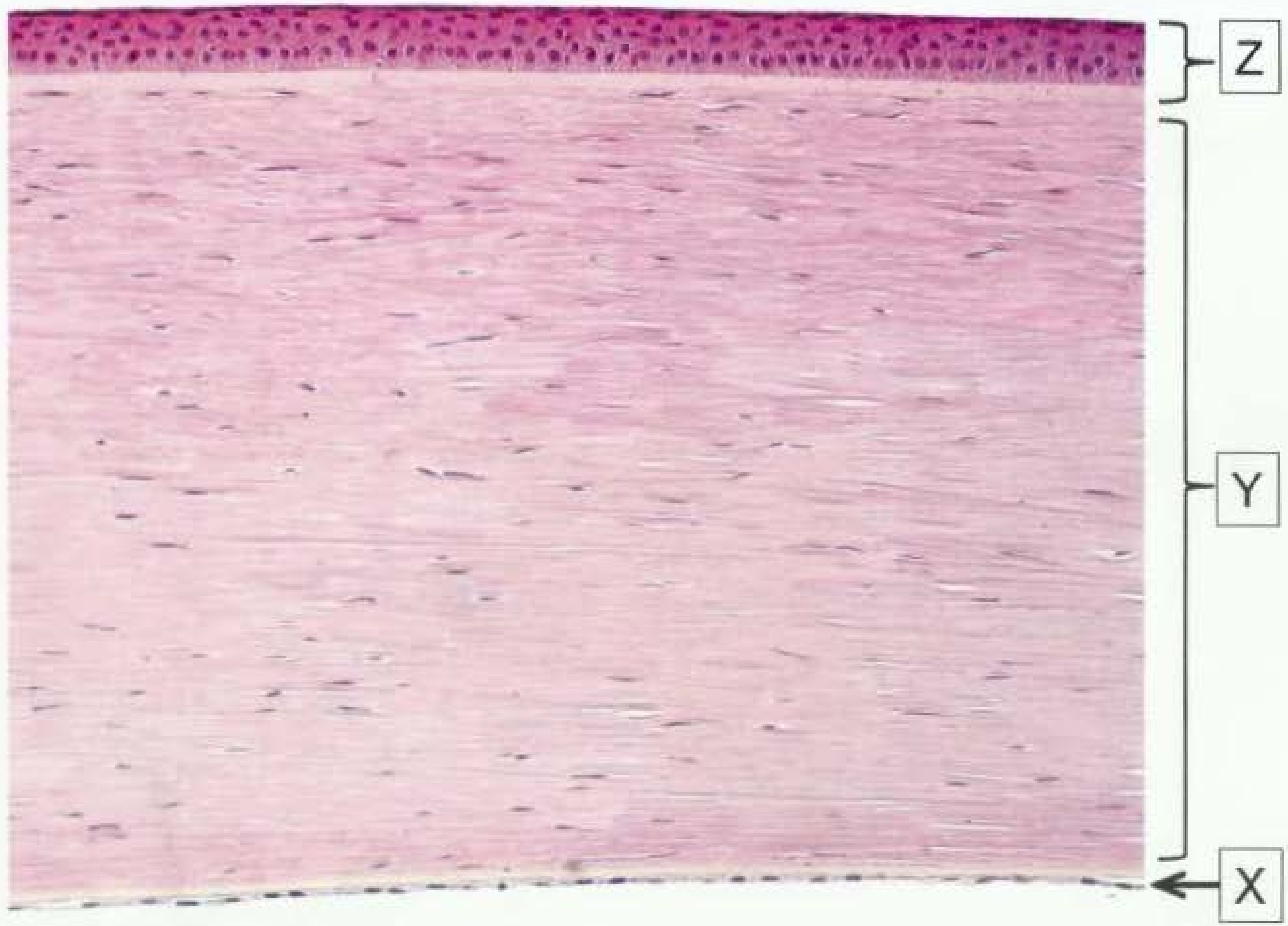
____

c) Type of epithelium Z

____

d) The structure shown in this photomicrograph

____



Photomicrograph P

Question 2

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

POST-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph Q, showing structures in an eyeball.

a) Identify the surfaces labelled A and B (4 marks)

b) Identify the structures labelled Y and Z (4 marks)

c) State the type of tissue of Y (1 mark)

d) Identify the structure shown in this photomicrograph (1 mark)

