Online blended learning using virtual microscopy for students: Seeing and naming patterns

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Online blended learning using virtual microscopy for students

Seeing and naming patterns

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Abstract

Background: The role of blended learning has gained importance in the teaching of microscopy to undergraduate students; however, there is limited evidence to demonstrate whether virtual microscopy is more effective that glass slide in teaching histology. In this study, the role of virtual microscopy was compared to a glass slide/textbook approach as an effective alternative for training Biomedical Science undergraduate students. This study explored processing style, working memory, motivation, and stress as predictors of student success with the use of psychometric tasks.

Methods: The study was a convergent design mixed methods research in which quantitative methods preceded qualitative methods. Twenty-eight students with an average age of 27.9 and 79% were women, completed a series of psychometric tasks to assess their processing style, processing speed, working memory, stress, and motivation. The students were assigned to one of two groups based on their processing style and working memory: a) tutorial sessions and conventional microscopy sessions and b) tutorial sessions and Westminster Path XL. The teaching delivery took five weeks, and students completed three online quizzes on weeks 6, 10 and 17. All students were invited to complete a feedback questionnaire, and a representative selection completed an interview.

Results: Initially, a pilot study was conducted and included a control group (tutorial sessions only – group C), which demonstrated that any intervention, glass slide or virtual microscopy, was better than no intervention.

The intervention study conducted in 2017-18 included students from three institutions and the control group was not included. The average results for the quizzes were 15.9, 16.5 and 15.5 respectively. There was no significant difference between the results of group A and B. The dropout rate of the study was 3.6%. There was no significant improvement in tissue recognition when using virtual microscopy to teach undergraduate students when compared to glass slide and microscope.

Fifteen students completed the questionnaire. Thirteen students agreed that the intervention was useful, and fifteen students would recommend the learning resource to their colleagues. Ten students were invited to complete an interview and nine students were available. The themes highlighted as good practice during the interviews were the usability of Westminster Path XL, the training delivery, application of the intervention delivery, the use of technology and the use of microscope.

Conclusion: Virtual microscopy is as good as glass slide for teaching students tissue recognition. The use of psychometric tasks cannot predict student outcome, so they should not be used to differentiate students teaching methodology for tissue recognition in histology. Students engaged positively with the technology, and it is recommended that both approaches should be used concurrently to allow students to gain microscopy skills and apply them in the use of technology.

List of Contents

List of Tables

List of Figures

List of Abbreviations

BPS – The British Psychological Society

CE – European Conformity (French origin – Conformité Européenne)

CPD – Continuous Professional Development

FCC/FDA – Food and Drug Administration/Federal Communications Commission

GDPR – Good Data Protection Regulation

HE – Haematoxilyn-eosin

HTA – Human Tissue Authority

ICNHST – Imperial College National Healthcare System

IPC – Institute of Psychometric Coaching

LM – light microscope/microscopy

LMetU – London Metropolitan University

LNS – Letter Number Sequencing

MCQs – multiple-choice questions

MMR – Mixed Methods Research

MOOC – Massive Open Online courses

NHS – National Healthcare System

NSS - The National Student Survey

NWLP – North West London Pathology

OM – Optical microscope/microscopy

PIS – Participant Information Sheet

PSS – Perceived Stress Scale

QAA – Quality Assurance Agency

RCPath – Royal College of Pathologist

RO – Rey-Osterrieth

TMT – Trail Making Task

TPACK – Technological Pedagogical Content Knowledge Framework

UK – United Kingdom

UoW – University of Westminster

VLE – Virtual Learning Environment

VM – virtual microscope/microscopy

WAIS – Wechsler Adult Intelligence Scale Version III

WPXL – Westminster Path XL

WSI – Whole-Slide Imaging

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Author’s declaration

I declare that the present work was carried out in accordance with the Guidelines and Regulations of the University of Westminster. The work is original except were indicated by particular reference in the text. I declare that all the material contained in this thesis is my own work.

The submission as a whole or part is not substantially the same as any that I previously made or am currently making, whether in published form, for a degree, diploma or similar qualification at any university or similar institution.

Any views expressed in this work are those of the author and in no way represent those of the University of Westminster.

I confirm and declare that I have no conflict of interests.

Preface

The researcher started her Biomedical Scientist career in 2003 in the UK. In 2011, she began working in Cellular Pathology at North West London Pathology hosted by Imperial College NHS Trust as a Senior Healthcare Scientist and assumed the role of Laboratory Manager in July 2017. The researcher has many years of experience in training staff in histology and since 2006 has been responsible for training newly qualified staff in the professional setting. This training role is required to allow trainees to complete their Certificate of Competence, a legal requirement for registration with the HCPC as a Biomedical Scientist, and the Specialist Portfolio in Cellular Pathology which is a specialised professional qualification required for practice as a specialist in Histology. The researcher has been a professional representative for the IBMS since 2009, a guest lecturer at London Metropolitan University since 2014 and has been the module leader for the IBMS Certificate of Extended Practice in Training online, Module 2 – Professional and Academic Qualifications since 2016 for Biomedical Scientists.

The researcher started the Professional Doctorate at the University of Westminster in 2012 to explore the role of blended learning with VM in teaching and training students. Her interest stems from having trained many staff and having understood that many students lack flexibility with integrating what has been taught during their degree and its application in the professional setting. One challenge in the workplace was tissue recognition, which is the ability to recognise microscopic features in an image or glass slide and based on previous knowledge, determine the tissue type and the condition present on the tissue. Anecdotally, this seemed to relate how much these individuals were exposed to histology during their degree and how much of that learning remains in the students' memory.

In September 2018, the researcher started the Postgraduate Certificate in Teaching and Learning in Higher Education and completed the qualification in July 2020.

The researcher proposed to explore whether VM is more effective in teaching students than glass slide/textbook approach and how students engaged with technology to provide a better student experience. The researcher was also interested in assessing if working memory, processing style, stress and motivation were modifiable factors that could provide a more positive student experience.

The study allowed the researcher to experience first-hand the preparation and delivery of histology content using the conventional method of delivery teaching and using blended learning strategies. It also allowed the researcher to explore with students and independently, the students' engagement with the learning process and ease with technology.

In the write-up of the thesis, as appropriate, the researcher included reflections and personal development comments in the relevant sections to allow the reader to understand the motivation and thinking processes of the researcher.

1. Introduction and structure of the thesis

Biomedical Sciences and related university degree courses where Cellular Pathology is a core module have been facing many challenges in the last decade (QAA, 2020). The delivery of practical microscopy easily and scalable is one of the many challenges facing the delivery of practical skills in a modern degree with large cohorts. The traditional method of teaching undergraduate students relies on a steady supply of glass slides, and it requires numerous microscopy practical sessions with teaching to glass slides repeatedly to ensure that students can learn tissue recognition.

The increasing number of students enrolling for Biomedical Science courses and the changes to the regulation on the use human tissue, availability, and consent in using tissue for teaching purposes has created challenges to the effective delivery of tissue recognition using the traditional methods, specifically practical microscopy sessions with glass slides (Dee, 2009; Simavalai et al., 2011; HTA, 2016). There has been great development to demonstrate that adult learners' characteristics are very different than young learners' and the development of effective teaching strategies for each age group of learners (Knowles, 1973; Bandura, 1986 in Brentham, 2002). In this sense, the use of traditional learning methods for teaching practices is being challenged and new opportunities have arisen using different approaches to teaching, particularly in the realms of using technology to teach adult learners (Wood et al., 1976; Nivala et al., 2012).

Many alternatives to traditional methods of teaching are being sought and considered by different researchers worldwide. The underpinning for these is the learning theories where the alternatives are classified broadly as blended learning approaches. These include the use of different types of technology, distance learning modes, asynchronous learning, peer learning and teaching support strategies, and independent learning models (Mason, 2001; Garrison & Cleveland-Innes, 2005; Vonderwell et al., 2007; Moore et al., 2011; Kattoua et al., 2016; Pritchard & Morrow, 2017).

The current study compared traditional learning methods (with face-to-face tutorial sessions and laboratory practice with microscopy and glass slides and the use of atlases) with an approach using blended learning with face-to-face tutorial sessions and an interactive online learning platform/methodology to deliver VM. The virtual delivery platform was Westminster Path XL (Path XL, 2013) and the summative assessment of students was delivered using the online tool.

The students that participated in the study were willing volunteers that consented to participate in the study. In that sense, constructivist theories aligned with andragogical learning theories provided a framework for the current study, where students were active agents, independent and self-motivated to pursue the learning., In most parts, these students had prior knowledge in tissue sciences and the current study enabled them to build up upon that knowledge. The teacher was a facilitator in the process available to support and guide the students in a conducive learning environment (Knowles, 1973; Wood et al., 1976; Vygotsky, 1978).

The current study had an element of delivering microscopy practical sessions as this is already available for students in most universities and compared it with a different delivery method that featured the use of technology as a strategy for teaching and assessing the students’ outcomes.

Bloom's taxonomy defines six levels of cognitive learning that learners need to construct to learn (Cannon & Feinstein, 2005; Adams, 2015). The ADDIE model (acronym for Analysis, Design, Development, Implementation, & Evaluation) is a process used by instructional designers and trainers to build effective learning tools. The Technological Pedagogical Content Knowledge Framework (TPACK) enables teachers to evaluate the tools available for delivery of online content and develop the content being used. These are the theories and models that underpinned the development and the delivery of this study. From a learner perspective, students learn first by remembering, then understanding and later applying the knowledge. Only once the learning is embedded in the learner's mind, does the creative process takes place as defined as the highest level of cognitive learning in Bloom's taxonomy (Mishra & Koehler, 2006; Olson & Hergenhahn, 2012; Kay & Kibble, 2016).

From a design perspective for the study, a gap analysis was performed to identify the areas that needed to be addressed. The study was designed based on the literature reviewed and developed by the researcher based on those findings. A pilot study was tested and reviewed and then the intervention study was implemented with the feedback received. The intervention study was evaluated at the end of the delivery process.

In the last decades, education and training have traditionally been delivered through face-to-face sessions, ranging from tutorial sessions, group work and textbooks, practical sessions, and independent learning. With the advent of web-based technology, blended learning has gained popularity at all levels of teaching whereby students learn in a mixed environment using both face-to-face and online teaching.

Alongside the shift in methodology, a more student-centered approach has been suggested that focuses on the students' own interests, learning abilities and learning styles. Barbeau et al. (2013) reported that there was a 17% increase in online enrolment in higher education in 2008-09 compared to a 1.2% increase in the overall enrolment in higher education for the same period, this demonstrates a need to investigate online teaching strategies and its effectiveness.

Web-based technology has expanded in the last 20 years due to increased demand to use technology for teaching for varied purposes and multiple target groups, but its application has not reached a broader audience to ensure its effective use. For Healthcare Scientists and Biomedical Scientists there are core modules that are included in the curricula as anatomy, physiology, and cellular pathology both undergraduate and postgraduate level. Traditionally, these subjects were taught using textbooks, glass slides and conventional microscopy (Kim et al., 2008; Dee, 2009; Hamilton et al., 2012; Tian et al., 2014) but there is a significant shift to the exploration and use of blended learning tools. The literature has now been convincing in demonstrating an improvement of measurable learning outcomes (Wang et al., 2012).

As the technology for teaching and content delivery has developed, students' assessment and feedback have been reviewed to adapt to the teaching strategies, these favour online assessments and personalised feedback (Arend, 2006; Biggs & Tang, 2011). Along with these, new strategies for students' interactions with one another and with teacher/facilitators evolved. Technology allows different interactions and new modes of communication. This is particularly evident when considering peer interaction as this can be at the same level of learning or amongst students in different years as described in near-peer learning theories and students-teacher relationship as it allows different levels of engagement between students, simultaneously or asynchronous (Vonderwell et al., 2007; Pritchard & Morrow, 2017). Students' roles as active agents in learning have a role to play in the design and delivery of learning where the teacher is seen as a facilitator to promote and support the learning for the student. This is further highlighted and supported by the results of NSS feedback and the guidelines for the Universities in the UK (Gibbs, 2013; Healey et al., 2014; NSS, 2019).

In the realms of cognitive science and cognitive theories, much work has been undertaken to understand pattern recognition and the role of memory in learning. Since its inception in the late 1800s, the use psychometric tasks have gained popularity, whether to understand children's development or to understand whether an individual is suited to a specific role or a job (Baddeley, 2007; Brydges et al., 2018).

This study has specifically evaluated whether a set of psychometric tasks to assess working memory, processing style and speed could be used as predictors of student success. The tasks used were guided by the research supervisor and the use of the sequence of the tasks was innovative.

Pattern recognition in histology is still currently poorly understood and the researcher was aiming to understand whether processing style could be used to facilitate the learning of histology in undergraduate degrees and in the workplace.

The role of motivation and stress was also considered as predictors of student success and engagement in the current study. These two elements have been constantly raised by students in NSS feedback as a factor affecting student performance (NSS, 2019); the researcher further explored the role of motivation with the students during the interview's sessions.

This theory-based study aimed to be an inclusive approach to understanding a student's psychometric profile including stress, motivation, processing style and working memory and how this could inform the delivery and assessment of blended learning approach using traditional laboratory-based session and technology led VM for the teaching and learning of Cellular Pathology and the study explored students experience and student's motivation to learn Cellular Pathology. The thesis includes a section on the contribution of the findings to the software development and highlights areas for research in field of teaching-assisted learning.

The thesis structure follows the format provided from UoW. Chapter 2 provides the pedagogical underpinnings for adult education with consideration to blended learning and the role of assessment and feedback in the learning process.

Chapter 3 describes VM and its applications in the different areas of practice with focus on teaching of healthcare professionals. There is a section in the chapter that describes the literature review on the theme of VM overall and how some key papers have been instrumental for this study.

Chapter 4 discusses the role of memory and pattern recognition considering the theoretical framework and particular functions that can be measured: processing speed, processing style, working memory and attentional flexibility.

Chapter 5 describes the use of psychometric tasks that can measured considering the functions described in previous chapter and were used in this study.

Chapter 6 describes the methodology used in the study and includes the aims and the research questions and which qualitative and quantitative methods were used to address the hypothesis. It also includes the methods approach, the study design and describes the sample selection and recruitment of students.

Chapter 7 describes that pilot study, the findings and discussion and includes the psychometric tasks, the quiz, and the feedback questionnaire results.

Chapter 8 describes the findings from the intervention study considering the results of the psychometric tasks, the results for the three quizzes, the feedback questionnaire results and the themes that arose from the interviews. In this chapter other findings are presented that relate to how the psychometric tasks can be used as predictor of the students results.

Chapter 9 provides a discussion about the results of the study considering the research questions posed. It also includes the use of technology, the curriculum at UoW, the feedback to Westminster Path XL, VM in the workplace and guidelines and regulations.

Chapter 10 provides a conclusion and recommendations the researcher considered important to highlight.

Chapter 11 is the author’s reflexive statement.

2. Pedagogical underpinning

This chapter provides an overarching review of the pedagogical underpinnings for adult education with consideration in blended learning. It considers different learning theories and how students build upon knowledge. Curriculum development, the role of assessment and feedback are also explored.

2.1. Pedagogical underpinning - Teaching and Learning

Learning is a lifelong process that starts as early as when the individual is born until they die. Contemporary learning theories include behaviourism, constructivism, and cognitivist theories. The first is based on the learner's behaviours, constructivism focuses on the experience and how learners apply their knowledge, and cognitivism is focused on understanding the cognitive processes that learners go through to acquire knowledge (Schunk, 2014).

In recent decades, a range of definitions of learning have been proposed by theorists. A definition of learning requires situational context, disciplinary approach, and a perspective on learning. Qvortrup et al. (2016) opined that learning is a collection of perspectives and conceptualisation, including the acquisition of words, participation, and creation of knowledge. In the context of teaching in a formal setting, learning can be defined as a process of acquiring new knowledge by studying or experiencing a situation or condition (Qvortrup et al., 2016).

Traditional learning methods are classroom orientated, where the teacher manages students in a unidirectional way, and students are passive agents who assimilate knowledge (Ramsden, 2003). As learning theories developed over the decades, with the development of the neurosciences and the technological advances, teaching and learning strategies have shifted to a student-centered approach that considers different learning approaches and cognitive and behavioural styles that appeal to different individual characteristics and learning styles (Knowles, 1973; Fleming & Mills, 1992; Gibbons & Wentworth, 2001; Huang, 2002; Shadiev et al., 2014), for example, inclusion of self-directed learning and group activities to suit students with different learning preferences and needs. Constructivist theories posit that learning is built on understanding new information with existing knowledge and experiences to create their own learning. Here, knowledge is developed in a student-centered environment that is authentic and collaborative, where active participation, inquisition, discovery, and problem-based activities support student learning (Jonassen et al., 1999; Huang, 2002; Snyder 2009).

Huang (2002) summarised the role of constructivist theories in online instructional learning and concluded that constructivist principles in adult learning provide ideas to support online learning through interaction and collaborative learning. In authentic learning practices, students can critically reflect on own practices and experiences. In this context the delivery environment is of high-quality and the learner is at the centre of the process, considering learners different needs (Raymond et al., 2013; Lucua & Marina, 2014).

Teaching strategies have evolved from the large lecture sessions accompanied by smaller group tutorials and workshops and independent study to include active learning, problem-solving and work-based learning which is student-led. More recently, with the advent of technology in the classroom and outside the classroom, with the use of MOOCs, flipped classroom and blended learning (Achuthan et al., 2017) there are new opportunities to teaching and learning to take place for example, video recorded sessions, live online classrooms, and the use of software to deliver practical sessions.

There is a multitude of learning methods used to teach students, differently suited for different learning levels, and these include:

- active participation activities,
- exploratory and brainstorming discussions,
- problem-solving activities,
- student-led and student supported activities,
- scenario and simulation activities,
- laboratory based practical,
- independent self-reflective activities,
- feedback based learning and professional reflection.

The list above is not an exhaustive list of learning methods, but it provides the context to explore the multiple learning theories that could be considered to deliver the most effective learning strategy to the learner. Some are more instructional and directive whilst others are more experiential and require different levels of engagement with the material and with the other learners (Abela, 2009; Atkinson, 2009).

The different learning methods allows students to reflect on the learning and also to think through the learnings in a manner that makes sense to each individually. Though the process is student-led, they are mediated by different agents, students, and instructors respectively, some require group work and peer support (Laurillard, 2009; Taylor & Hamdy, 2013).

Considering the theoretical underpinning and the situational context of the learning in the current study, the students' experiences and cognitive processes are most relevant. These need to be understood in the context of the pedagogies used for teaching using blended learning approaches.

2.2. Blended learning

With the development of the application of computers and the Worldwide Web for teaching purposes, computer-based instructions, and gamification of learning content to facilitate learning and provide students with alternatives to learning that are suited to the different learning styles and tools available to learn (Olson & Hergenhahn, 2012). These include virtual space and third space and implications these may have on student learning and student interaction and engagement. The use of forums for students to connect, the use of personas or the metaphors in the learning process are examples of the use of different spaces for learning (Haggis, 2004; Smith & O'Halloran, 2011). As they progress to the next stage of learning and professional development, they are exposed to the learning methods, developing, and engaging actively in higher cognitive skills and more complex activities such as: problem-solving scenarios, simulations, pattern recognition, laboratory based practical, professional reflection.