ANSWERS:

a) Surface A ____________________

Surface B ____________________

b) Y ____________________

Z ____________________

c) Type of tissue of Y

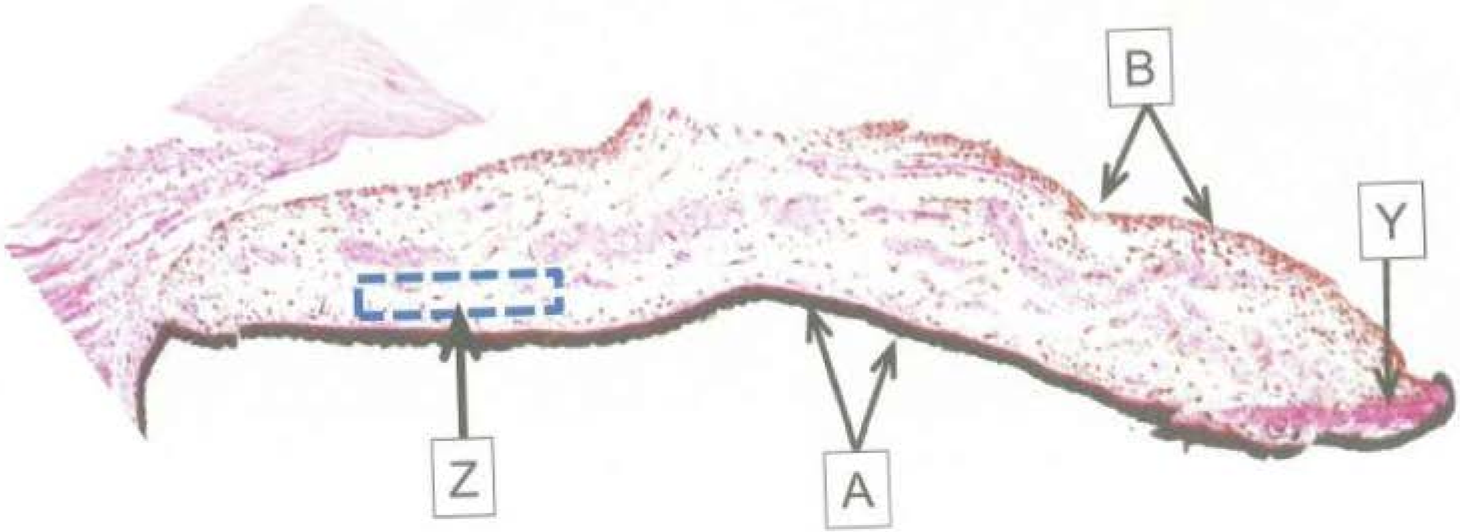
____

____

d) The structure shown in this photomicrograph

____

Photomicrograph Q



Question 3

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

POST-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph R, showing structures in an eyeball.

a) Identify chambers A and B (1 mark)

b) Identify the structures labelled W, X, Y and Z (8 marks)

c) State the type of tissue of W (1 mark)

ANSWERS:

a) Chamber A ____________________

Chamber B ____________________

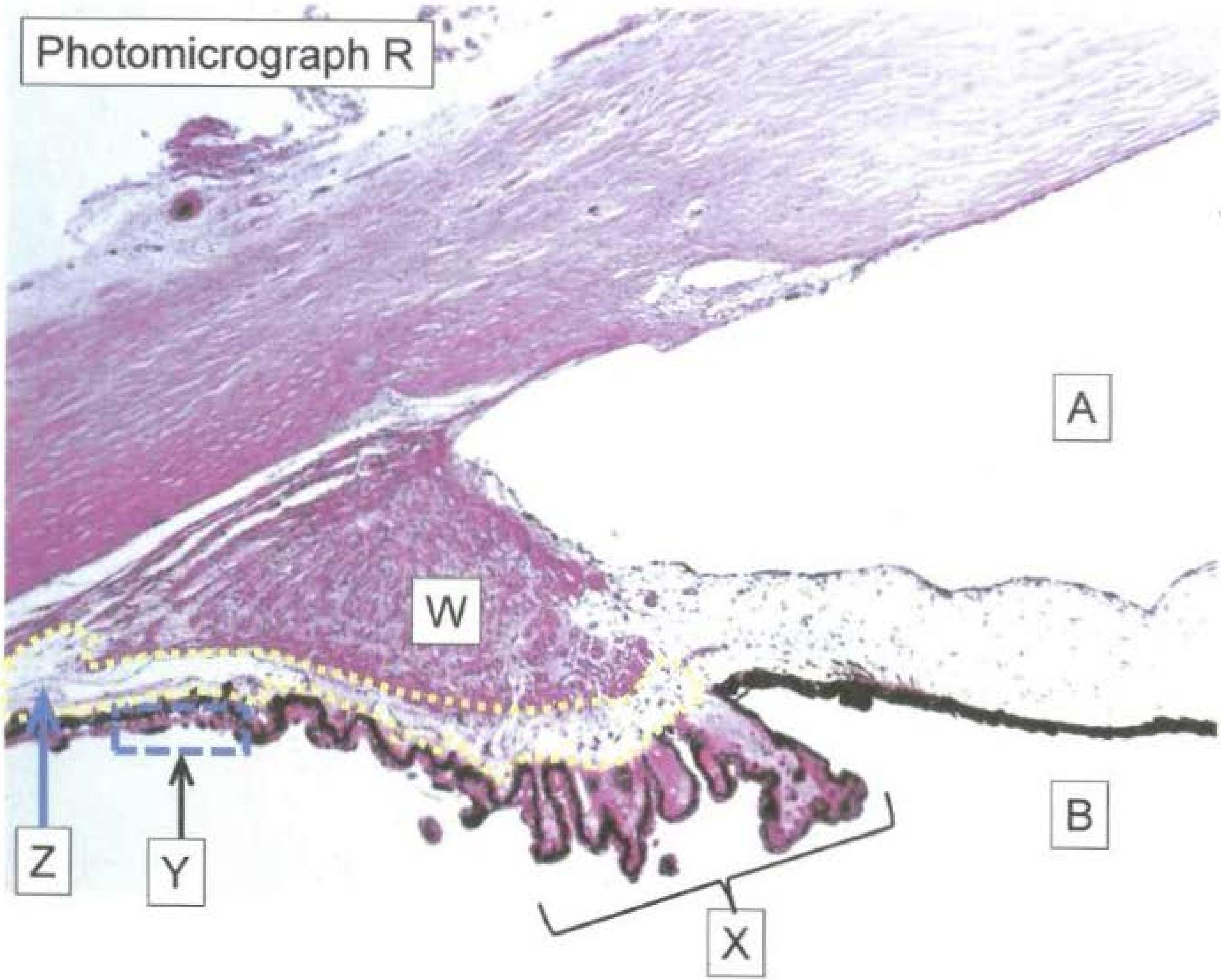
b) W ____________________

X ____________________

Y ____________________

Z ____________________

c) Tissue type of W ____________________


Photomicrograph R
A
W
B
Z
Y
X

Question 4

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

POST-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph S1, showing layers in an eyeball.

a) Identify the layers labelled X and Y (4 marks)

b) State TWO (2) characteristic histological features for X (3 marks)

c) State TWO (2) characteristic histological features for Y (3 marks)

ANSWERS:

a) Layer X ____________________

Layer Y ____________________

b) TWO (2) characteristic histological features for X

____

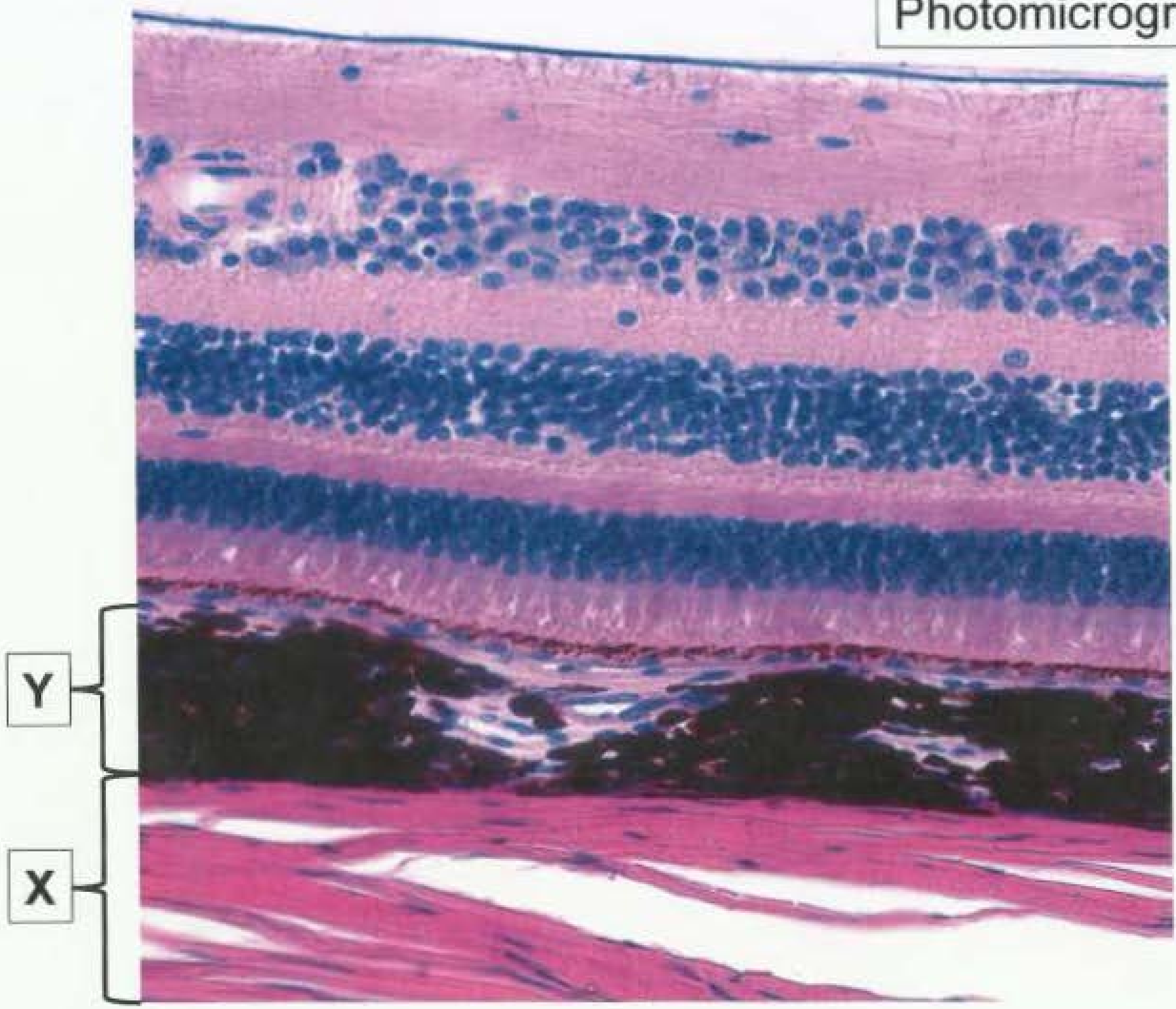
____

c) TWO (2) characteristic histological features for Y

____

____

Photomicrograph S1



Question 5

PUSAT PENGAJIAN SAINS PERUBATAN

KAMPUS KESIHATAN UNIVERSITI SAINS MALAYSIA

POST-PRACTICAL EXAMINATION

DATE: 2 DECEMBER 2017

You are provided with photomicrograph S2, showing layers in an eyeball.

a) Identify the layers labelled A, B, C, D, E, F, G and H (8 marks)

b) State the contents in F (1 mark)

c) Identify structure Z (1 mark)

ANSWERS:

a) Layer A ____________________

Layer B ____________________

Layer C ____________________

Layer D ____________________

Layer E ____________________

Layer F ____________________

Layer G ____________________

Layer H ____________________

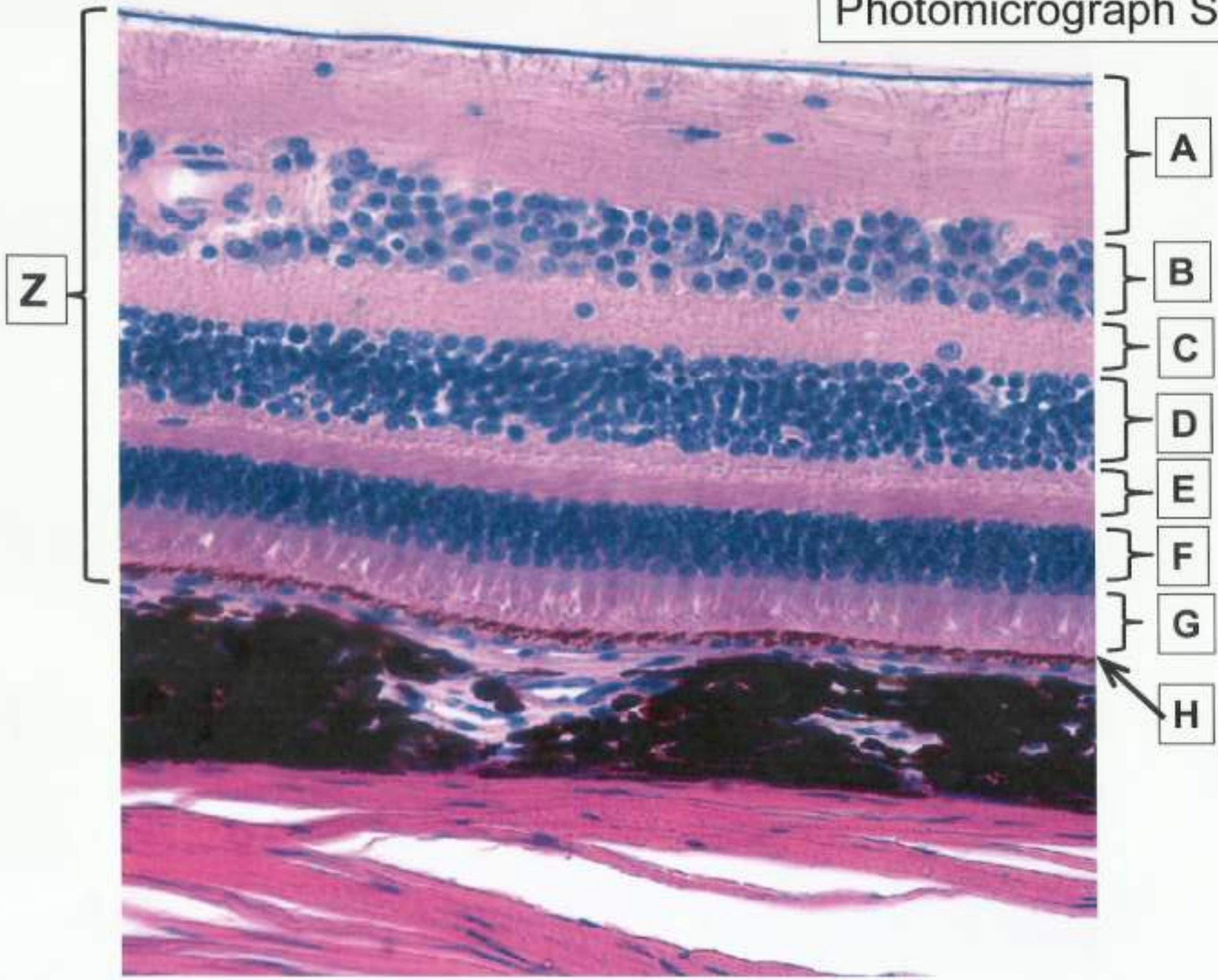
b) Contents of F

____

____

c) Structure Z ____________________

Photomicrograph S2



APPENDIX E: SURVEY FORM (Satisfaction and Intrinsic Motivation Inventory)

Comparison of Optical Microscopy and Virtual Microscopy

For Learning Histology

Dear students,

Thank you for taking the time to complete this questionnaire. Your insight and information are very valuable to us in making decisions about the training we provide to future students.

The purpose of this questionnaire is to assess your satisfaction towards learning histology by using the learning tool exposed to you during this research (either virtual microscope or optical microscope).

Your response will be confidential. Please do not write down your name on this questionnaire.