These activities listed above are more experiential and easily relatable to the day-to-day practice of the practice as a Biomedical Scientist and in that sense more authentic experience for the student (Archbald & Newman, 1998 in Cumming & Maxwell, 1999). Starting from a passive role as learners, these students become active agents who take responsibility for their learning and can cumulatively experience and assimilate new knowledge.

Blended learning is a recently defined term as a “hybrid of traditional face-to-face and online learning so that instruction occurs both in the classroom and online, and where the online component becomes a natural extension of traditional classroom learning” (Colis & Moonen, 2001 in Rovai & Jordan, 2004, p. 3).

One characteristic of blended learning is the creation of a sense of community that enables the process of learning through socialisation and a sense of belonging (Sethy, 2008 in Tayebinik & Puteh, 2013). It provides the student with flexibility of access and independence of learning through the availability of online resources and digital libraries (Sharifabadi, 2006). Blended learning has been suggested to provide more significant interactions between student and tutor, particularly outside the classroom setting. By using online media like emails and discussion forums, students are conscious of the strategies available in a more structured manner and teachers can be more effective in providing tailored support (Tayebinik & Puteh, 2013).

When considering technology as a learning method, there are many terms used to describe this which are used interchangeably: e-learning, online learning, distance learning, VLE and Learning Management System (LMS) (Mason, 2001; Moore et al., 2011).

Defining the term “Online learning” is challenging as there is no consensus definition between this term and other like e-learning and distant learning. Carliner (2004 in Moore et al., 2011, p. 1) states that "online learning refers to learning and other supportive resources that are available through a computer". This implies that the learner has some distance from the tutor and that the learner uses some form of technology to access the learning materials, the materials are presented to the learner in a varied manner: CDs/DVDs, documents, videos, reference material, animated presentations, voice-over PowerPoints (VOPPs), interactive software. These are some examples of the tools available to students in which the content is available anytime anywhere. Considering the list provided, using VM for teaching purposes is considered an online learning strategy (Mason, 2001; Garrison & Cleveland-Innes, 2005; Moore et al., 2011).

2.2.1. Advantages and disadvantages of blended learning

In an online learning environment, students can be flexible in their use of the technology in a manner that suits their context. They can be part of a learning community despite being geographically distant and, depending on the setting, they can participate in structured discussions. In this manner they can demonstrate how they have engaged with the content and are also formatively assessed – asynchronous learning (Vonderwell et al., 2007; Pritchard & Morrow, 2017). Once the online system is initially set up, the delivery of subsequent years becomes less expensive and more affordable, the systems only require periodic review and updates to ensure relevance. In addition, students can be more autonomous and track their own progress and provide support to peers (Mason, 2001; Garrison & Cleveland-Innes, 2005; Moore et al., 2011; Kattoua et al., 2016).

There are many advantages to using online learning strategies as described in the literature. However, the literature also describes disadvantages and limitations to using online learning strategies. Firstly, it requires a reliable internet connection with good speed which is always not possible and particularly in geographically remote areas. The online software used needs to be carefully selected to fulfil the requirements that it is proposed to achieve. There are a multitude of software packages and platforms that allows different applications and support different styles of learning. Once the software package/software are chosen, changes may incur financial burden and the technical issues of moving data and adapting to the new teaching platform need to be considered. The equipment used to view the online course and the familiarity with the online system will also have an impact of the learning for if the system is not user-friendly, it will cause challenges for tutors and students (Masson, 2001; Huang, 2002; Rovai & Jordan, 2004; Kattoua et al., 2016).

A personal characteristic that needs to be considered in online learning is the high level of self-discipline and self-motivation required of students. At times, online learning may seem a lonely process (Gregori et al., 2018). A significant limitation in an online system only is the level of social interaction which is managed in a completely different way as there is no face-to-face contact (Kattoua et al., 2016). An approach where online learning is the only means for teaching undergraduate students needs careful consideration, the strategy for delivering teaching, the purpose of the approach and the retention strategy of students to minimise student dropout and student disengagement (Garrison & Cleveland-Innes, 2005; Arend, 2006; Salmon, et al., 2017).

2.2.2. Applications of blended learning

Rovai and Jordan (2004) conducted a study to examine the sense of community and evaluated the learning of students taking a master's degree in educational courses. In their research, they were able to demonstrate that in the blended course, students scored significantly higher on the connectedness post-test and achieved a higher estimated marginal mean for learning. The results for the connectedness post-test for traditional and the fully online approach were not significant for connectedness and learning for traditional approach was marginally higher than fully online though still not significant. A traditional approach and a fully online approach did not perform as well as the blended approach.

A study conducted in Australia by Farah and Maybury (2009) that aimed at introducing VM in pathology to third-year dental students demonstrated that students expressed a higher preference for VM and that their learning experience was enhanced by using VM in the students' curricula. Also, a study published by Triola and Holloway (2011) and another by Ordi et al. (2015) concluded that there are no differences between conventional microscopy and VM. Therefore, VM can replace traditional methods effectively.

An example of online learning using VM was a study conducted in Canada by Barbeau et al. (2013) for the Microscopy Anatomy Laboratory course. In this study, images were digitised using the Aperio ScanScope and the images were available in virtual slidebox platform. The students were divided in two groups, the first would have face-to-face sessions and could use slide/ microscopes and the digitised images; the other group (online only) would have pre-recorded sessions and have access to virtual slidebox. A third group was created for a Summer intake which was online delivery only. The results of their study demonstrated that online training is equivalent to the traditional method and maintains very high institutional standards. Online teaching created the additional advantage of allowing a summer semester version with minimal impact on teaching commitment and additional resources such as laboratory availability.

A study by Herodotou et al. (2018) reviewed the role of blended learning versus online only using in the delivery of a course with the Open University. The UK Virtual Microscope is used to deliver the campus-based module in the bachelor's degree in Geology and Petroleum Geology in a blended approach and distant-based modules in Earth science and Biology courses online only. The study concluded that blended learning is better than online only, the retention rate improved and the dropout of students in geology improved from 11% to 3%. They also concluded that the online delivery of online may not support students as well as blended learning approach. In the study, they described the role of students personal characteristics as age, gender, previous experience, and previous physical microscope experience. The study included the pedagogy perception of one-hundred and thirty-nine students through completion of questionnaires and the team conducted eleven interviews to understand further the students' perception of students engaging with the resources and completing the course.

McLean (2018) evaluated the delivery of a flipped blended learning approach in histology to undergraduate medical students where the delivery model that was evaluated had VOPPs prior to the face-to-face sessions. In this approach, students were explained the delivery method and the reasoning for this. The content was provided prior to the sessions and students would then complete online discussions. During the practical sessions, the students could discuss their learning more effectively with their peers and the teacher. The students demonstrated a high appreciation of the use of podcasts, quizzes, and MCQs in learning histology in an engaging and supportive manner.

2.2.3. Curriculum development in blended learning

From the studies highlighted above, blended learning following constructive alignment principle is seen as an inclusive approach to teaching due to its flexibility, adaptability to different circumstances and student reach and acceptability. The constructive alignment principle (Biggs, 1999; Biggs, 2003) was used to establish that the curriculum, the intended learning outcomes, the teaching methods, and the assessment tasks were aligned with each other to allow the effectively delivery of the content by the teacher and the online platform which is understood and assimilated by the student. Further studies are required in specific fields of practice, namely healthcare to validate VM as a reliable approach for teaching purposes.

To develop a curriculum, many learning theories have been postulated. McLoughlin (2000) proposed an inclusive cultural Instructional Design (ID) that considers an epistemological approach with authentic learning activities. This included flexible tasks, a community of practice, clear student roles and responsibilities, communication tools and social interaction, flexible tutoring responsive to learner needs, varied resources, flexible in learning goals, outcomes, and models of assessment (McLoughlin, 2000). According to Dick et al. (2005), ID theory suggests a system where resources and procedures are available to promote learning (Dick et al., 2005), the resources evolve over time as new online tools are available. Also, the ADDIE model is used by many researchers in the Curriculum development as this is flexible for the different delivery methods, face-to-face, online, and blended learning, it positions the learner at the centre of the process and considers the knowledge, skills and attitudes learners need to develop (Allen, 2006; Fresen, 2007; Ilberck et al., 2006; Olson & Hergenhahn, 2012; Kay & Kibble, 2016).

Technological Pedagogical Content Knowledge (TPACK) is a framework used for good teaching practices with technology drawing from many kinds of knowledge. The earlier model was 2-dimensional and would consider that content knowledge and pedagogical knowledge were the only two components that affected teaching and learning. The first is related to the teacher's knowledge and the pedagogical knowledge was related to the practices, processes and methods applied to teaching and learning (Shulman, 1986; Shulman, 1987). The technological knowledge element was introduced with the onset of technology in teaching and learning, from conventional methods of teaching (chalk and board, books, and pens). Teaching and learning was conveyed with smartboard, presentations, and audio and, more recently, with the use of virtual classrooms which included the use of software technology. The technological content knowledge (TCK) describes the relationship between technology and learning objectives. The technological pedagogical knowledge (TPK) relates to the technology and pedagogical content practices and theories. The pedagogical content knowledge (PCK) describes the pedagogical practices and learning objectives (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

Mishra and Koehler (2006) summarised the TPACK framework considering all the different components involved in teaching and learning. They demonstrated that the relatedness of content, pedagogy and technology were more than the sum of each independently. In a holistic way, this framework is concerned with how students learn, the knowledge students have prior and post learning, students process of learning, representation and formulation of concepts, pedagogical techniques, and theories of epistemology in a technological environment.

Salmon et al. (2009) proposed an online learning 5-stage model that postulated the scaffolding of learning in five stages: Access and motivation, Online socialisation, Information exchange, Knowledge construction and Development. Students start by entering the online environment, and developing their identity, learning some basic technical skills and simple content. Then they progress to deepening their knowledge and completing complex tasks. This type of setting has different amounts of interactivity and the learner engagement with different teachers and facilitators who have distinct roles in the process of learning (Goodyear et al., 2001; Salmon, 2002; Salmon et al., 2010).

In the context of education, 'learning styles are used to refer to a range of constructs from instructional preferences to cognitive styles' (Riding & Cheema, 1991 in Sadler-Smith, 2001, p. 609). Fleming and Mills (1992) proposed four individual learning styles: visual, auditory/aural, reading/writing, and kinaesthetic - VARK. Understanding individual learning styles need to be considered as it needs to stimulate students in a multitude of ways so that learning can be assimilated. In the context of blended learning using VM, some of these styles are inherent to the method (visual) while others may require additional development.

Buşan (2014) reported that the general population, learning style is considered as 65% visual learners, 30% auditory learners and 5% kinaesthetic learners. In this study there was a different breakdown for medical students: 45% are visual, 36% are auditory, and 19% are kinaesthetic and, the role of practice, simulation and clinical practice are more relevant in this professional field. The findings from Buşan studies demonstrated that medical students have a different breakdown from the general population considerably. Considering this study, it could be postulated that other healthcare professional would follow the same trend. Learning styles affect learning; however, there are insufficient reports in the literature to suggest how this affects Biomedical Scientists, particularly and only scattered reports are available in the healthcare field.

2.3. New technologies and principles used in education

The emergence of digital technologies allowed diversification of teaching strategies and the opportunity for students at an academically higher-level teaching, facilitating, and supporting a lower-level student to complete a task or learning event. This is referred to as being near-peer learning or a variation of this term, this term was first described by Murphey and Murakami in 1998. Goldberg and Dintzis (2007) demonstrated the positive impact of team based VM sessions in physiology and histology in a cohort of one hundred and twenty medical students in the first year. Gatumu et al. (2014) demonstrated that the implementation of VM improved teaching and learning in histology practical sessions and revision, the cohort of students was larger and included students in medical, veterinary and dentistry courses.

The near-peer principle rests on the fact that learning is consolidated by practice and that peers can relate better to each other to support learning. While it is practiced in a peer environment, this approach still has some teacher dependency. The benefits reported to the student-teacher/leader are the development and practice of instructional skills. Further improvement of their employability arose from developing and demonstrating softer skills as critical thinking, problem solving, teamwork and communication during the learning sessions and by subsequent reflective practice. The benefit to the student is that learning evolves as a shared insight from another student. Students can relate better with students at the same or just above their level more effectively, helping to build a safe learning environment along with the development of social skills and improved engagement and motivation. The reported benefits to the teacher and the university are an improved student experience, the development of student potential, creating of an enabling environment, consolidation of class teaching through the support of different learning styles for students (Goldberg & Dintzis, 2007; Gatumu et al., 2014; Khaw & Raw, 2016).

Cambrón-Carmona et al. (2016) demonstrated that near-peer teaching practical sessions in histology for students completing a Medical Histology module were an effective alternative teaching method with equivalent outcomes to traditional method which consisted of learning tissue processing and ways to perform a cytology test. The team reported that there were no outcome differences, but students reported a better-valued experience.

Communities of practice are defined as platforms which enables knowledge transfer by practitioners (Wenger, 2000; Wenger, 2004). All those in the group share a passion or have an interest in the subject are motivated and have a common purpose and communicate regularly. With the development of technological tools, this concept was further developed to include virtual communities of learning (Vygotsky, 1978; Snyder, 2009). Today, more than ever, this concept has a new dimension, people are working from home and Universities are delivering teaching online. When considering the development of communities of practice, sharing a common interest is important, early theory suggests that this emerges informally and grows organically to maturity (Brown & Druguid, 1991). Hanisch (2006) states that Universities delivering online learning need to consider other elements, including familiarity with online digital tools, individual characteristics such as learning and cognitive styles and socio-cultural diversity (Gaytan & McEwen, 2007).

2.4. Student compliance and attrition rate

The student completion rate and attrition are considered measures of success in learning. The concept of dropping out of a course is measured differently by different research groups, and while some state that attrition is standard and expected, others prefer to distinguish different times in a course in which the attrition rate and only student dropout at later stages in a course is significant, change of courses and early dropout are not considered. Simpson (2013) proposed three student dropout attitudes, from a survival of the fitness model (Darwinist), an Academic Fatalistic Model fatalist model when the student drops out for a reason beyond their control, to a model where the student dropout is due to the lack of support (Rovai, 2003; Woodley, 2004; Simpson, 2013).

On reviewing the literature, Arend (2006) suggested that 11% of learners from a cohort of 411 students, took on online learning as they considered it easier than other modes. 70% of students completed online training, and only 16% wanted or needed to complete the training for their work. Gregori et al. (2018) research demonstrated a high attrition rate when comparing undergraduate degrees, Masters' degrees and Masters' distant learning degrees, and the latter had a higher dropout rate. With the additional support for students taking distant learning degrees, the university saw the attrition rate being reduced and students felt better supported to complete their degrees. The attrition rate on MOOCs is reportedly higher (Gregori et al., 2018) and Onah et al. (2014) reported a 13% dropout rate considering MOOCs online courses on Coursera.

Dutton et al. (2001) discussed the completion rate terminology on an Introduction to Computer Programming course where one-hundred and forty-one online students had a 72.2% completion rate, and one-hundred and seventy-one face-to-face students had a 90.3% completion rate. In the same study, they stated that the online students who completed the course did better than face-to-face undergraduate students.

The literature provided many justifications for the students' dropout:

- students struggle to engage with the platform,
- a non-personalised approach as students feels isolated,
- lack of digital skills or poor technical preparation by the students,
- personal reasons as lack of time,

- students’ financial constraints,
- incompatible schedules with family demands,
- job related challenges as change in professional circumstances, lack of work support or too much work,
- teaching and academic-related reason as academic ability, educational aspirations, lack of tutor or peer support.
- study habits and bad experiences at university

Course changes tend are infrequent in UK Universities, they are more frequent in liberal arts degrees; however, this is considered dropout of the previous course which can be misleading. Student dropout should also consider individual characteristics as intention and motivation, expectations, and own interests (Willging & Johnson, 2004; Woodley, 2004; Gregori et al., 2018).

Recent data published by the Higher Education Statistics Agency (HESA) revealed that in 2016/17, socio-economics factors affected attrition rates mostly: 8.8% of full-time first-degree students under-21 from disadvantaged backgrounds are more likely to drop out of university compared to their more advantaged peers at 6.0% (Department for Education & The Rt Hon Damian Hinds MP, 2019).

Two factors that are important to highlight when considering student success and attrition are stress and motivation. Stress has been defined as the physiological and psychological experience of significant life events (Thoits, 2010). In the stress response model introduced by Selye (1956), the response pattern is captured in the general adaptation model: alarm, resistance, and exhaustion. However, stress can be viewed as a stimulus. This theory was introduced in the 1960s in which stress has an active role in life as a response mechanism where individuals had to adapt or adjust to different circumstances: demand response had to be adjusted or adapted to life. Holmes and Rahe (1967) described the Social Readjustment Rating Scale consisting in 42 life events scored to measure the experienced stress caused to the individual (Joels et al., 2006; Stangor & Walinga, 2014).

The role of stress in learning is debatable, but there is some evidence to suggest that small levels of stress in the context of learning may be favourable to induce focused attention and improve memory (Elias et al., 2011; Joels et al., 2006; Stangor & Walinga, 2014; Woolfolk, 2014; Rudland et al., 2020). On the other hand, high levels of stress can be disruptive and damaging to the learning process (Joels et al., 2006; Stangor & Walinga, 2014). Also, motivation is a vital facet to consider when discussing students' learning and success. A cognitive approach to motivation suggests that learners are active, curious agents searching for practical information to solve their problems (Malone, 1981). Dewey (1902) proposed a dimension on education about experiential education (hands-on) in which the students are actively involved with the curriculum, and the teacher is an agent to help students realise their potential as equal partners; this was at the basis of the works proposed by later theories on experiential learning by Kolb et al. (1999) which are still valid (Dewey, 1902; Kolb et al., 1999; Sternberg & Zhang, 2000).

The origin of motivation has been described by Deci and Ryan (1985, in Ryan & Deci, 2000) and they distinguished between intrinsic and extrinsic motivation in their theory of Self-Determination. Intrinsic motivation has an inherent drive as personal development or fulfilment while extrinsic motivation refers to external drivers such as recognition or wealth. Student's outcome is influenced by their motivation for learning, and this depends on the individual personality, the nature of the activity, the social and classroom environment at the time of performing the activity (Ryan & Deci, 2000; Deci & Ryan, 2008). It is essential to consider the personal interest of the individual for performing a particular task or learning, and the positive reinforcement and development of creativity that the task or learning will bring to the individual (reward). This was not considered in earlier research but has been shown to be an important factor in recent studies (Jovanovic & Matejevic, 2014).

Having considered the pedagogical theories in adult teaching and learning in blended learning, chapter 3 introduces VM, and its use in teaching and learning.

3. Virtual microscopy

This chapter will explore in detail the theoretical underpinning for using VM in teaching and education, the advantages and disadvantages its application. In this chapter, there will also be an exploration on the choice and implementation of a VM system and its use in teaching, assessment, and feedback. It will also highlight the basis of the literature search to be included that address the relevant topics on thesis and those materials that will be used as essential and those that are complementary to the topics highlighted.

3.1. Theoretical underpinning

Cellular pathology is one of the core subjects of a Biomedical Science undergraduate degree in the UK, in this module, students are exposed to normal and abnormal human tissue content and are taught the different tissue patterns in normal and abnormal conditions. A range of methods has been used in teaching normal tissue and pathology to students to allow them to recognise microscopic features in a glass slide.

The most typical process to teach undergraduate students is based on didactical, theoretical, and instructional sessions, followed by practical laboratory-based sessions demonstrating recognisable microscopic features and then reinforced by independent student learning through self-directed activities with the aid of textbooks (histological atlases). This cycle is repeated throughout the module and for the various tissue types that students need to learn (Ramsden, 2003). These methods are effective with some students, while other students require diverse approaches and repeated sessions on the same topics to understand and internalise the materials (Gopalan et al., 2018). Recently there have been additional challenges to the teaching of tissue recognition overall, this is due to time constraints, large student cohorts and the availability of microscope and glass slides for teaching purposes (Huang, 2002; Helle et al., 2013; Chan, 2010; Hande et al., 2017; Gopalan et al., 2018; McLean, 2018).

Bloodgood and Ogilvie (2006) reported a 50% decline in histology laboratory hours in medical schools for the period 1967-2009 which highlighted the need to investigate other approaches to the teaching of microscopy and glass slide interpretation (Bloodgood & Ogilvie, 2006, Nivala et al., 2013).

Theories and models have been developed to explain the tissue recognition model, the traditional route of direct observation of the histology slide both microscope and glass slide and VM, mathematical and probabilistic graphic models and those more digital models that include machine learning, deep learning, and artificial intelligence (Garcia et al., 2007; Ben-Gal, 2008; Hamilton et al., 2012; Randell et al., 2013; Holländer, 2020; UCL, 2021).

Probabilistic graphical models are statistical frameworks that allows the representation of complex events using probability distributions, the application of such models is used in machine learning, computer vision, natural language processing and computational biology (Ben-Gal, 2008; Hamilton et al., 2012). Bayesian network is a directed graphical model with an observable variable which has been proposed to explain the process of tissue recognition, and the inferences are based on a content-based decision tree mapping that determines the margin probability of on event occurring. An example in histology would be based on the cellular and nuclear features where a probability matrix with a decision tree mapping can set up, in this system each of the features would have a different weighting to allow the diagnosis of a particular condition (Garcia et al., 2007; Ben-Gal, 2008; Holländer, 2020; Hamilton et al., 2012).

Theories of medical image interpretation (traditional direct observation) have been used to attempt to describe the role of visual perception and expertise in histopathology using analytical and non-analytical pathways in which recognition could be the result of development of perceptual skills or the development of high and automated cognitive processes. Both theories described above are amongst different models to explain tissue recognition; however, none has produced reproducible outcomes to validate the process of tissue recognition, therefore, the process of tissue recognition remains poorly understood in psychology and this leads to teaching methods for tissue recognition being based on best practice rather than fitness for practice, this is that current teaching relies of microscopy and glass and more recently, digital methods have been introduced; however, graphic models, machine learning, deep learning, and artificial intelligence are still not applied in diagnostic histology (Hamilton et al., 2009; Helle et al., 2011; Nivala et al., 2013; Woolfolk et al., 2013; Holländer, 2020).

The students attending university are adults, and one of the characteristics of adult learning is their internal motivation which plays a significant role in developing memory and directing behaviour. There are many theories about motivation and of interest is the cognitive approach where learners are seen to be active, curious, and inquisitive agents, searching for practical information to solve their problems. This theory demonstrates that among the learner's needs are self-determination, autonomy and self-efficacy that refers to an individual's belief in his/her own capacity to produce a specific outcome (Knowles, 1973; Malone, 1981; Bandura, 1986 in Brentham, 2002; Woolfolk et al., 2013). The students' personal characteristics are being used in the teaching approaches at all levels, and this is being further explored by teachers, psychologists, and other groups to improve the quality of teaching (Gregori, 2012; Woolfolk et al., 2013; Qvortrup, 2016).

In the wider curricular training of healthcare professionals, it is fundamental that individuals learn normal cell structure and tissue function, pathology and the processes that cause disease in the human body. The curriculum is developed in terms of complexity: in the first-year, students learn the basic histology following a functional approach, in the second year, students learn about biology of disease and pathobiology including inflammation and dysplasia, and in the third year the students explore malignancy disease and associate previous acquired knowledge to more complex diseases (moved from methods to here).

Conventionally, human anatomy and pathology are learned by exposing students to the theory through lectures, textbooks, and self-teaching and by practical microscopy sessions. In recent years, access to primary source material (stained tissue sections mounted on glass slides) for the purpose of teaching has diminished for a range of reasons, partly due to new legislation on the use of patient material and the transport of diagnostic material which may have been or not consented by patients which is described in the HTA regulation (HTA, 2016). Alongside these, obtaining enough glass slides for students particularly of rarer diseases and having a constant repertoire of good quality glass slides for students has become increasingly difficult to source and to maintain. This is compounded with the natural fading of the stains, damage of slides, breakages, and loss of slides. Also, with the increase in the number of students in the healthcare field and the increased cost of equipment such as microscopes and their maintenance, has contributed to the challenges of teaching students using glass slides (Dee, 2009; Rocha et al., 2009; Simavalai et al., 2011).

Until recently, the use of glass slides and microscopes to teach adults in healthcare was deemed to be adequate in most contexts where these tools are available. In the past, individual students would prepare and keep their own glass slide sets and, in this way, have direct feedback from tutors on tissue preparation and visualisation techniques. Today, universities have larger cohorts of students, from having 10 to 50 students, classes are now attended by 100 to 300 students, and practical sessions need to have multiple sessions to accommodate all students. Any glass slide produced is exposed to environmental risks. Also, stains fade with time and glass slides occasionally break even with proper use and following good laboratory practices (Rocha et al., 2009). All these challenges have increased the demand for glass slides for teaching purposes. Therefore, the use of technology-enhanced methods in adult learning seems to promise an effective alternative to the use of glass slides.

3.2. Applications of VM

The College of American Pathologists reported for the first time the use of the computer for educational purposes for pathologists in 1962, a decade after the first computer was used for clinical trials. In the 70s and 80s, histology teaching was aided by 35mm film slides and short cartoon-like films of staining tissue sections, and later the use of technology in histology and cytology became widespread with the introduction of affordable digital cameras with proper resolution and colour balance. At the end of the 20^{th} century, web-based technology was introduced and it rapidly gained popularity amongst tutors and became widely used as an educational tool for pathologists and other medical staff due to the advancements in technology, ease of capturing and sharing resources online and availability for online storage, also, the use of technology for teaching allows a wider audience to benefit from the resources available worldwide (Blake et al., 2003; Krippendorf & Lough, 2005; Braun & Kearns, 2008; Farah, 2009; Weinstein et al., 2009; Huisman et al., 2010; Paulsen et al., 2010; Park et al., 2013).

In this context, the use of technology has been grouped under the term VM; however, this concept is still fluid. Helle, Nivala and Kronqvist (2013) proposed a definition of VM as a “collection of digital images”, which allows the user to view and highlight and zooming of microscopic features, comparing normal and abnormal areas, overlaying different digital images of the same stricture/area, inserting text, comments, and videos, and ultimately creating integrated learning materials. The applications of VM can be broadly grouped in diagnostics, education, and research and archiving (Helle et al., 2013).

In the context of VM in Cellular Pathology, the main goal of VM is primary reporting of digital slides, all other applications of VM are secondary. The educational opportunities provide greater teaching opportunities through blended learning and the use of technology to allow for enhanced teaching quality. The research opportunities allowed research groups to review material using technology by creating algorithms and mapping of features of interest which can then be translated into diagnostic tools. The archiving opportunities are related to diagnostic purposes and also to the limited storage capacity that institutions need to have to store the materials; VM allows easier retrieval of cases required for multidisciplinary meeting that is part of the diagnostic tools for the patient and once the slides are electronically stored they can be retrieved at any time easily and without any additional costs or slide damages (Rocha et al.; 2009; Weinstein et al. 2009; Huisman et al., 2010; Krenács et al., 2010; Paulsen et al., 2010; Cornish & McClintock, 2014; Parks et al.; 2013; Brinson, 2015).

The use of VM applied to diagnostics was first described in 1986 as telepathology where images were sent to another pathologist for review (static telepathology) or when the microscope could be controlled remotely (dynamic telepathology) (Rocha et al., 2009). In the realms of diagnostic pathology, it is possible to report frozen sections with high confidence using telepathology and VM as reported by Evans et al. (2009). However, the uptake of this practice in the UK has been slow. In the UK, the first fully digital pathology laboratory was established in 2018 in the Leeds Teaching Hospital. This was made possible by many years of validating digital scanning for the purpose of primary reporting of tissue sections (Aldridge, 2018). There are now multiple diagnostic laboratories in the UK that have digitised settings: Oxford

University Hospitals (OUH) NHS Foundation Trust, South West London Pathology in 2020 and the purpose-built facilities in Betsi Cadwaladr in North Wales with other centres to follow (Pathology in Practice, 2020; South West London Pathology, 2020; Babawale et al., 2021).

Digital slide archiving is another opportunity that VM has created which saves time and resources, once the slide is scanned, the image can be stored indefinitely in the system server, depending on the need to access the slide, this can be in short term memory, easily retrieved or long-term memory which compresses the file but keeping the image properties. This removes the need for a physical slide archive which requires a physical space that handles a heavyweight of the glass slides and then having an individual to retrieve the glass slides when these are requested for opinion and required for multi-disciplinary meetings (Huisman et al., 2010). However, there is an increased demand for electronic storage, maintaining software updates, and higher security features with using a digital system but the benefits of research libraries outweigh the terabytes of storage. In the UK digital slide archiving is not routine practise for most laboratories and so there are laboratories that use an enormous amount of space in the hospitals to archive material with costs of renting space within the Hospital premises and outside to comply with the guidelines set by the RCPath (Weinstein et al., 2009; Huisman et al., 2010; Paulsen et al., 2010; Park et al., 2013).

The use of tissue microarray technique allows staining and analysis of over 500 cores per slide, which lets multiple biomarkers to be tested consecutively. The applications of VM are still not fully realised, VM enables slides to be digitised and the viewing features allows the images to be zoomed, image overlay of the same area of interest with different markers, mapping of the images and data analysis of the images is straightforward. Furthermore, algorithms can be developed to aid in analysing staining pattern (Krenács et al., 2010) and consequently the creation of algorithms allows standardisation of tissue recognition for pathologies and patterns of mutation without the bias of human error. With the development of artificial intelligence, there is a renewed opportunity to use VM considering new machine learning and deep learning technology (Garcia et al., 2007; Ben-Gal, 2008; Randell et al., 2013; Holländer, 2020; UCL, 2021).

In education, the opportunities to apply VM range from teaching undergraduate students in the several healthcare fields, for example, medicine, dentistry and oral pathology, histology, cytology and haematology, training registrars and pathologists during their academic training and in the diagnostic setting as specialist registrars and CPD. There are some reports of the use of VM in veterinary teaching (Gatumu et al., 2014).

Another area where VM is contributing to practice is in CPD for professionals. United Kingdom National External Quality Assurance Scheme for Haematology (UKNEQAS(H)) provides a service to over 2000 professionals in the UK and internationally (Brereton et al., 2015). Individuals were provided with large digital images in a setting like a LM which they need to interpret a blood film. In their study, Brereton et al. aimed at understanding the process of decision making in diagnosing the condition; however, they were not able to further contribute to the understanding of tissue recognition in VM.

Diagnostic pathology has been the main driver for the development of VM technology. However, in the most recent years, the use of VM in educational fields across the healthcare arena has been dramatically expanded (Table 3.1). Some studies demonstrated that the use of web-based technology is being sought as an alternative to the challenges posed by acquiring glass slides, equipment and technological advancement are driving the impact of VM, and this is likely to increase in the years to come (Dee, 2009). From the studies illustrated above and those in Table 3.1, studies by different groups worldwide reported that educators and students perceive that the teaching and learning experience using VM is positive and students are inclined to use VM, yet further studies are necessary including bigger cohorts of students and in different courses/modules to explore the role of VM and extended strategies in the teaching and education and assessment using VM (Dee, 2009; Paulsen et al., 2010; Simavalai et al., 2011; Hamilton et al., 2012; Helle et al., 2013).

The demand from higher education institutions, employers and students for accessible and flexible learning strategies has been gaining momentum over recent years. As part of the response to this demand, the UoW developed and introduced a development strategy in 2012-13 aiming to ensure that the university can lead in delivering a distinctive, transformative, and engaging learning experience. As part of the support for innovative development, the then Faculty of Science and Technology, led by Dr Anthony Madgwick, introduced an unlimited access licence for Westminster Path XL Tutor for use in teaching histology and related subjects in VLE. To provide evidence-based support for the current efficacy of the approach and to identify future opportunities for enhanced independent learning.

The use of VM has many advantages, the greatest being the availability of slides "anytime, anywhere" by multiple people. In a diagnostic setting, it allows remote diagnosis, faster revision, and consultation of slides. Panels and meetings can happen virtually instead of by face-to-face interactions and with positive integration of VM with the laboratory software system. Hospital space for storage of slides and blocks is at a premium, and more commonly this is being sent offsite. Archived cases can be easily retrieved if they have been digitised for any purposes, saving retrieval costs of blocks and glass slides, time and the need of the tissue being recut. Also, long term storage degrades the staining on the slides, and digital slides keep the quality of the staining at the time of diagnosis.

Considering the training element, the VM software enable the use of reference slides, annotated slides, and slide tagging. VM allows various learning and testing to be developed for students, allowing students to independently drive their own learning. Another development with some of the VM platforms is the online testing functionality with instant feedback, this is possible by creating MCQs with answers on the VM platform that can provide results once the test is submitted, short answer questions may also be possible and for these, marking is required. Furthermore, VM creates increased interactions between supervisors and students, allows more significant peer support interactions, and allows the learner take control and responsibility of their own learning pattern in an asynchronous student-centered learning (Vonderwell et al., 2007; Dee, 2009; Huisman et al., 2010; Paulsen et al., 2010; Pritchard & Morrow, 2017).

A recent report by Fonseca et al. (2015) included a questionnaire with six questions and one open-ended questions which was used rarely by students. This highlighted better quality student-teacher interaction and the teaching itself rather than spending time managing the classroom, slide distribution and setting microscopes also, all students were viewing the same structure in the same section of the viewer, simulating the multi-header experience without the limitations of space and motion sickness. Overall, there was a better student compliance and engagement with the teaching methodology and students were more enthusiastic. In addition, the use of technology allows for the resources to be shared in different modules, reduces space needed for microscopy labs and allows the teaching time to be used more effectively. Despite all the advantages reported by students and teachers, a limitation is the high costs required to acquire the systems which is off set with the usage of the system. Ahmed et al. (2018) reported less positive feedback related to the use of technology, when this hinders learning or at least questions the value of using both VM and OM methods, so students are supported in their learning, such as internet speed, quality of screen/viewer which has an impact of the quality of the image seen and freezing of images.

3.3. Choosing and implementing VM

Technology as changed over the years to accommodate the needs of society, the 21st century has seen a growth in the use of technology in all fields of practice, and in everyday life. The term technological evolution was coined by Radovan Richta (1967). The advancements and application of technology in healthcare demonstrate this theory in practice, from 35mm film images in the 70s and 80s, to digital scanners that can digitise slides in a few seconds and be displayed in screens everywhere in the world. The notion that one innovation follows a S-shape curve from development to a mature product one at a time, has been replaced by many innovations being developed and the S-shape curve overlapping one another. In this process, feedback is constant and thriving of innovation in niche areas is better than using a scattered approach to technological innovation (Sood & Tellis, 2005; Bardeen & Cerpa, 2015).

A collection of images in a technological system is a long and complex process that involves a series of actions and investment in costly equipment, the process starts with the having the relevant equipment and slides: obtaining slides from reliable sources considering the purpose of the project/study, the supplier must comply with the regulatory criteria and appropriate consent must be obtained for the release of the slides. The scanning of the images involves the slides, the scanner, and the viewer software. When the slides have been digitised, the images need to be labelled and catalogued, tagged and notes may be needed. The size of the server to store the images needs to be reasonable to store the images in short term capacity and if the images need to be stored for long periods, a schedule for storage needs to be set up. The server needs to secure and maintained on a regular basis as well as the viewing software. When creating a collection of digital slides, consideration of the server size is very important; until recently, servers have been local and there are issues with increasing the server size – spatially and financially. With the developments of cloud storage and GDPR and information security, new opportunities are available to facilitate and enable big size storage of digital images. To assist in overcoming some of the challenges related to hardware and software elements of VM, Rocha et al.

(2009) explored new developments such as user-friendly software, improved scanning speed, a software programme that can be linked to a laboratory database, increased storage capacity for data and growth of economical scanners and software. Considering the latter development, several companies developed new scanners and software solutions which are readily available on the market for use for diagnostic purposes mainly and to assist with telepathology in remote areas where access to pathologist expertise is limited (Rocha et al., 2009; Paulsen et al., 2010; Wand et al., 2012; Helle et al., 2013; Gatumu et al., 2014; Appasamy, 2018; Zarella et al., 2019).

The first challenge to VM implementation is the constant equipment (scanners) development, to respond to the needs of the market, slidescaners are in constant development with new and more refined features being made available. Closely associated with the equipment, is the high maintenance costs. The second challenge are the continuous advances in software that is used to analyse and view slides, like the equipment, new software with greater capacity of analysis is being developed, most of them associated to the scanner suppliers.

The scanners that are available in the market range in price, size, scanning capacity, speed, and functionality (Rocha et al., 2009), these need to be carefully considered when implementing a VM setting, including the short- and long-term strategy for the use of the system. A challenge that may arise relates to the purchase of an additional software product to assist with the interpretation and analysis of the scanned material. As with the choice of scanner, careful consideration is required, the software also needs to be compatible with the scanner and a scanner/software package may be required to avoid technology issues later. If these points are not considered early on, prior to acquiring the products, this can lead to the huge financial investment and the human resources invested in the process to be wasted and create disengagement with technology (Dee, 2009; Rocha et al., 2009; Krenács et al., 2010; Wang et al., 2012; Park et al., 2013; Gatumu et al., 2014).