Student Code Number :

Date :

Should you have any queries about this questionnaire, please contact:

Dr. Fazlina Kasim
Anatomy Department, PPSP, USM
09-7676952 (office), 013-9401230 (mobile phone)
e-mail: fazlinakb@usm.my

Dr. Anna Alicia Simok
Trainee Lecturer, Anatomy Department, PPSP, USM
09-7676071 (office), 017-9555994 (mobile phone)
e-mail: annalicia@usm.my

Please indicate your degree of agreement or disagreement with each question using the following scale:

Scale 1 - Strongly Disagree
Scale 2 - Disagree
Scale 3 - Unsure
Scale 4 - Agree
Scale 5 - Strongly Agree

Please **circle** the number below that indicates how much you agree or disagree with each statement. Circle one number for each statement.

1. **Interest / Enjoyment**

The word **"activity"** in the following statements refers to **"learning histology by using the learning tool exposed to you"** during the practical sessions (either virtual microscope or optical microscope).

No.	Statement	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
1	I enjoyed doing this ***activity** very much.	1	2	3	4	5
2	This ***activity** was fun to do.	1	2	3	4	5
3	I thought this was a boring ***activity**.	1	2	3	4	5
4	This ***activity** did not held my attention at all.	1	2	3	4	5
5	I would describe this ***activity** as very interesting.	1	2	3	4	5
6	I thought this ***activity** was quite enjoyable.	1	2	3	4	5
7	While I was doing this ***activity**, I was thinking about how much I enjoyed it.	1	2	3	4	5

***activity** refers to 'learning histology by using the learning tool exposed to you'

2. <u>Perceived competence</u>

The word **"task"** in the following statements refers to **"identifying histological structures by using the learning tool exposed to you"** during the practical session (either virtual microscope or optical microscope).

No.	Statements	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
1	I think I am pretty good at this ***task**.	1	2	3	4	5
2	I think I did pretty well at this ***task**, compared to other students.	1	2	3	4	5
3	After working at this ***task** for a while, I felt pretty competent.	1	2	3	4	5
4	I am satisfied with my performance at this ***task**.	1	2	3	4	5
5	I am pretty skilled at this ***task**.	1	2	3	4	5
6	This was a ***task** that I could not do very well.	1	2	3	4	5

***task** refers to 'identifying histological stuctures by using the learning tool exposed to you'

3. **Pressure / Tension**

The word **"task"** in the following statements refers to **"identifying histological structures by using the learning tool exposed to you"** during the practical session (either virtual microscope or optical microscope).

No.	Statement	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
1	I did not feel nervous at all while doing this ***task**.	1	2	3	4	5
2	I felt very tense while doing this ***task**.	1	2	3	4	5
3	I was very relaxed in doing this ***task**.	1	2	3	4	5
4	I was anxious while working on this ***task**.	1	2	3	4	5
5	I felt burdened while doing this ***task**.	1	2	3	4	5

***task** refers to 'identifying histological stuctures by using the learning tool exposed to you'

4. Value / Usefulness

The word **"activity"** in the following statements refers to **"learning histology by using the learning tool exposed to you"** during the practical session (either virtual microscope or optical microscope).

No.	Statement	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
1	I believe this ***activity** could be of some value to me.	1	2	3	4	5
2	I think that doing this ***activity** is useful for understanding histology.	1	2	3	4	5
3	I think this ***activity** is important to do because it helps me to identify histological structures.	1	2	3	4	5
4	I would be willing to do this ***activity** again because it has some value to me.	1	2	3	4	5
5	I think doing this ***activity** could help me to understand structures of the organs.	1	2	3	4	5
6	I believe doing this ***activity** could be beneficial to me.	1	2	3	4	5
7	I think this is an important ***activity**.	1	2	3	4	5

***activity** refers to 'learning histology by using the learning tool exposed to you'

5. Overall, how satisfied were you with the learning tool exposed to you during the practical session (either virtual microscope or optical microscope). Please **tick** one response below.

- ☐ Very dissatisfied
- ☐ Dissatisfied
- ☐ Neutral
- ☐ Satisfied
- ☐ Very satisfied

6. Please provide additional comments and suggestions on how this learning tool might improve histology teaching and learning.

____

____

____

7. Please provide additional comments and suggestions on how we might improve histology teaching and learning.

____

____

____

END OF THE QUESTIONNAIRE

Thank you for completing this questionnaire, your participation is much appreciated!