There are many scanners on the market, and in the last decade there has been an exponential increase in makes and models for VM use: single or multiple scanning capacity, regular (routine) slides and large slides, sophisticated scanning for cytology, scanners that can digitise special techniques as polarised light or immunofluorescence. In terms of viewing software there are many options to consider, web-based software has seen a significant development, from free software that can be designed without a great time and low-cost implications to the creation of programmes. There are companies that customise viewers and develop high-definition screens of multiple sizes touch screen features and develop other sophisticated tools to create more attractive software. Some software allows image capture, adding graticule and changing magnifications. The magnification feature in the scanners is fundamental, the slides are scanned at a known magnification, depending on the scanner type and the quality required for the scan, generally x20, for certain techniques and tissue types x40 is recommended. Once the slide is digitised, the software allows the user to change the magnification available in the software to visualise the image at a different magnification (details of Westminster Path XL the viewer in Appendix 8), this is easier, without losing focus and less straining to the eye. Some software has been developed as patient simulators which would enable students to follow a complete patient pathway in a considered scenario (Blake et al., 2003; Evered & Dudding, 2011; Hamilton, et al.; 2012; Wang et al., 2012;

Barbeau, 2013; Craig et al., 2014; Gatumu et al., 2014; Appasamy, 2018; Zarella et al., 2019).

The literature available reported scanners and software development in haematology, cytology besides VM in histology; this is noteworthy as the reasoning for the development of VM is to visualise cells in different ways. In the context of histology, it is cells within the context of tissues and organs and cell associations whilst in haematology and cytology, the process is the visualisation of the cell morphology, i.e., the individual cell shape, size, structure, and form (Evered & Dudding, 2011; Donelly et al., 2012; Brereton et al., 2015; QAA, 2020).

Saco et al. (2016) described three areas to consider WSI for VM: the equipment, the viewer, and the digital slide. When considering the equipment, there is a greater prior computer knowledge today than before, once the slides are digitised, they are available anywhere providing internet access is available, and it allows remote access, the images can be used by multiple people at the same time as the images are stored in a cloud-based environment. The software allows simulation of the experience with using OM, this is software dependent. According to this work, there is an improvement of interactions between students and student-teacher interaction as students are seeing the same image whilst teaching and discussion are taking place. The other not seen advantage is that the service maintenance for microscopes can be waived and the space to store many microscopes and the glass slides can be utilised differently. Despite the fact mentioned earlier, a study by Bloodgood and Ogilvie reported that the significant increase of computer-aided instruction had not been accompanied by a decrease in the use of microscopes and glass slides, with nearly 93% reporting they will use computer-aided instruction only 33% indicated they would use computer-aided instruction only (Bloodgood & Ogilvie, 2006; Triola & Holloway, 2011; Parker et al., 2017; Vainer et al., 2017).

The viewer (software) allows image orientation, the inclusion of multiple techniques available to students in one area, it will enable several slides in one screen super-imposed and the development of mega screens for viewing – screen mosaics with great resolution. The viewer also allows the development of automatic marking and feedback, it will enable dynamic annotations to be available for students and the search function for instant access is possible (Wang et al., 2012).

3.4. Advantages and disadvantages of VM

There are many advantages of the digital slide: there is no deterioration over time which means no need to replace the slides regularly. There is greater homogeneity amongst what students are seeing as that is the same image, and students can get to the same mapping points by going to the same position on the image slide. Considering VM in comparison with glass slides, one set of digitized slides are sufficient for students in the VM context and any unusual stains/diseases which may require expertise only need to be digitized once and they are then available for students, this is a cost reduction and a better provision of resources for students. If glass slides were required for each student, the costs and resources would need to be much greater to enable students to participate in the learning sessions (Krenács et al., 2010; Cornish & McClintock, 2014; Ahmed et al., 2018).

With the development of scanners, there are scanners that can digitise large slides and slides stained with fluorescent techniques. Large slides are bigger than the regular slides and require a larger insert for the scanners, the tissue stained in the slide is bigger, so it requires longer times for scanning. Fluorescence techniques and fluorescence techniques rely on the molecules properties in the cells absorb high energy, short wavelength light, and then emit coloured radiation which can be visualised, due to the nature of the technique, these preparations are short-lived and fade quickly. The cost of scanners that can scan these types of slides/cells are still considerably more expensive. However, being able to scan this represents an innovation in VM applications (Rocha et al., 2009; Cornish & McClintock, 2014; Elliott et al., 2008).

There are reported weaknesses when using VM: initial high investment for the equipment and software, consideration if multiple scanners are required for various scanning needs, the need of a suitable sized server to store the digital images. As important is the system, for the server maintenance to ensure continuity and a seamless flow of images being digitised and then available for viewing is required. There are multiple software options (minimised by scanner developers), there is a loss of use of microscope and slide preparation and could lead to the reduction of social interactions. Also, the terminology and the way it is applied in VM differs from the LM, namely resolution and magnification and the possibility of zooming in VM. (Weinstein et al., 2009; Krenács et al., 2010; Cornish & McClintock, 2014; Ahmed et al., 2018).

Z-stacking phenomena is process in which multiple images are combined to produce a focused digital image, Weinstein et al. (2009) reported concerns regarding Z-stacking in cytology as there are many layers of cells in cytology that may not be decompensated when digitising slides causing issues when viewing the individual cells in a digital image (Weinstein et al., 2009; Donnelly et al., 2012).

Zarella et al. (2019) reported some challenges concerning image compression, colour preservation and image analysis/manipulation as this will have a direct impact of image viewing and interpretation, a distortion of the original image will have an impact on the clinical diagnosis of the tissue section and they suggest some considerations when purchasing a VM solution, for example, saving the images in the correct file format, having high definition screens to visualise the images, storing the image files appropriately (generally per case) in the server and maintaining quality server back-ups. They also expressed concerns regarding the terminology "magnification" due to lack of good guides in the literature and added a few dimensions that need to be considered in the VM field: image management system, artificial intelligence and learning machine as concepts and practices that need to be considered soon as there is great development in these fields of expertise (Holländer, 2020; UCL, 2021).

3.5. VM and teaching

For universities having a steady supply of glass slides of varied nature with quality and relevant to the teaching curriculum has proven to be challenging over the years, hence the use of VM being hugely advantageous financially for the universities and as a useful and up to date resource to the students (Dee, 2009; Huisman et al., 2010; Paulsen et al., 2010).

Web-based technologies, including VM, have been developed for pathology, radiology, nursing, surgery, and dental practice. The survey results reported by Merk et al. (2010) in Germany revealed high acceptance of web-based digital histology by students between the 3rd and 5th year of medical education, the use of VM increased prior to the exams in the faculty campus and the image quality was rated slightly higher compared to glass slides (Merk et al., 2010).

The process of tissue recognition is not entirely understood by scholars, and more studies are required to understand the process of tissue recognition (Hamilton et al., 2009). Student interaction and teaching effectiveness with blended learning particularly of web-based technology are being sought at all levels of education. However, students' engagement with VM is controversial and has not fully been explored, in addition the research demonstrated inconclusive results regarding better outcomes for students using VM particularly in cytology (Scoville & Buskirk, 2007; Dee, 2009; Hamilton et al., 2009; Evered & Dudding, 2011; Simavalai et al., 2011; Donnelly et al., 2012; Diaz-Perez et al., 2014; Brinson, 2015; Gopalan et al., 2018).

A survey by Pratt (2009) in the USA about physicians' perception of the use of computer-based instructional technologies revealed that 88% of physicians consider that students must have microscopy training. According to the respondents, VM is not as good as viewing the slide on the microscope, also, it is essential for students to acquire microscopy skills and being able to learn cells and tissues, not just an image, of the microscopy features of the tissue, a hybrid model should be considered according to Pratt's report.

Noteworthy mentioning is the article by Mione et al. (2013) who conducted a study in two academic years: 2006-07 and 2007-08 that reported students learn histology independent of the mode of teaching – VM versus OM, and, in their findings, VM was equivalent to OM thus offering new directions to the teaching of histology to students such as blended learning and fully digital systems to teach students. Assessment and some feedback would be possible using the VM, asynchronous learning and near-peer learning can also be considered (Vonderwell et al., 2007; Cambrón-Carmona et al. 2016; Kattoua et al., 2016; Llamas-Nistal et al., 2016; McLean, 2018).

In the same year, Holaday et al. (2013) released the results of a survey about students' study habits and the use of various histology resources available to them and their use over time. The published results report that students prefer electronic resources over traditional resources and students demonstrated a strong preference for individual learning rather than group sessions. This study adds to the body of literature promoting the use of innovative educational tools.

A study by Jaarsma et al. (2015) reported a three-stage model for expert development first described by Boshuizen and Schmidt (1992), in this model, they considered expert, intermediate and novice levels of expertise for VM. The expert has developed a significant level of knowledge and confidence in the field, the intermediate level the individual has the knowledge and is still developing the expertise while the novice is newly exposed to the field and is less confident. In their study, they reviewed the role of expertise in VM for different cohorts and included eye tracking to understand the way that individuals reach a diagnosis. The experts were confident and quicker with fewer microscope movements and used mainly lower magnification to scan the slide and only higher magnifications to go in-depth, and they had shorter reasoning chains to describe the condition. The opposite was reported for the novice cohort, they used higher magnifications to search in greater detail, described the conditions based on appearance and had longer reasoning chains.

A meta-analysis conducted by Wilson et al. (2016) with the aim of reviewing and comparing the literature available in the field of learner performance and preference in using VM and OM, reviewed twelve articles and demonstrated there was a small positive effect in learning with VM compared to OM. Considering students perception, 33% of students preferred OM and 70% of students preferred VM. When considering cytology teams, the preference to use OM is still prevalent rather than VM, this is due to the issues with magnification, image overlay and fluidity of focusing when looking at membrane changes (Donnelly et al., 2012).

A study conducted by Hande et al. (2017) included three distinct groups: A – conventional microscopy, B – VM, C – conventional and VM. The team reported that pre and post-test performed with the students demonstrated a statistically significant sequentially difference whereby students in group C performed better, followed by group B and last group A.

Vainer et al. (2017) in Copenhagen reported their experience in implementing a VM system, including the pilot study started in 2006. Vainer et al. included the faculty and teachers' considerations, their learning along the period of implementation, included how they aligned the teaching to the VM system and the reviewed organisation and administrative structure to support the development of VM. It is interesting to note that the university had to make a substantial financial commitment to the acquisition of scanners and the viewing software – Path XL, this is the only published article considering this viewing software. The university was delivering a fully automatic digital microscopy system with full acceptance of teachers and students and was phasing out the delivery of conventional microscopy from the Autumn of 2016. However, no additional reports are available in the literature, which poses several questions: is the implementation of the VM curriculum been effective, are there additional areas for consideration when implementing a VM in teaching and learning, are there any other factors and variables that affect teaching and learning when using blended learning approaches, are students engaging with VM and are the students' outcomes better? Considering the diagnostic setting, it took years for fully digital services to be set-up, so it is not surprising that fully digital modules are still not in delivery mode.

A study by McDaniel et al. (2018) conducted a survey with physician assistants' students to determine the difference in learning outcomes and student's preference. In the cross-over study, students were assigned to a cohort, LM or instructor directed video streaming (VM) and at a pre-determined mid-point the delivery styles were switched over. Students completed a test prior to the cross-over and students in the VM group had significant better learning outcomes that the group in the LM group;

however, at the end, the students learning outcomes showed no difference between the groups. The students on the LM cohort improved more than the students in the group that had VM first. Counterintuitively, students that participated in the study preferred the instructor directed video streaming (VM) approach to LM.

In a study by Gopalan et al. (2018) aimed at improving medical student's learning experience in pathology with two cohorts of students they concluded that the overall score was marginally different for the traditional sessions and the ones with the pathology lecture sessions (VM). The teaching with the VM approach included clinical based scenarios and specimen dissection. Student feedback included positive comments, particularly related to the inclusion of a clinical scenario and a multidisciplinary approach for students in engaging students in learning pathology. This finding is valuable as it demonstrates that students challenge in associating knowledge, by using multidisciplinary approaches, students can understand and remember how histology fits in the diagnostic process and the patient pathway.

Nauhria and Ramdass (2019) reported a study conducted in the academic year 2017/18 with medical students. In the study, students were allocated a group – LM or VM, and mid-point they were switched over. The student’s outcome for each of the groups where VM was the intervention, had higher mean percentage scores. Students demonstrated a preference with VM over LM by responding to a survey with a 5-point Likert scale. However, it was also suggested by the students that manual skills of glass preparation and microscopy should not be neglected in the education of students.

3.5.1. Assessment and feedback

Assessment is an essential component of learning in both formative and summative assessment modes. To improve student performance and support students in their learning, assessment is a tool that allows students and teachers to assess students' progress. Timely and well-structured feedback increases student's confidence and self-awareness and provides an opportunity for reflection and added support.

Summative assessment can be described as the measurement of what students have learned at the "end of an instructional unit, end of a course" concerning learning goals and expected outcomes (Heargreaves, 2008 in Gikandi et al., 2011, p. 2336). In the context of online learning, JISC (2006) has defined e-assessment is the entire process where Information and communications technology (ICT) is used (Llamas-Nistal et al., 2013). Arend (2006) suggested that assessment strategies allowed an understanding of the quality of the learning and numerous studies have demonstrated the link between assessment practice and learning strategies (Biggs, 1998). The better they are related, the easier it is for knowledge to be acquired. There are general and specialised platforms and software that allows for the use of open-response exams, open-ended exams, and automatic test correction type-questions exams. Considering the latter, MCQs are used widespread for assessment in the most varied modes. More recent development of software enables the student to be automatically directed to the area that is being assessed when the student gets to the relevant question (Haladyna et al., 2002; Ramsden, 2003; Heinrich et al., 2009; Llamas-Nistal et al., 2013).

Feedback is closely linked assessment. Assessment allows an evaluation of an individuals' learning considering the learning outcomes (Arend, 2006; Biggs & Tang, 2011) and feedback provides students details that enables them to understand the extent to which they met the learning outcomes (Rowntree, 1987). Conversely, student feedback enables an evaluation of the teacher and institution achievements and practices to improve the quality of teaching and support available for students (Carless, 2006; Nicol & Macfarlane-Dick, 2006; Nicol, 2010; Evans, 2011).

Another dimension is peer feedback where students engage in providing feedback to each other in a constructive and safe environment. This has been demonstrated to be valuable for improving learning and writing skills, the student experience, and increased social transferable skills. Despite some concerns expressed by authors about the reliability and validity and the challenge of power relations in peer feedback compared to self or teacher feedback, this practice seems appreciated by students but requires careful consideration when implemented in the classroom (Ramsden, 2003; Evans, 2011; Nicol et al., 2014; Huisman et al., 2019). When considering peer feedback, this also includes the feedback and support provided by peer teacher/supervisors and includes own self-reflection (Brookfield, 1998; Brookfield, 2017).

Commonly, feedback would follow the same medium used with the assessment and most commonly, individual written feedback is used. However, there are innovative ways in which this can be released to students which includes group feedback, individually recorded feedback and working with the students individually and/or in groups to work through the assessment grid to get students to critically provide the feedback. With the emergence of the online tools as rubrics, automated feedback is also possible in which allows for a systematic and more consistent scoring scheme (Heinrich et al., 2009, The University of Edinburgh, 2020).

Alotaibi and AlQahtani (2016) measured students' preferences in using LM and VM in a with nine questions and an open-ended section and reported that students preferred VM despite some students demonstrating different learning styles and reporting limitations when using VM, for example, the size of the digital files and issues with loading the images or freezing images. The microscope allowed students to examine the slide without the use of technology and this felt more experiential.

A systematic review by Kuo and Leo (2018) considered that since 1997 there is an increase in the number of studies on clinical and educational use of VM. According to the criteria established for reviews in the field there are 19 studies for medical students or residents. Their report articulates that according to students' experience, VM should not replace OM. Instead, both should be used in conjunction as a learning strategy for teaching. In the context of using VM for teaching purposes, students' feedback has been paramount to enhance teaching strategies and has been the means to evaluate the success of the interventions (Ordi et al., 2015; Alotaibi & AlQahtani, 2016; Ahmed et al., 2018; Kuo & Leo, 2018).

3.6. VM – Literature Review

The literature review for any study is lifelong, it started when the first ideas were drawn, the process was refined as the learning and the research question was developed and continues until the study is submitted for the last time.

The researcher used critical appraisal tools that were available and known to the research at the time. As new information and approaches were learnt, the researcher modified and adapted the way the notes were collated. The earliest tool used was the Critical Appraisal Skills Programme – CASP (Critical Appraisal Skills Programme, 2015). This was the main tool used throughout the study to read articles and other medium to include or exclude as reference material and summarise the content of those that were to be included and were relevant to this study and the appropriate CASP checklists were adapted as required for ease of use. An additional tool that was used lesser in the study was the Preferred Reporting Items for Systematic Reviews and Meta-Analyses – PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses, 2019), this was particularly useful for meta-analysis in the later stages of the literature review as it allowed the researcher to review the meta-analysis systematically and drawing relevant information in an orderly and relevant manner.

The starting point for the literature review was by using Google Scholar, relevant professional journals in pathology and academic databases: typing the keywords or phrases that were appropriate for the study and selecting resources from the search engines. The use of Boolean logic, phrase searching, truncating, field searching, English language only publications, alternative spellings and advanced searches helped with reducing the number of items made available including articles, books and other written or audio material. As the process developed, other search terms not originally considered were added, a note of all the words and phrases were kept on a Microsoft Excel 365 spreadsheet including the date of search by the researcher. This process allowed the researcher to scope the literature and formulate the research question, understand the gap in the literature and support and validate the development of the methodology and support the discussion section.

The stages described earlier were a critical part of the process and that set the foundation for the literature review and the formulation of the hypothesis. It allowed searching for articles in a more systematic manner using the keywords, authors, and publications on the subject. Subscriptions to journals and certain topics were submitted to receive notifications regarding the research in the fields of interest.

Any search on the keywords and area of interest produced an excess of articles, books and other items as posters, infographics, images, videos, presentations from varied sources. In terms of the literature search and which material was to be kept, the abstracts for the articles were reviewed to assess appropriateness and those articles deemed appropriate were downloaded in full and saved on the researcher' computer in a folder identified by the search date. A spreadsheet was completed with the date of search, the article's title, authors, publication details, country of origin and year and the field of interest. The articles were read, and additional notes added using the CASP checklist for the type of article to review. Additional comments were added to the spreadsheet for the article if this was to be kept as the population size, methodology and a summary of the study.

Reviewing the articles to include in the research literature led to articles being included as direct reference or framing thinking for discussions and articles that were not relevant to the study was disregarded. In the process, other terms were identified, and authors cited by earlier articles were searched online and reviewed. Additional comments on the spreadsheet were recorded and updated as well as the degree on influence on the current study and the quality of the publication for the research.

Many articles required the researcher to use the university credentials to allow the article to display and others were only available when searched from the library search engine. A few articles were only available using the NHS credentials and others required the use of the British Library credentials to purchase them.

Some of the academic databases used include: APA Psyc Net, Cochrane Library, EBESCO publishing, Elsevier, ERIC, IEEE Explore, JSTOR, Medline, ProQuest, Research Gate, SAGE Journals, ScienceDirect and ScienceOpen, SpringerLink, Taylor & Francis Online, The Learning & Technology Library, Wiley Online library.

The inclusion criteria for the material used included English as the language element. All controlled studies regardless of the publication period and the number of participants in the fields of education, teaching and training, medical development and information technology were deemed acceptable.

The literature review was a comprehensive process which evolved over time, required considerable time and a great level of time management and organisational skill to integrate the different areas of interest in the current study.

The approach of searching and reviewing articles was less organised and less focused during the earlier stages of the research and the researcher felt somehow overwhelmed with the amount of work. Attending Critical Appraisal tutorials and CPD tutorials on article searching helped the researcher to improve organisational and search skills and to differentiate between relevant and non-relevant material. This process supported the researcher in the later stages of the write-up to ensure that processes were reviewed systematically. The use of the spreadsheet, and the saving of articles following the approach described, was invaluable at the earlier stages. Once the study started it was more challenging to keep process updated and this happened periodically. Additional material was tracked by diary.

An extensive literature review was conducted using the terms digital pathology, VM, virtual slides, LM, traditional microscopy, teaching, learning, histology, pathology.

The literature review was performed at the several stages of the current study and the summary is presented in table below. Over one thousand articles were found, those relevant for the literature reviewed have been referred in the literature review. Among all the articles reviewed, twenty-six articles have been included in Table 3.1 as being most influential in VM and for the current study.

Twenty articles are in the medical field and the six remaining are in other areas of healthcare or science. There are nearly the same number of studies in Europe and in the USA, nine and eight respectively, of which four of the European studies are in the UK. The number of studies in the UK is the same number of studies conducted in Australia (4) considering the same period.

Studies and reviews about VM for educational purposes in the medical field are being carried out in many parts of the world (Table 3.1). However, the uptake in the UK by non-clinical staff had been slow as demonstrated in Table 3.1. There were four studies in the UK, two in diagnostic settings, one in training of medical students and one in training of undergraduate students in another scientific field. Considering the studies available in Table 3.1, VM is an area with considerable growth as a novel technology with applications in the patient pathway, research, training and education and storage and archive.

Table 3.1 – List of studies in the field on VM most influential in the current study published in the last 15 years.

Year	**Author**	**Title**	**Population/ country**
2003	Blake, C.; Lavoie, H.; Milette, C.	Teaching medical histology at the University of South Carolina School of Medicine: Transition to virtual slides and virtual microscope	70 medical students USA
2005	Krippendorf, B.; Lough, J.	Complete and rapid switch from light microscopy to virtual microscopy for teaching medical histology	1020 medical students USA
2007	Goldberg, H. R.; Dintzis, R.	The positive impact of team-based virtual microscopy on student learning in physiology and histology	120 1st year medical students USA
2008	Braun, M.; Kearns, K.	Improved learning efficiency and increased student collaboration through use of virtual microscopy in the teaching of human pathology	85 medical students USA

2008	Kim, M.; Park, Y.; Seo, D.; Lim, Y.; Kim, D.; Kim, C.; Kim, W.	Virtual microscopy as a practical alternative to conventional microscopy in pathology education	160 medical students Korea
2009	Farah, C.; Maybury, T.	Implementing digital technology to enhance student learning of pathology	60 dental students Australia
2010	Merk, M.; Knuechel, R.; Perez-Bouza, A.	Web based virtual microscopy at the RWTH Aachen University: Didactic concept, methods and analysis of acceptance by the students	182 medical students Germany
2011	Evered, A.; Dudding, N.	Accuracy and perceptions of virtual microscopy compared with glass slide microscopy in cervical cytology	24 cytologists UK
2011	Helle, L.; Nivala, M.; Kronqvist, P.; Gegenfurtner, A.; Björk, P.; Säljö	Traditional microscopy versus process-oriented virtual microscopy: a naturalistic experiment with control group	120 medical students Finland
2011	Simavalai, S.; Murthy, S.; Gupta, T.; Wolley, T.	Teaching pathology via online digital microscopy: Positive learning outcomes for rural based medical students	96 medical students Australia
2012	Wang, Y.; Williamson, K.; Kelly, P.; James, J.; Hamilton, P.	Surfaceslide: a multitouch digital pathology platform	13 pathologists and IT UK
2012	Donnelly, A. D.; Mukherjee, M. S.; Lyden, E. R.; Radio, S. J.	Virtual microscopy in cytotechnology education: Application of knowledge from virtual to glass	6 students USA
2013	Barbeau, M.; Johnson, M.; Gibson, C.; Rogers, K.	The development and assessment of an online microscopic anatomy laboratory course	236 BSc students Canada

2013	Helle, L.; Nivala, M.; Kronqvist, P.	More technology, better learning resources, better learning? Lessons from adopting virtual microscopy in undergraduate medical education	126 medical students Finland
2013	Randell, R.; Ruddle, R.; Mello-Thoms, C.; Thomas, R.; Quirke, P.; Treanor, D.	Virtual reality microscope versus conventional microscope regarding time to diagnosis: an experimental study	16 histologists/ SPrs UK/USA
2013	Holaday, L.; Selvig, D.; Purkiss, J.; Hortsch, M.	Preference of Interactive Electronic Versus Traditional Learning Resources by University of Michigan Medical Students during the First Year Histology Component	146 medical students USA
2013	Mione, S.; Valcke, M.; Cornelissen, M.	Evaluation of virtual microscopy in medical histology teaching	199 medical students Belgium
2014	Tian, Y.; Xiao, W.; Li, C.; Liu, Y.; Qin, M.; Wu, Y.; Xiao, L.; Li, H.	Virtual microscopy system at Chinese medical university: an assisted teaching platform for promoting active learning and problem-solving skills	229 medical students China
2014	Craig, F. E.; McGee, J. B.; Mahoney J. F.; Roth, C. G.	The Virtual Pathology Instructor: a medical student teaching tool developed using patient simulator software.	122 medical students USA
2015	Ordi, O.; Bombí, J.; Martínez, A.; Ramírez, J.; Alòs, L.; Saco, A.; Ribalta, T.; Fernández, P.; Campo, E.; Ordi, J.	Virtual microscopy in the undergraduate teaching of pathology	90 medical students Spain
2016	Alotaibi, O.; AlQahtani, D.	Measuring dental students' preference: A comparison of light microscopy and virtual microscopy as teaching tools in oral histology and pathology.	87 dental students Saudi Arabia

2016	Sahota, M.; Leung, B.; Dowdell, S.; Velan, G.	Learning pathology using collaborative vs individual annotation of whole slide images: a mixed methods trial	131 medical students Australia
2017	Foad, A.	Comparing the use of virtual and conventional light microscopy in practical sessions: Virtual reality in Tabuk University	40 medical students Saudi Arabia
2017	Hande, A. H., Lohe, V. K., Chaudhary, M. S., Gawande, M. N., Patil, S. K., Zade, P. R.	Impact of virtual microscopy with conventional microscopy on student learning in dental histology	105 dental histology India
2018	Gopalan, V.; Kasem, K.; Pillai, S.; Olveda, D.; Ariana, A.; Leung, M. and Lam, A. K.	Evaluation of multidisciplinary strategies and traditional approaches in teaching pathology in medical students	272 medical students Australia
2018	Herodotou, C.; Muirhead, D.; Aristeidou, M.; Hole, M.; Kelley, S.; Scanlon, E.; Duffy, M.	Blended and online learning: a comparative study of virtual microscopy in Higher Education	150 undergraduate students UK

The studies highlighted in grey have supported the development of the methodology for the intervention study.

From the selection of the articles above, nine were critical in the development of the methodology (highlighted in grey) for the study including the pilot study and the intervention study and in supporting the underpinning of the thesis. The earlier study was conducted in 2005 (Krippendorf & Lough) and the later ones in 2017 (Hande et al. and Foad), considering where the studies were conducted, they were widespread: three in Europe, two in North America, two in Asia, one in Australia and one in the Middle East. One of the studies was qualitative only (Farah & Maybury, 2009), four studies were quantitative driven methods (Barbeau et al., 2013; Tian et al., 2014; Ordi et al., 2015, Foad, 2017) and four studies were concerned about student outcome and student perception from a qualitative viewpoint (Krippendorf & Lough, 2005; Helle et al., 2011; Helle et al., 2013, Hande et al., 2017).

It is striking that most of the studies in VM are in the diagnostic setting, twenty articles of twenty-six included in Table 3.1, which is the same trend for the articles available in the literature review. The applications of VM in diagnostic medicine, particularly histology is known and well described in the literature. Other areas of healthcare and research settings are following trend in demonstrating the use of VM in their practices. The advantages, disadvantages and limitations of scanners and scanning, viewing platforms applied to the fields of practice: diagnostic, research and storage have been experienced and adequately described in the literature. However, in the field of teaching and learning there are still many uncertainties about the value of VM for teaching and learning, students learning outcomes using VM, and those studies that are teaching and training related, are based on students' perception of VM rather than measuring learning outcomes of the use of VM and traditional approaches to teaching and learning in undergraduate education.

This chapter described VM and its applications broadly, advantages and disadvantages. Also, in this chapter there was an exploration of VM in the context of teaching and learning in sciences.

In chapter 4, the work developed by psychologists in the realms of pattern recognition will be explored considering processing speed, processing style, working memory and attentional flexibility.

4. Pattern recognition and memory

The role of memory in tissue recognition is poorly understood. This chapter explores of the theories around memory and pattern recognition and how what is known can be used to understand the mechanisms that occur in teaching and learning. There will be a focus of characteristics and tasks that can be used to measure them in the context of teaching and learning.

4.1. Theoretical framework

Over the last 50 years, adult learning theories have gained popularity among psychologists and educationalists both in terms of teaching methods and learning theories. Malcolm Knowles (1980) explained an approach to self-directed learning in which individuals take the initiative for their own learning. The process of self-directed learning includes different stages, understanding and accessing own needs, the planning stage, and the implementation of learning strategies to achieve the desired learning outcomes and the evaluation of the learning outcomes. Knowles described the process of adult learning based on the following characteristics: self-concept and self-regulation, the role of experience in learning, readiness to learn, orientation of the learning, internal motivation and need to know for learning (Knowles, 1973; Gibbons & Wentworth, 2001; Huang, 2002; Knowles, 1980, p. 43 in Chan, 2010; Gregory, 2012). In undergraduate studies, there is an element of self-directed study and when considering blended learning and VM strategies for teaching, self-directed learning, orientation to learn and internal motivation play an important role in learning. Those students that are aware of their strengths and goals are most likely to succeed than the others (Nivala et al., 2013; Woolfolk et al., 2013).

Jerome Bruner (1986) developed a constructivist theory on adult learning that highlighted that students learn by building on already acquired knowledge and by integrating new experiences into existing knowledge (in Gregory, 2012; Huang, 2002; Schunk, 2014), in other words, it is the assimilation of new content based on previous knowledge, development of concepts and understanding through using inquiry based and problem-solving skills which lead to understanding of complex scenarios and simulation-based activities. The role of the instructor/teacher is supporting this process of gradual development. In histology, for example, it is learning first the terminology and the normal features of tissues and cells prior to understanding and learning tissues and tissue abnormalities. This theory was an advance on the instructional scaffolding theory that states that teachers are present in earlier instructional processes, teachers then allow the students to learn independently and where students can stretch their capabilities, the teacher is there for support and guide as appropriate. These characteristics are essential particularly when considering the learning using VM (Wood et al., 1976; Nivala et al., 2012).

To understand the term "learning" from a cognitive psychology approach, work has been developed around the role of memory, attention (ability to selectively concentrate on a stimulus), perception (the sensory experience of the world) and thinking. Learning is viewed as an active process of acquiring, reasoning, remembering, problem-solving and using knowledge, in this context, memory and learning are closely related to ensure students learn from content, experiences and by integrating new knowledge in existing knowledge (Squires, 1986; Brentham, 2002; Baddeley, 2007; Woolfolk, 2014).

The brain is the specialised organ in the body where cognitive processes take place. Each area of the brain is associated with different cognitive aspects. The frontal cortex is associated with decision making, planning, and working memory, the temporal lobes are associated with learning and memory (particularly the hippocampus), the parietal cortex is associated with sensory information, the limbic system is related to emotional processing. According to the Early information Processing Theory, the input is received by our senses creating a sensory memory system that has a limited capacity. For example, the ability to repeat six or seven digits straight after hearing the numbers or the repetition of a simple task performed a couple of hours after the first time. If an individual is exposed to information that is not important, the task is simply forgotten. However, when the data is made meaningful, the information is filtered through the working memory where it can be manipulated and stored for a limited period. A further example of this is when an individual follows spoken instructions on how to get from point A to point B (Gregory, 2012; Woolfolk, 2014), as the information provided verbally is required to reach the destination, the individual hearing the information must make sense to them so they can reach their destination. In this context, “attention” is awareness of a phenomenon to the exclusion of other stimuli and “perception” is the process of recognising and interpreting the events. These two concepts are intrinsically connected and are the gateway for cognitive input. The input received is processed in different areas of the brain and gives enables data to be coded, stored, and retrieved in different ways depending on the type of storage of the information in the memory: short term memory, working memory and long-term memory (Baddeley, 2007; Woolfolk, 2014).

Short term memory is short and passive without any manipulative and interpretative capacity, with limited duration and decays rapidly (few seconds), has limited storage (around 7 items) and is mainly acoustic, all other senses is very limited. The working memory is temporary storage and limited in nature but is responsive and can be activated through continuous input, the individual can process new information with existing information and create new knowledge and perform other complex tasks as reasoning (Averbach & Coriell, 1961; Baddeley, 2007; Cowan, 2008). It is proved that short term memory is a sub-component of working memory, if the information is required for more than a few seconds or manipulation is required, the information will be filtered to working memory. The learning process takes place in working memory. When information in working memory is encoded in long term memory, the content is processed at a deeper level through complex mechanisms that require long term storage or connections with other information, for example, remembering the date of birth of a relative or the events that happened many years previously or knowing the meaning of a word (Atkinson & Shiffrin, 1968 in Wolfson, 2014; Brydges et al., 2018). Cowan (2008) proposed the definition of working memory as a "multi-component system that holds and manipulates information in short term memory, and as the use of attention to manage short term memory" (Cowan, 2008, p. 11) in which cognitive tasks can be used to measure its performance.

Long term memory has virtually unlimited capacity, and information remains stored indefinitely (Atkinson & Shiffrin, 1968 in Wolfson, 2014). Once the data is stored in long term memory it is possible to recall the information at any time, independent of the time passed. However, it may require a particular intervention for the information to be activated (Nivala et al., 2013). Most cognitive psychologists distinguish between implicit memory (unconscious or non-declarative procedural memory) and explicit memory (conscious or declarative memory) (Ashcraft & Radvansky, 2009; Wolfson, 2014). An example of implicit memory is driving a car a few years after having passed the driving test where the individual can drive without thinking about it, it becomes an automatic process. Explicit memory is further divided into semantic memory and episodic memory. The former refers to organised knowledge or factual information, such as knowing the capital city of a country, and the latter is autobiographical in the sense that memories are related to the individual as specific personal experiences such as "I remember visiting Lisbon" (Tulving & Donaldson, 1972; Squire, 1986; Ashcraft & Radvansky, 2009).

There are many definitions of intelligence, and a variety of theories that attempt to describe the role and scope of intelligence. Intelligence is the ability to acquire, process and apply the knowledge and skills (Pal et al., 2004). This is a simplistic definition. Considering the Multifactor theory proposed by Thorndike (1914) which states each mental activity requires a set of abilities with four distinguished attributes: level of difficulty, range of tasks, number of situations an individual can respond and the speed at which it can be responded. Unlike the previous theory, Thurstone (1938) suggested that certain mental operations have primary factors that give them a functional unity that is differentiated from other mental operations. These can include the following six primary factors: number factor which allows mathematical calculations, verbal factor involved in verbal comprehension, the space factor, memory, the word fluency factor involved in rapid decision making and the reasoning factor. Cattell (1971) proposed a theory that considering the genetic potential is described as fluid and another aspect that integrates new experiences with past ones described as a crystallised theory (Pal et al., 2004). Salthouse et al. (2008) demonstrated that there is a variety of control variables involved in cognitive abilities and that these overlap with age-related factors, all affecting the optimum functioning of cognitive abilities including fluid intelligence, memory, and perceptual speed. The variable described above will have an impact of student learning and the way students can understand and integrate new knowledge with previous knowledge.

The role of perception, attention and memory processes can be applied and integrated into educational psychology theories. Considering perception, for example, it is known that some individuals have a tendency towards a featural processing style or towards a holistic processing style meaning that they perceive particulars as a whole (holistic) or in parts respectively (featural). This will be further explored in section 4.3. Attention and memory processes may differ at different times for each individual, and this can be modified by mood, arousal and motivation. In other words, individuals look at and percceive images differently. Thus, it may be inferred that the visual-spatial memory loop has a critical role to play in tissue recognition in that how individuals discriminate sensory input will determine how this information will be processed and retained and recalled in their memory.

Understanding the way cognitive abilities affect teaching and learning of students in the VM context are central to this study and the introduction of VM as a teaching strategy will enhancing or not the learning process. In the study, pattern recognition with VM should facilitate the retention of images by students considering the features of working memory described above.

Cognitive abilities can be assessed quantitatively using a variety of tests, and the data produced can analysed in the context of the individuals' personal characteristics, these will be described in chapter 5. For short term memory, simple activities are used as drawing an image or recalling a series of digits are used. For working memory and long-term memory, more complex activities are available as recalling a series of digit in a different order or remembering an image and drawing the image (Baddeley, 2007; Woolfolk, 2014).

Brain impairments, disability and other natural and pathological conditions affect memory and the learning process in different ways. Most of these characteristics and factors have been extensively described in the literature in pathological conditions more so than in healthy individuals (Joels et al., 2006; Faja et al., 2009; Stangor & Walinga, 2014; MacPherson et al., 2017).

4.2. Processing speed

The executive functions take place in the pre-frontal region of the brain (Dempster, 1992; West, 2000). These are related to high order functions of control and are responsible for the coordination of cognitive operations such as processing speed. Processing speed is a cognitive ability defined as the time it takes an individual to perform a mental task, from receiving the sensorial input to the time it takes the individual to react (the reaction time). The processing speed varies with personal characteristics such as age and gender (Fry & Hale, 1996; Albinet et al., 2012). Furthermore, previous knowledge and experience play a role in the processing speed and repetition and practice improve the processing speed.

The anterior brain that includes the pre-frontal cortex is sensitive to the ageing process (Salthouse, 2000; Albinet et al., 2012). That processing speed decreases with the ageing process is described by the Processing speed theory (Salthouse, 2000; Albinet et al., 2012). Slower processing speed affects working memory, particularly in processes where longer attention is required. Nettelbeck and Burns reported a difference observed between younger adults (18-45) and older adults (55-87), and the decline in the latter is more prominent than in younger adults (Nettelbeck & Burns, 2010). When considering teaching students histology with VM, processing speed will have a role to play considering the age of the students.

The role of gender differences is controversial. While some studies (Solianik et al., 2016) demonstrated that there were no gender differences observed in memory and attention task performance, other studies (Harness et al., 2008) showed that women were better than men in short term memory tasks. It was suggested that switching the level of focus is unpredictable and this may be at the core of the performance variability observed, this is further explained in section 4.5. It could be inferred that the processing speed and the attentional switching will influence learning and that they are age variable.

Harness et al. (2008) stated that men show diffuse bilateral activation of visuospatial task and women show right hemispheric laterality. In their study, they revealed that women are better at visuospatial and men are better at digit span tasks. The literature reviewed also confirmed that cognitive speed deficiency affects working memory negatively (Joels et al., 2006; Faja et al., 2009; Stangor & Walinga, 2014) which means that besides age, brain impairments and gender will affect learning speed.

Averbach and Corriel (1961) proposed a simple view of variables that affect processing speed. the capacity of completing the tasks versus the storage time of a task/procedure. Salthouse (2000) reviewed and added several variables that affect processing speed including:

- decision speed, that is the internal time taken from the input to the decision being made and may include complex processes,
- perceptual speed which related to the sensory-motor processes which are simpler,
- psychomotor speed for those activities where there is an initial learning that can later became automatic,
- reaction time, this is the time taken from the stimulus to the observable response,
- psychophysical speed which is the internal time taken from the sensory stimulus to the sensory system acknowledging the stimulus,
- time course of internal responses that is the time taken for the internal processes to take place.

All these are characteristics which can be measured individually, can predict how long the individual learning process takes, the priority is to identify which variables affect learning greatly so this can be assessed and modified if possible. Although exposure and experience might be anticipated to affect learning there are few published studies on how processing speed affects student learning (Averbach & Corriel 1961; Salthouse, 2000).

4.3. Processing style

"Forest before the trees" was the title Navon (1977) used for his article referring to the human visual system in the context of processing styles. Processing style is how individuals perceive sensory input and organise it mentally. Defined as perceptual organisation (Chamberlain et al., 2017), this can be described as global representation, i.e., when the sensory input captures the greater view, the processing is global and when it narrows the view field to the details, the processing is featural. For example, looking at a painting and absorbing the entire image as opposed to looking at the same painting and focusing on one specific area or quadrant of the image disregarding the entirety of the painting.

Global or holistic processing is defined as the combined information about the spatial relationships between features, both at encoding and retrieval stages, allowing the individual to see one image. This is a top-down process where higher-order forms are processed first. Featural processing is where information about specific physical features is processed at a local and specific level (Chamberlain et al., 2017; Davidoff et al., 2018).

The literature reviewed demonstrated that global processing is the norm for most people (Davidoff et al., 2008). However, there are individual differentiation considering internal factors as age and gender and, the external context as culture and bias, that generically conditions individuals' processing style. in this context, individuals tend to see the overall picture rather than focusing on the detail of elements/situations. To complement this theory; other studies suggested that individuals can switch between featural and global styles and vice-versa, that is, individuals can modify their behaviours, adapting and flexing their processing styles according to the context and the environment. This ability of switching styles can be taught and learnt (Salthouse, 2000; Davidoff et al., 2008; Faja et al., 2009; Insch et al., 2012), in this case, tissue recognition processes could be taught.

The transfer appropriate processing theory (Morris, Brandsford & Franks, 1977 and Roediger, 1990 in Weston et al., 2008) suggested that optimal memory performance was achieved when the encoding process matches the retrieval process. This is when the processing and the relationship between the coding and the retrieval of the information have been done effectively, for example, a phone number memorised properly can be retrieved at a much later date accurately. The process of memorising information, quite often, involves a process called "chunking" (or clustering) which is when the individual takes the information and groups it in a particular meaningful way to increase the level of retention of the information, for example, when memorising a phone number with a sequence of 10 to 15 digits, grouping the sequence into 3 to 5 chunks of information. The information is retained in these chunks and deviations from this will make it more difficult to recollect the information, on the other hand, remembering the information many years later will be easier in chunks as they were assimilated.

Applying the theory to facial recognition, Weston et al. (2008) suggested that optimal face recognition was achieved when holistic processing was used at both stages, and any interference or disruption at either stage reduced accuracy. In the context of facial recognition, processing style was affected by race rather than other characteristics (Weston et al., 2008). In facial discrimination studies, it was shown that Western humans show global processing in upright faces, but when presented with inverted faces this was deteriorated, that was, individuals were not able to recognise the faces. On the other hand, East Asian individuals were more sensitive to the visual background when looking at faces. In terms of verbally articulating their thinking, individuals that process in a global manner could recognise faces better as well as having a better reaction time. In the same study, individuals that processed in a local way only improved facial recognition when personality and physical judgment tasks were used at the encoding stage.

Processing style has been shown to have an impact on disorders such as individuals with autism spectrum disorders (ASD) and obsessive-compulsive disorders have shown slower responses to global structures or lower processing ability, while artists and musicians have shown enhanced local processing (Davidoff et al., 2008; Faja et al., 2009; Nigro et al., 2019; Chamberlain et al., 2017). Global processing in healthy individuals is mainly global but artistic professions shown local processing features;

microscopy images are mainly patterns; however, there is a three-dimensional structure to it. Nigro et al. (2012) demonstrated that the featural processing style amongst people was more prevalent in the cohort of people with disorders.

There were occasional reports on processing style and facial recognition (Davidoff et al., 2008; Weston et al., 2008). Considering the role of processing style in facial recognition, it could be questioned whether there is any advantage of either processing style to learn tissue recognition.

4.4. Working memory

The term working memory was coined by Atkinson and Shiffrin (1968). Working memory is seen as a cognitive ability which can be measured and is composed of a multi-part system that includes the central executive functions, the phonological loop and the visuospatial sketchpad, each part has a specific function, working memory also includes short term memory (Baddeley, 2007; Brydges et al., 2018).

Baddeley and Hitch (1974) defined the role of the central executive system in four areas which were (1) attentional controller and storage systems, (2) the phonological loop, (3) the visuospatial sketchpad, and (4) the episodic buffer. It is in the working memory that the most of the complex span tasks will take place and include auditory processing and discrimination, focused attention, registration of the object, this is the assimilation of the properties to create a mental image of the object, or event and sustained effort. It also includes clustering which is the cognitive process characterised by the formation of a unit different form a complete set of information possible in long and complex tasks which is irrelevant in simple tasks (Baddeley, 2007; Miller, 1956 in Mathy et al., 2018). The latter property is important when learning as it allows students to memorise information systematically.

The storage is active and involves manipulation, transformation and/or integration of information in the brain (Cornoldi & Vecchi, 2003 in Brown, 2016) and considering the role of executive attention, memory representations are kept in an active high state in the face of interference in working memory (Kane & Engle, 2002 in Conway et al., 2005). The storage of the images is kept active with recall, in the context to learning tissue recognition this will be important to allow the student to identify the cellular features to be able to remember and integrate different tissue types and cellular morphology.

In the realms of neuroscience, the role of expertise has been investigated along with the storage of patterns, automatic actions, novice versus expert and the notion that there are specialised areas for knowledge in the brain. It was suggested that when the working memory is active and exercised in a subject area, and the higher the level of attention and perceptions, the greater the expertise of an individual in that subject area – expert (Boshuizen & Schmidt, 1992; Jaarsma et al., 2015). In this context, experts are defined by their ability to maintain consistency and engage in learning even in the presence of interference.

The tasks used to measure the working memory span include many variables described in the literature to account for age and race. These include: counting activities, operational and reading activities for verbal serial recall, visuospatial recall activities, complex activities, re-sequencing activities, auditory activities, reading and spoken activities, motor activities and more recently additional developments with latent variant activity (Baddeley, 2007).

The visuospatial recall activities are the number of distinct visual elements that can be processed in a parallel multi-element array, and they can include numbers, letters and symbols or a combination of any of these (Baddeley, 2007; Harness et al., 2008).

Fry and Hale (1996) demonstrated and described the developmental cascade in which processing speed directly affects working memory capacity which, in turn, has a direct impact on individual differences in fluid intelligence (Fry & Hale, 1996; Tourva et al., 2016). Fluid intelligence is the capacity to think logically, reasoning, problem-solving and adaptation to new situations, and it is involved in the ability to identify patterns and relationships (Cattel, 1971 in Salthouse et al., 2008). Working memory and intelligence are interconnected, and working memory is affected by personal characteristics, particularly age. The simple development cascade for working memory theory states that until age 20 years the working memory increases and then the trends are reversed until middle age, from age 55 years there are other age-related factors and health factors that affect processing speed which accounts for a non-linear decrease of working memory (Nettelbeck & Burns, 2010).

Working memory affects learning in the ways mentioned above, but the role of working memory in tissue recognition is still unknown. It could be suggested that the visual sketchpad and the phonological loop may have a role to play in memorising and the verbalising the correct medical terminology, in particular histology terms during the learning process, and the link between visual input and verbalisation is affected by attention; however, there are no studies described in the literature to support and demonstrate this mechanism.

4.5. Attentional flexibility

Attentional flexibility is the ability to shift the attention between different elements or levels of focus, considering the painting described in section 4.3, it is the ability to switch from the overview of the painting to specific areas and vice versa in a way that is constant and does not let the viewer lose sight of the detail and the overall image. Attentional flexibility is inherently connected with processing style (Arbuthnott & Frank 2000; Kortte et al., 2002).

Mental agility is the function that allows an individual to take a complex scenario, examine it and, through associations and connections of known situations, deconstruct it in a manner that is understood more simply. Education and language and terminology are elements that need to be considered when discussing mental agility. Schear and Sato (1989) demonstrated that included motor speed and mental agility as factors that affect attentional flexibility when conducting an experiment when subjecting individuals to tasks including TMTB. Language is another factor that needs to be considered, is it being spoken in the native language or not, does the student translate the words/concepts in their mind before understanding the meaning of the words/concept, is the terminology familiar to the student or is it new to the student are some considerations when individuals are exposed to complex scenarios. The speed (time) and accuracy (being as close as possible to the measure, being correct) at which this take place have an impact on the mental agility of students and how frequently it is practiced maintaining the stimulus and the learning (Schear and Sato, 1989; Kortte et al., 2002, Bak et al., 2016).

Measuring attentional flexibility alone is probably of less value than measuring it as part of a panel that includes processing speed, as healthy individuals learn and practice, they become better at alternating between tasks, thus reducing preparation time and reaction time. When an individual is exposed to a subject area, they become familiar with the terminology and verbal cognition is better, as opposed to a novice which will take longer and struggle with verbalisation until the subject area becomes familiar. On the other hand, once the new learner can improve their skills, their cognitive ability is enhanced, and their interpretations are meaningful, relevant, and holistic (Kortte et al., 2002; Nivala et al., 2013).

Attentional flexibility seems relevant in the processing of learning tissue recognition. However, there were no reports in the literature suggesting how attentional flexibility may affect the learning of tissue recognition. There were comparative studies (Boshuizen & Schmidt, 1992; Jaarsma et al., 2015) on the role of the novice (studying in the early years of medical school), intermediate (nearly qualified or recently qualified medics) and experts (pathologists) in histopathology that suggested the role of attentional flexibility in tissue recognition as described in section 4.5 in which the expert individual has developed the confidence and the expertise to switch from global to featural processing quicker and more easily than the novice. In this context, tissue recognition is a skill that requires learning and experiential practice to develop over a period with adequate support, including material and virtual resources of quality and mentorship/supervision, (Hamilton et al., 2009; Randell et al., 2013).

To understand pattern recognition as a process, it is important to understand memory. This chapter described cognitive abilities that affect memory: processing speed, processing style, working memory and attentional flexibility.

The next chapter will describe specific psychometric tasks and how these will be used in the intervention study to allocate the students to a particular learning group.

5. Psychometric tasks

This chapter outlines the history of psychometric tasks and how these can be used in the context of this study to describe the role of memory and pattern recognition functions.

Baddeley (2007) summarised the history of psychometric tasks in his book on working memory, including the modern approach to psychometric tasks arose from the works from Alfred Binet, Victor Henri, and Theodore Simon in France in the late 1800s and early 1900s, when they attempted to identify young children affected by mental deficiencies with the aim of developing a tailored educational program for those children. These tasks fulfilled specific criteria, that is, the tasks had to be objective and independent of the teacher's judgment and replicable. Spearman (1904) used cognitive tests in the context of the development of the term intelligence (Baddeley, 2007).

Psychometric tasks are a series of tests that are designed to measure the cognitive ability of an individual to assist in identifying mental capabilities and behavioural characteristics that are essential for a specific role, for example, numerical reasoning if the individual is responsible for accounts and financial statements, verbal and deducting reasoning and emotional intelligence amongst many if the individual is in a teaching role or in particular healthcare roles (IPC, 2021). These tasks are standard, are reproducible under the scientific method and fall within parameters (range) that can be interpreted and analysed in the context of a variant. There is generally no pass/fail grade for these tasks, and the results of the psychometric tasks will enable the individual to know and understand hidden characteristics that otherwise would not be known, in that sense, it can support a particular intervention or a series of practices to assist individual development, for example, if the individual has a lower than average emotional intelligence, measures can be put in place to enable the individual to increase empathy through targeted interventions to enable the individual to raise their self-awareness and ability to rapport with others and in that way, raise their emotional intelligence (Stangor & Walinga, 2014; IPC, 2021).

The studies reviewed in the field of cognitive psychology and pattern recognition included an average of three to seven tasks on average described in the methodology for a short-term study (Baddeley, 2007; Stangor & Walinga, 2014; Woolfolk, 2014; Brown, 2016). Albinet et al. (2012) is an example of a study that includes the use of cognitive tasks to assess processing speed (1) with simple and choice reaction time and digit symbol substitution tasks and executive functions (2) inhibition, shifting and updating working memory tasks.

There are certain characteristics needed for a psychometric task, these are standardisation, reliability, and validity. A standardised test meant that the results from a sample population are representative of the overall population. Also, a standardised test provides confidence that repeating the test in the future under the same conditions provides replicable results – objectivity and reliability of scoring ensures that all candidates are treated in the same way for ethical reasons, analytical consistency, and reduced bias (Stangor & Walinga, 2014; BPS, 2017).

Reliability of a test means that the test produces consistent results, and they are not significantly affected by outside such as the results of a test should be comparable whether the individual is stressed or relaxed. The indication of the reliability of the tasks needs to be included when considering the results as these signposts the error rate that affects the test, and this needs to be included in the interpretation of the results so the data can be accurately assessed (Stangor & Walinga, 2014; BPS, 2017).

Validity is the one characteristic that demonstrates that the test being used is measuring the intended variable rather than another variable. In the study, the tasks being used are very specific in measuring the variables considered, for example, to measure processing style two tasks are being used: RO task and Navon task, this means that the data produced from these tasks are valid for processing speed (Stangor & Walinga, 2014; BPS, 2017).

Standardisation, reliability, and validity of a test are critical elements in the delivery and assessment of the results thus a good test ensures that the variable is measured appropriately, providing consistent results and allows comparison of results with anyone whose characteristics are like the variable that is being considered (Stangor & Walinga, 2014; BPS, 2017).

Psychometric tasks need to be delivered according to the author/publishers' instructions in a professional manner and by trained individuals. To achieve this, the tasks instructions need to be delivered in a consistent and reproducible manner, there are spatial, environmental and location (room) factors need to be considered and include physical space, lighting, ventilation, desk, and table layout. This is to enable a good testing environment (Stangor & Walinga, 2014; Woolfolk, 2014; BPS, 2017). Verbal instructions (real time or recorded) need to be communicated in a clear and precise manner, if written instructions are required, these need to be correctly written, legible, and clear to reassure the individual taking the task need to feel safe and protected. The outcomes will be raw data that requires analysis and interpretation against normalised groups set for comparison, that in turn can be plotted against a scaled score or percentile scores (Stangor & Walinga, 2014; Woolfolk, 2014; BPS, 2017).

The other two elements to deliver a task are the individual administering the task and the individual who is completing the task. The former needs to ensure standardisation of delivery and, according to the publishers' instructions, to ensure high reliability, their presence and delivery style needs to be neutral paced and constant. Bias in the task delivery will compromise the outcomes, the experience, the level of confidence of the individual delivering the tasks and the flow of the sessions should also be considered (Stangor & Walinga, 2014; Woolfolk, 2014; BPS, 2017).

The candidate's performance can be affected by the physical environment, individuals' preparedness, and the individuals' characteristic (including age, gender, race, motivation, stress levels and cognitive ability) and the delivery mode of the tasks. An enabling environment for the candidate is fundamental for the success of the session and reliability of the data produced (Stangor & Walinga, 2014; Woolfolk, 2014; BPS, 2017; IPC, 2021).

There are inherent challenges to delivering psychometric tasks which require careful consideration in the earlier stages of any study (Stangor & Walinga, 2014; Woolfolk, 2014; BPS, 2017; IPC, 2021):

- the sample size and how representative it is of the overall population,

- the choice of tasks to be included in the study, depending on what the characteristic/ability is being measured,
- the visual-spatial conditions when administering the tasks,
- the mastery in the delivery of the tasks, which includes preparation and may require qualifications from the individual delivering the tasks,
- the method of scoring the data considering the standardised scores,
- the assessment of usefulness of the psychometric tasks in demonstrating the variable/s being measured.

The delivery of psychometric tasks has multiple uses, they measure individuals' abilities when applying for a job or can be used to describe and assess individuals' inherent characteristics with the aim of understanding behaviours. In the current study, the psychometric tasks have profiled the processing style, working memory, motivation, and stress levels of each of the students to allocate them to a teaching approach.

5.1. Rey-Osterrieth Complex Figure

The RO complex Figure is used to evaluate the working memory and processing style of individuals in the current study.

The image test was first developed by Rey (1941), and later Osterrieth proposed a scoring system for the image. The RO complex Figure (Rey, 1941; Osterrieth, 1944) is a useful task to analyse processing style, perceptual organisation (sensory organisation of a stimulus), visual memory, and problem-solving (Fastenau et al., 1999; Caffarra et al., 2002; Davidoff et al., 2008). The image also allows measuring of more complex executive functions (Weber et al., 2013) which require more extensive testing and interpretation.

The core principle is that an individual must copy a complex geometric stimulus on a blank sheet of paper (copy). After the copy trial task, the stimulus and the copy are removed, and the individual must draw from memory the same image on a blank sheet of paper (delay). After a delay of at least 20-minutes, the trial task is repeated on a new blank sheet of paper (recall). During the entire process the examiner can track the individual's constructional approach by recording the sequence of lines as they are drawn, the number of lines drawn, and the time taken to complete each task. The information can be used to measure working memory capacity in terms of retention of information at the different moments – copy, delay and recall visually and in terms of how the individual has organised the information. It will allow the evaluation of the processing style of individuals: holistic or featural – depending on which lines are drawn first. The time to complete the task should also be recorded and, this will assist in evaluating the recall in long term memory (Fastenau et al., 1999; Weber et al., 2013).

The image used for the RO complex Figure in the current study had 36 lines in total. The way an individual starts the drawing lines determines the way the individual perceives reality in general and determines the processing style of the individual. This task includes three evaluations, and these may be consistent or may differ depending on internal memory processes that individuals have developed over the years. Recollection of the image may be influenced by the previous task performed or completely different experiences that individuals may recall. From the patterns drawn by the individuals during the three different occasions, it is possible to infer the processing style of an individual – global or featural processing (Fastenau et al., 1999; Weber et al., 2013).

The main factors that affect the success of the task are age and education. Fastenau et al. (1999), defends that gender does not seem to be a factor that affects the direct copy but may have some role in the delayed recall and, education may be a variable to consider but the results were unclear.

In the current study, the RO task was used to measures the role of working memory (spatial) and the processing style of the students. The working memory was to be understood in the context of the sequence of drawings and by how much each student could remember the original drawing, the copy, and the recall drawings. The processing style will allow the researcher to evaluate how students processed the images in terms of how they initiated the drawing. This task has been used in combination with the Navon task for processing style.

5.2. Navon task

The Navon task is used to evaluate processing style of individuals in the current study. The Navon task (1977) is another task commonly used to measure processing style. According to the Transfer Appropriate Processing Model (Tulving & Donaldson, 1972), optimal visual recognition is achieved and retrieved through holistic processing. The most well-known Navon task is the letter identification task, there are others that include geometrical shapes and object sequences, and this task comes with some variations. There are standardised scores for all the variants of the Navon task for all age groups (Davidoff et al., 2008; Chamberlain et al., 2017).

Considering the use of letter identification for the Navon task, there are two variations: large letters made of the same small letters in a congruent manner (big S made of small S letters) or large letter made of a different letter than the small letters in an incongruent manner (big S made of small A letters). Individuals may identify the stimulus, i.e., the letters differently, either the larger shape or, the smaller letters. Navon’s research demonstrated that there are two different types of processing: global or local and individuals may lean towards either a bird’s-eye (or global) view approach, or a more compartmentalised approach where local processing styles predominate (Weston et al., 2008). Navon reported that individuals respond faster and more accurately to global hierarchical structures and encounter interference from global level less disruptive, in other words, individuals see the bigger picture first and are less distracted when viewing global features rather than the detailed images (Navon in Chamberlain et al., 2017).

Processing styles tasks have been used for testing facial recognition (Weston et al., 2008), but no studies have been found in the literature to support the nature of processing styles that may facilitate tissue recognition in histology. It could be postulated that one processing style may be more advantageous over another, for example, when learning cellular and nuclear features, individuals need to be able to focus their view to the details in the tissue; however, it is important that the individual is able to also be able to observe the cells composing the tissue. In diagnostic pathology, the first view under the microscope is always a bird's-eye view and from finding the cues, the individual can focus their attention to the detail. The skill of learning microscopy considering processing styles may be useful for teaching.

By considering this task, along with the RO, it was possible to identify the best strategy for teaching a student with a differential processing style. The use of RO and Navon task in the same study to determine processing style of individuals has not been reported in the literature. Using them in the same study will strengthen the results and demonstrate whether the tasks are congruent.

5.3. Wechsler Adult Intelligence Scale Version III (WAIS)

The WAIS version III task is used to evaluate auditory working memory, processing speed and attentional flexibility of individuals in the current study.

WAIS is a scale used in neurophysiological assessments and is a scale of intelligence used commonly in children and young adults and is also used to determine the degree of brain pathology in particular conditions as dementia. The Wechsler Adult Intelligence Scale Version III (WAIS, 1987) is widely used to evaluate working memory. A series of numbers and letters are verbally called out and individuals need to repeat them, the series ranges from 2 to 9 characters. This allows assessment of working memory and attention capacity both at an auditory and visual-spatial function (Crowe, 2000). Clustering working memory and information manipulation are executive functions that can be assessed through WAIS. The digit span forward measures procedural learning and, the digit span backwards measures manipulation of data, understanding the value of numbers and ability to track numbers. This latter task cannot be rehearsed until the last digit is presented as the two previous digit spans. The Letter-Number Sequencing (LNS) combines the previous two and includes higher complexity of thinking and organisation. This allows the researcher to evaluate the working memory and the processing speed at which the individual can manipulate data. It may also consider the attentional flexibility in the sense that the individual has to switch from one element to another in a short amount of time while making sense of the data presented (Wechsler, 1987; Crowe, 2000; Brown, 2016; Brydges et al., 2018).

The raw data produced by this task can be standardised to scaled scores standardised on age allowing patterns to emerge that indicate the working memory and processing speed to the individual (Wechsler, 1987; Brown, 2016). When reviewing the data produced by the scaled scores, a low value indicates a low working memory and processing speed, and a high value suggests a high working memory and processing speed.

Brown (2016) reported that age and education affect WAIS results; like all working memory tasks, the process of ageing leads to a decline on the working memory functions so the results for WAIS are generally worse. In this work, for individuals with more years of education, WAIS levels proved to be better and regarding gender in this sample, males have performed better than women. There are other papers reviewed in the literature suggesting that the data for gender was inconclusive; In addition, there are reported racial differences and WAIS, but this has weaker evidence (Crowe, 2000; Brown, 2016; Brydges et al., 2018).

The WAIS task consists of three activities in which the individual needs to rearrange the sequence of the information being given, number and letters: number sequence forward, number sequencing backward and LNS. The first two trials consist of seven sets (pair) each where the individual need to arrange the numbers being said in numerical order, in the first activity it is from the lowest to the highest number and in the second activity the individual needs to say the numbers from the highest to the lowest. In the third activity the set includes three lines per set and includes numbers and letters, in this activity, the individual needs to arrange the numbers and letters, numerically and alphabetically before saying them out loud (Wechsler, 1987; Crowe, 2000).

As this task is dependent on oral instructions, the presentation of the digits should be one per second, the pace, pitch, and clarity of the digit need to be very clear without any bias or chunking by the speaker. No digit can be skipped or swapped. The task includes two trials for each set, and there are seven sets for each task, the delivery should not be discontinued until the candidate scores 0 on both trials, and three for the LNS. The answers from the candidates need to be recorded verbatim instead of ticked on the sheet to ensure all data is captured and nothing is lost.

The use of WAIS complete task allows a full assessment of the auditory working memory and the processing speed in the sense of how long each individual takes to complete the task and the LNS added the attentional flexibility element.

5.4. Trail making Task

The TMT is used to evaluate working memory, processing speed and attentional flexibility of individuals in the current study.

The TMT was first described and delivered as part of the Army Individual Battery Test in 1944 (Partington and Leiter, 1949). After its first use, it has been integrated in other battery of tests to evaluate executive function, information of visual search, scanning, speed of processing, mental flexibility, symbolic complexity, symbolic complexity, spatial arrangement thus providing a very reliable and useful indicator of executive function, overall they allow an evaluation of the working memory properties and processing speed, trail making task A (TMTA) reveals motor and visual search speed and trail making task B (TMTB) shows working memory set-shifting and inhibition tasks. TMT allows for an evaluation of fluid memory in that it requires a degree of reasoning and rapid problem-solving skills to complete a task in a timely manner (Arbuthnott & Frank 2000; Kortte et al., 2002; Salthouse, 2011; MacPherson et al., 2017).

Individuals need to complete two trails. The score is based on the time taken to complete the task. In TMTA, candidates with a pen must connect numbers in order from the lowest to the highest, the highest being 25. In TMTB the candidate must connect numbers and letters alternately starting with the lowest number (1), then the earliest alphabet letter (A) and so on, ending with the highest number (13), this task is available in Appendix 6. The time taken to complete the task is normalised against data sets for the individuals' age group. The time taken to complete each task is recorded and the scaled score age/time is used to evaluate the working memory and processing speed of the individual.

There is a decline with age in the task in a healthy ageing population like with all the working memory tasks (Tombaugh, 2004; MacPherson et al., 2017). TMTB declines faster than TMTA in older adults, i.e., individuals take longer to complete TMTB than TMTA as they get older. Education seems to be a variable when completing TMT, particularly TMTB, as it requires the individual to remember the numbers and the alphabet quickly and, in the latter, associate letters with numbers. However, gender does not seem relevant for successful completion of the TMT (Tombaugh, 2004; MacPherson et al., 2017).

The TMT is sensitive to neurological impairment, can reveal attention deficit and inability or decreased task alternation abilities in individuals with brain injury (Tombaugh, 2004; MacPherson et al., 2017). Considering the TMT, the research considered the executive function of the students, both working memory and processing speed in learning new content and the role of attentional flexibility (TMTB) as an indicator of the individual switching their attention.

WAIS and TMT are generally used together to allow adequate characterisation of the working memory, processing speed. In addition, the LNS and TMTB allow the assessment of the attentional flexibility of the individual (Kortte et al., 2002).

This study will assess students considering four cognitive abilities: working memory, processing speed, attentional flexibility, and processing style. The tasks that will be used to measure the abilities are sumamrised below (Table 5.1.)

Table 5.1 – Summary of psychometric tasks that were included in the current study and the cognitive ability that the tasks was measuring.

Task/Cognitive ability	Working memory	Processing Speed	Attentional flexibility	Processing style
RO	Yes Visual spatial	No	No	Yes
WAIS – Digit span	Yes Auditory	Yes	No	No
WAIS – LNS	Yes - Auditory	Yes	Yes	No
TMTA	Yes - Motor execution and visual	Yes	No	No
TMTB	Yes - Motor execution, set-shifting and inhibition	Yes	Yes	No
Navon	No	No	No	Yes

Yes – meant the task measure the cognitive ability. No – means the task does not measure the cognitive ability.

5.5. Stress and Motivation Assessment

As explored in chapter 2, stress and motivation affect learning in many ways. A healthy combination of stress and motivation promote learning and encourage students to strive. However, an imbalance can lead to disengagement and dropout from the study: excessive stress can hinder learning (Joels et al., 2006; Stangor &

Walinga, 2014) and the acquisition of new knowledge and better learning outcomes be a reward in learning (Jovanovic & Matejevic, 2014) as discussed in section 2.4.

Students that participated in the study agreed to participate in addition to their own workload and commitments. It is important to understand the overall students' motivation and stress levels to assist them in managing their expectations and to assess how these two variable affect learning.

To assist in evaluating student motivation and stress levels associated with the psychometric tasks, a stress and a motivation questionnaire were included as part of psychometric tasks.

From the range of tasks available to measure stress and motivation and the test approved by the university, the Perceived Stress Scale questionnaire by Cohen (1994) and the Motivation questionnaire by Tuan, Chin and Shieh (Tuan et al., 2005) were chosen due to their simplicity in use and the ease to evaluate the results. In both questionnaires, individuals highlight their feelings on a 5-point range Likert-type scale.

The Perceived Stress Scale questionnaire measures the individual's perception of stress in life and includes ten questions scored out of 40 and, the higher the total summed value, the higher the stress levels.

The Motivation questionnaire measures students' motivation toward science learning (SMTSL) in six domains: self-efficacy, active learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation. The questionnaire includes thirty-five questions scored out of 175 and, the higher the total summed value, the higher the motivation levels.

Assessment may be a combination of cognitive tasks that can assist with predicting students' performance and success prior to delivering an intervention. Pattern recognition, problem-solving and decision making are complex cognitive processes that are of great relevance when learning microscopy skills and in learning to interpret visual stimuli (Hamilton et al., 2009; Hamilton et al., 2012), in the sense that tissue recognition are patterns that can be learnt and the identification of the nuclear and cellular features allow the individual to process the information and make a decision on the tissue type and condition a tissue section may demonstrate.

Experience has a role to play when acquiring new knowledge and integrating it with existing, and this is more challenging with complex cognitive processes (Knowles, 1973; Vygotsky, 1978; Gregory, 2012; Kay & Kibble, 2016; Huang, 2002; Schunk, 2014). A novice learner in histopathology engaging for the first time with a glass slide will have no memory or recollection of any meaning while expert learners would have unconscious automatic processes that allow them to identify structures that are presented to them correctly through reasoning, association, and experience (Brentham, 2002; Woolfolk, 2014). However, learning of tissue recognition is not well understood using pattern recognition analogy. Students struggle with tissue recognition in the workplace due to the limited access during the academic degree. It could be proposed that greater exposure to tissue recognition during the academic degree would improve students' skill and knowledge.

To mitigate this lack of confidence from students, the investment in new technologies and the use of VM should facilitate tissue recognition. Learning tissue recognition using VM may allow students to learn quicker and retain more content to improve learning outcomes. Considering scaffolding learning theories, it could be postulated that learning new information with a weaker foundation, could lead to student disengagement (McLoughlin, 2000; Salmon et al., 2010) and this may hinder the learning process. However, learning starts from the basic structures and being able to experience the functionalities using a microscope and refer to atlases and books before using technology allows students to build their knowledge from previous experiences. It could also be suggested that students learning VM only may not be able to revert to a microscope and glass slide as they have not learnt the microscopy skills and so they will be at a disadvantage when applying for a job as VM is not widely spread as a diagnostic tool.

The combination of the RO complex Figure and Navon task allowed the researcher to evaluate students processing style. Also, the TMT enabled the researcher to evaluate the processing speed and psychological flexibility of students, that is, the degree that the student-individual can switch from one processing style to another, which can be related to better performance (Crowe, 2000; Faja et al., 2009). Stress and motivation allowed the researcher to assess the context and what motivated the students to participate in the study.

5.6. Summary

Considering teaching and learning in the context of blended learning with VM, the theory and concepts are continuously progressing and evolving as demonstrated in previous chapters, there are studies that evidenced student perception and experience when using VM as being positive and preferred by students as described in Table 3.1 (Scoville & Buskirk, 2008; Helle et al., 2011; Hande et al., 2017). However, there were few studies that demonstrated a difference in the student outcome using VM of whether there was a significant difference (Barbeau et al., 2013; Helle et al., 2013; Tian et al., 2014). This research is aimed to address student's perception and demonstrate whether there is a difference in students' outcome as the use of VM will be a necessity in the years to come particularly with the international changes with the pandemic in 2020.

There was a rise in the number of studies on blended learning and the use of digital technology for teaching and learning and these studies are addressing the question around the use of VM for teaching purposes expressed in better student learning outcomes. More work is still required to understand the differences in methodologies, students' outcomes, perception, and engagement with this approach.

The role of memory and pattern recognition in early childhood and in youngsters, in pathologies of the brain or post-accident and trauma cases is researched better. However, there are few studies that consider pattern recognition and the role of memory applied to university students (Tombaugh, 2004; Conway et al., 2005; Salthouse, 2011; Weber et al., 2013; Solianik et al., 2016; Tourva et al., 2016) and these are generic and not convincing enough to allow the understanding of the role of memory and pattern recognition applied to education. The application of pattern recognition tools to evaluate memory in healthy undergraduate results is exciting and could bring forth a pattern to predict student success depending on student processing styles and memory span.

The use of psychometric tasks is widely used for career choices and job applications. The way it is being used in this research highlights the original use of these, to assess motivation, memory characteristics and how people behave in a particular context, there are many tasks available for psychologists and social therapist and other professionals to use and the choices are down to individual preferences or theories followed. This study considered specific tasks which were carefully selected by the researcher and supported by the supervisor to assist in answering the questions proposed by the researcher. The unique use of these tasks has been applied and evaluated in the study to explore if these can be used in the context of teaching and learning in a blended approach using VM.

This chapter set the scene to deliver and interpret psychometric tasks and then described the psychometric tasks that were chosen for this study: RO, WAIS, TMT, Navon Tasks and which cognitive abilities they measure, stress and motivation, and the way all these tasks are measured.

Chapter 6 that follows, describes the methodology used for the intervention study, including the rationale and the framework for the study.

6. Methodology

This is a mixed-methods research in which quantitative methods precede qualitative methods in which the qualitative data will supplement and contextualise the quantitative data. This chapter will address the aims and objectives, the methods approach, the study design including quantitative and qualitative methods, the sample selection and recruitment, materials and ethics and health and safety considerations.

6.1. Aims and hypothesis

The aim of the study: is blended learning with VM more effective than glass slide/textbook approaches in training Biomedical Science undergraduate students? In the context of the study, effectiveness was defined as the ability of students being able to learn and recognise normal and pathological features during and after the intervention in the function of time and speed of identifying the features online using Westminster Path XL.

The research questions (RQ) that the study investigated whether processing style or memory performance impacted on student success (RQ1), whether student motivation and stress levels were modifiable factors in learning (RQ2), whether VM improve learning outcomes (RQ3) and explore which method/s are preferred by students (RQ4).

6.2. Methods approach

The study developed a mixed method approach. At the onset of the study, a quantitative approach was preferred by the researcher and the supervision team as there was a concern about obtaining measures. In time however, on reviewing the literature, the formulation of the hypothesis and as the thesis started to develop, this approach was reviewed. It became clear that the students' personal, subjective values and opinions were also required to fully understand what was happening in the learning process. Based on the approaches of previous studies, qualitative methods had been used more frequently mostly exploring the students' experiences and opinions (Krippendorf & Lough, 2005; Farah & Maybury, 2009; Helle et al., 2011; Helle et al., 2013; Hande et al., 2017). MMR design was most suited to the study as it would provide more validity as it will go into more depth. This approach is more encompassing that the data produced and analysis of each of them separately in a manner that one informs the other and complements the validity of the results obtained mitigating for the weakness of one method over the other (Guba & Lincoln, 1994; Creswell & Plano Clark, 2011; Schoonenboom & Johnson, 2017). In addition to enriching the findings, MMR design allowed an increased depth of the study with more questions being considered, it allowed students to have an active voice and provide their input which in turn enables the study to improve the degree of reliability (Bazeley, 2015; Bazeley, 2018).

The methodology used in this research were MMR convergent design approach previously known as concurrent considering the data collection and time of analysis, were quantitative design methods preceded with the use of assessments and online questionnaires/surveys to provide measurable and objective results. The qualitative design methods were provided from the interviews with the students and the open-ended questions of the questionnaire provided qualitative information (Creswell et al., 2003; Creswell & Plano Clark, 2011; Doyle et al., 2016; Creamer, 2018).

The studies described in Table 3.1 which only used one design method over the other, demonstrate limitations related to the other: Krippendorf et al. (2015) considered students' perception and were only able to explore students' outcome superficially and Ordi et al. (2015) considered students' outcome and were unable to provide an explanation for their findings and were unable to explore students' experience and preferences. Helle et al. (2013) and Tian et al. (2014) studies used MMR design and could demonstrate students' outcome and preference in teaching mode and justify the results obtained.

There are limitations to using convergent design approach as familiarity and expertise with both methods, handling the design of different approaches and the increased amount of data generated in each method (Creswell & Plano Clark, 2011). To address these limitations in this study, this is being managed by a lengthy and detailed planning of the study delivery to include a pilot study and critical reflexivity at all stages of the study by the researcher.

6.2.1. Research paradigm

To develop and implement the research study it is paramount to understand the philosophical underpinnings, this will provide the framework and guide the researcher to ensure that all considerations are reviewed and discussed. This includes ontology, epistemology, theoretics perspective, methodology, methods, and sources (Creswell & Plano Clark, 2011; Creswell, 2013).

Considering ontology and epistemology, this study is a constructivist paradigm, where students shared their lived experiences and opinions. The reality of each of the students is different and their social contexts determined their experiences. Thematic analysis was used to analyse the data and interpret the results (Creswell & Plano Clark, 2011; Creswell, 2013). The researcher's views were relevant to understand the learning process. This is reflected in the more qualitative aspect of the study.

The data collection in terms of the psychometric tasks, the learning outcomes and their relationships in the study demonstrated a positivist and post-positivist paradigm of the study with measurements and statistical analysis whilst being aware of the limitations about generalization and assumptions to an entire population of students completing a Biomedical Science degree in the UK.

Pragmatism is at the foundation of MMR approaches and is practical in nature, focused in finding results and providing solutions rather than on what it should be (Creswell & Plano Clark, 2011; Creswell, 2013; Morgan 2014). As an MMR design study, this study followed a pragmatic paradigm approach, which connects different approaches: positivism/post-positivism and constructivism, in a balanced approach where students' voices are heard through the contextual case studies and the outcomes from the psychometric tasks and the learning outcomes justified through the students' experiences (Creswell et al., 2003; Creswell & Plano Clark, 2011).

6.2.2. Reflexivity

As part of the methods approach, the role of reflection is essential to assure that the method process was fit for use and to ensure objectivity and detachment from outcomes (Schoonenboom & Johnson, 2017).

Self-reflection is essential for the researcher to ensure reliability and allows the researcher to work within the frameworks that were set. Considering the epistemological approach described above, self-reflection will allow the researcher to keep focused on delivering the study whilst being able to gather all qualitative and quantitative data to analyse and provide the space for in depth discussions (Lincoln & Guba, 2000; Morgan, 2014).

In the context of the study and the educational approach, there are multiple reflexivity models that can be used, Brookfield's lenses provide a framework that can be easily used and adapted in the context of this study. Brookfield's reflective model defines four lenses by which adult educators can review learning and using reflections from different groups, improve the teaching: self-reflection, students' feedback, colleagues' experience and feedback and the theoretical literature. This model was first described in the 90's as has been reviewed recently in 2017; and it is still suitable (Brookfield, 1998; Reed, 2014; Brookfield, 2017).

The theoretical literature has been reviewed and reflections are included in the earlier chapter of the thesis (chapter 2, 3, 4 and 5). The students' experiences and perceptions will be explored in chapter 8 – the students' feedback questionnaire and the thematic analysis of the interviews.

The elements on self-reflection and supervisor feedback will be described and explored in the discussions and author's reflexive statement chapter (chapter 11).

6.3. Study Design

Students took part in the study over a period of twenty weeks. The study was designed as an educational program that included an episode with a series of sessions that the students agreed to take voluntarily and did not contribute to their final degree nor an automatic career progression.

The entire study was designed and delivered by the researcher, and the quality of the resources available was monitored by the supervisors. Dr Edington supported with the psychometric tasks, and the qualitative component of the study and Dr Madgwick assisted with the histology related content and the quantitative part of the study.

The recruitment and delivery of the psychometric tasks included confirmation the students understood the study (PIS and consent form – See Appendix 1), were available and provided written consent to participate in the study. Students were divided into group A – microscope and glass slide and group B – Westminster Path XL based on the psychometric tasks.

Students were required to attend the five tutorial sessions, each tutorial session lasted 30-minutes (Figure 6.1). The content was delivered through a series of presentations with relevant information that was distributed to the students in the form of handouts and annotations, this was histology specific content organised by the researcher that was reviewed by Dr Madgwick.

During the first tutorial session, all students were taught the theory of how to use a microscope and how to use of Westminster Path XL. After the session, students in group A had a 30-minute practical session in a laboratory with a microscope and glass slides. The students in the Westminster Path XL group only had the 30-minutes tutorial session and unlimited access to Westminster Path XL. After the first session, group B students received their credentials to use Westminster Path XL. Group A received their credentials to use Westminster Path XL two days prior to the scheduled date for the first quiz.

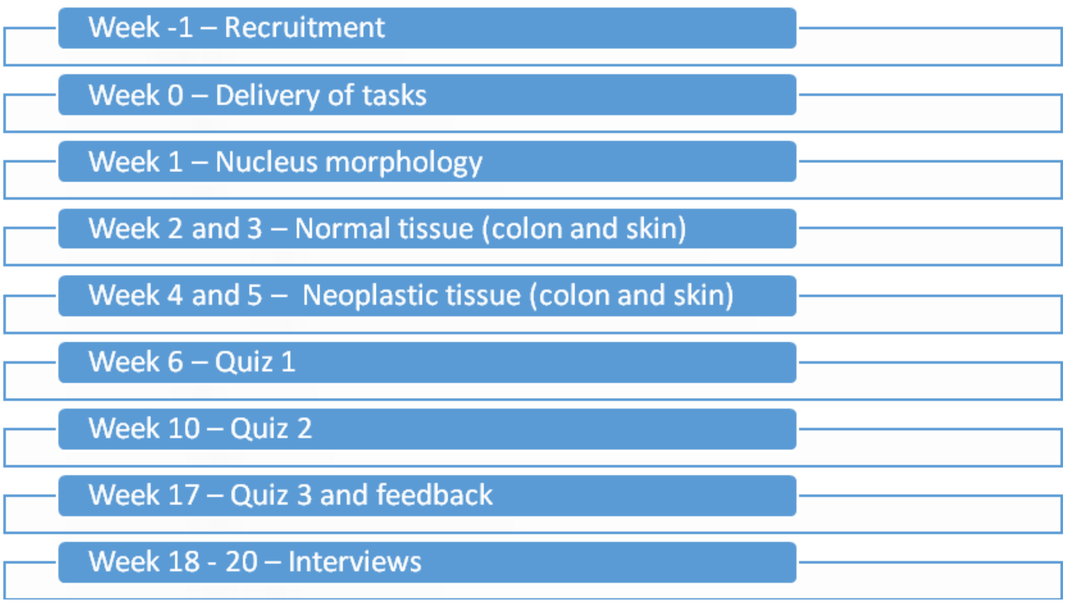

Figure 6.1 – Chronogram of the study.

Students completed several assessments over twelve weeks (online quizzes). The first assessment was on week 6, the assessment was carried out using Westminster Path XL, and this allowed the measurement of the level of knowledge at that time of completing the quiz and how students engaged with the teaching resources despite the teaching methodology. For group A, quiz one this was the first encounter with using Westminster Path XL.

After the first quiz students in group A were not given access to the glass slides and could log in to Westminster Path XL anytime.

On weeks 10 and 17, students completed a follow-up assessment to understand delayed memory processing. Students' access to Westminster Path XL was not restricted to any of the groups (A and B) from week 6 of the study. In Appendix 8 there are images of the viewer mode and the assessment mode for Westminster Path XL.

The study measured any significant improvements in learning via glass slides or VM while exploring the role of memory and processing style in the assimilation of new information. The familiarity with the online strategy was also considered in the discussions.

During the intervention study, students learnt basic histological morphology and malignancy. On week 6, students completed quiz one, on week 10 students completed quiz two and on week 17 students completed quiz three. The completion of the quizzes by the students allowed the researcher to understand the working memory capacity, this was five weeks and twelve weeks after the last tutorial session.

Once the intervention study was complete, all the students had an additional period until the end of the respective academic year where they could explore the content available during the study, using both the glass slides and the Westminster Path XL. To review the glass slides outside the practical sessions, the students contacted the researcher via email, so the glass slides and microscopes were made available to students. Westminster Path XL password would expire at the end of the academic year without the possibility of being renewed.

On completion of the interviews, certificates of participation in the study were sent to all students, this was in October 2018. Dr Madgwick approved these certificates, and students were able to use the participation in the study to enhance their professional learning and in their personal statements, *Curriculum Vitae,* and CPD portfolios.

Figure 6.2 summarises the methods used for gathering data in the study and the research questions each of them is addressing, the sequence of events is chronological.

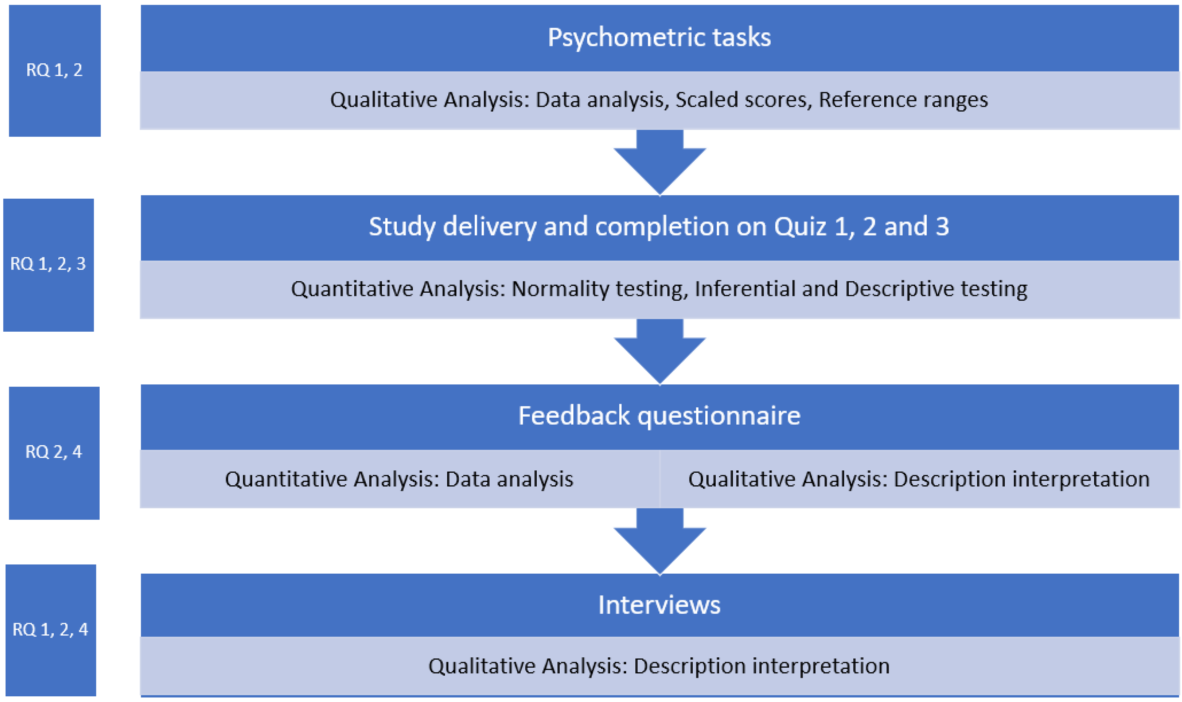

Figure 6.2 – Outline of data gathering in the study and the research question it is addressing chronologically.

6.3.1. Psychometric tasks

The psychometric tasks were decided by the researcher and the supervisor Dr Edginton. The researcher was taught by Dr Edginton on how to deliver the tasks effectively over two sessions. Some of the participants volunteered to take part in the task delivery session but they did not participate in the study. The delivery of the tasks was supervised and monitored by Dr Edginton.

Undergraduate students that were willing to participate in the study and had completed the consent form were exposed to a series of tasks to understand their working memory capacity and processing styles. Also, their motivation and stress levels at the start of the study (week 0) would need to be completed. The tasks being delivered to each participant followed the structure described below:

- Perceived Stress Scale questionnaire to determine the student stress level at the time of completion of the tasks – PSS (Cohen, 1994, See Appendix 2)

- Motivation questionnaire to appreciate the motivation level of students participating in the current study – MS (Tuan et al., 2005, See Appendix 3)

- RO complex image task to assess working memory and processing styles (provided by Dr Edginton, See Appendix 4)

    - Copy

    - Draw by memory

- Digit span and LNS tasks to evaluate working memory and memory speed (provided by Dr Edginton, See Appendix 5)

- TMT pattern to assess working memory and speed of learning (provided by Dr Edginton, See Appendix 6)

- Navon task to assess processing styles (developed by the researcher, See Appendix 7)

In the current study, the Navon Task set was prepared by the researcher. If the student viewed the letter as the larger image, the processing style was global. If the student reporting the smaller letter making up the larger letter this suggested that the processing style was featural.

- RO complex image task to assess working memory and processing style (provided by Dr Edginton, See Appendix 4)

- Delayed reaction

The completion of these tasks took approximately 30-minutes. The task results allowed the researcher to understand the individual characteristics of each participant and based on these characteristics the researcher divided the participants into four homogenous groups, the criteria to create the groups was based on their processing style (global or featural) and their working memory capacity (low or high) as described below:

- Featural processing and high working memory capacity
- Featural processing and low working memory capacity
- Global processing and high working memory capacity
- Global processing and low working memory capacity

All the task results were entered on Microsoft Excel 365 with the students' name anonymised. The appropriate tables were colour coded for processing style and working memory and the students were allocated an intervention. The researcher attempted to have an even distribution of male/female in each of the groups, so when there were similar characteristics, this was taken into consideration also. These criteria were sufficient to allocate participants in each group. As students were from three different sites, parity was considered initially per site and then overall.

Students in each of these groups were distributed evenly in:

- Group A – face-to-face sessions plus additional laboratory time (access to microscope and glass slides)

- Group B – face-to-face sessions plus Westminster Path XL access

The basis for this allocation was to allow an even distribution of students based on their cognitive ability rather than a random allocation, this enabled comparison of the same characteristic for different students.

As part of the results for the current study, the researcher reviewed some profiles considering the task delivery and student outcome. This was not related to a specific question and the study is most concerned with the group effect rather than individual profiles; however, there is an interest to understand whether there are character differences.

6.3.2. Quiz assessment

Students had to complete different quizzes; the quiz structure was the same for each of the three assessments. Each quiz comprised of three digital images and three questions per image (digital slide), all the functions of the viewer on Westminster Path XL were available in the quiz section. The students had to identify the tissue (Question 1), discriminate between normal and pathology (condition, Question 2) and justify their choices (Question 3). If positively recognising the tissue, the student was awarded 2 points, for discriminating between normal and pathology, the student was awarded 2 points, and for justifying their choices the student was awarded 3 points, one for each feature identified. Each image was scored at a maximum of 7 points and the maximum quiz score is 21 points. The pass rate was determined at 40% which was 8.4 points. There was no negative marking or time limit to complete the assessment, time to complete the quiz was outside of the scope of the study. Students could not use handouts or other web resources to complete the assessment. Students were not provided with the individual quiz results until after the completion of the three quizzes; however, there was a group feedback session after quiz one for each of the four cohorts.

Quiz one consisted of one image each of normal colon, adenocarcinoma of the colon and malignant melanoma of the skin. Quiz two consisted of one image each of normal skin, adenocarcinoma of the colon and a basal cell carcinoma of the skin. Quiz three consisted of an image each of adenocarcinoma of the colon, malignant melanoma of the skin and skin with squamous cell carcinoma. On quiz one there were two colon images, and on quiz two and quiz three, there were two images of skin. The quizzes were set up at the before the intervention study started and were not altered.

The results of the quizzes were entered on Microsoft Excel 365 and all descriptive and inferential quantitative data was analysed using IBM SPSS statistics version 25 for Windows. Alpha levels were set to $p<0.05$ unless otherwise specified. Graphical representations were created using IBMS SPSS statistics version 25 for Windows, GraphPad Prism version 9 and Microsoft Excel 365.

6.3.2.1. Normality of Data

Assessment of the normality of data will be done as a first statistical step to understand the distribution of the data (Mishra et al., 2019). The statistical methods that were considered are Kolmogorov–Smirnov test and the Shapiro–Wilk test. The latter is a more appropriate method for smaller sample sizes of less than 50.

6.3.2.2. Quiz data

The data was imported to IBM SPSS statistics version 25 for Windows and statistical tests were run considering the sample parametric and non-parametric distributions. Depending on the data normality results, for normal distribution, independent t-test statistical test with a 2-tailed distribution One-Way ANOVA was performed. In all cases, Man-Whitney U test was also performed as the sample sizes are small and this allows the data to be interrogated in a non-normal distribution setting. Independent samples median test, histogram distribution with frequency and Standard Deviation were included as descriptive tests to aid in the interpretation of the results. As appropriate, Boxplot representation of the results was added to provide a visual outlook of the results. To aid the researcher and provide greater context for interpretation of the data gathered, linear regressions, crosstabulations, percentiles and confidence intervals were also plotted, and bivariate correlations were derived to enable the researcher to infer about relationship between variables (Muijs, 2011, Doyle et al., 2016; Mishra et al., 2019).

The used of Microsoft Excel 365 was used firstly and then IBM SPSS statistics version 25 for Windows allowed the researcher to analyse the quiz results in function of the intervention and whether processing style, working memory, stress and motivation could be used as predictor of students' outcome.

Considering the summative assessment, the first assessment allowed the researcher to understand if students could discriminate morphologically the nucleus – normal and abnormal and the following assessments allowed the understanding whether students could recognise the tissue type and the pathology, in addition to the morphology. During the intervention students learnt new histology terminology which enhanced students learning and easy with the discipline.

The second and third assessment followed the same template as assessment one, and in addition, allowed the researcher to understand if students could discriminate morphologically the nucleus, recognise the tissue type, and justify their choices, it also allowed the researcher to understand the role of memory and motivation in learning new concepts and the use of technology and how effective was the use of technology for the assessment.

Most of the analysis will be considering the results from quiz one, there will be some evaluation of the results considering quiz two and three; however, this is a minor proportion of the findings.

6.3.3. Online Questionnaire

After quiz three, all students were be invited to complete a survey about their learning experience during the study.

The use of Likert type scales as a quantitative research method was first described and used in the early 30s to measure attitudes, the most used is a 5-point scale which describes the spectrum of attitudes, behaviours or interests the individual can present (Sullivan and Artino, 2013; Bishop and Herron, 2015). The use of questionnaire provides a great insight into the students experience in an objective and measurable manner.

The questionnaire (Appendix 9) was written considering the objectives of the study and included four sections. Section one included questions 1 to 14 were written considering the tutorial sessions, section two was related to the practical sessions: microscope (question 15 and 16) or Westminster Path XL (questions 17, 18 and 19) and section three were overall questions about the study (questions 20 and 21). Section four included questions 22, 23 and 24 with short answer questions that allowed students to provide feedback on the training – what went well and what could be improved. The student's perception in each of the groups and understand any topics of interest highlighted by the students. The topics that arose from the feedback were grouped into themes similarly to the process that occurred for the interviews (described below) in a simplified manner and allowed an understanding of strengths and weakness of the study and areas for development (Evans, 2011; Nicol et al., 2014; Kuo & Leo, 2018; Huisman et al., 2019).

6.3.4. Interviews

A representative selection of students (ten) that completed their training were invited to complete a semi-structured interview to explore their learning experience. Any student that withdrew from the study was also invited to participate in an interview.

The semi-structured interviews were set up to provide the learner to have an open discussion with the researcher. To assist in the process and to aim to cover the wide range of subjects that could be addressed, the researcher developed a set of guiding questions. The interviews were set up between the researcher and the participant at a mutual convenient time and date and researcher recorded the session with students' consent. The interviews were transcribed verbatim for the thematic analysis.

There are multiple methods to analyse and review the data produced by the interview and depending on the analysis required, a different approach can be chosen. Considering thematic analysis as articulated by Braun and Clarke (2006), it was most suited in this context: flexible, multi-layered that can be analysed from different perspectives of what was said by the students and the deeper analysis that provided interpretation and context to where students came from and what they said (Braun & Clarke, 2006; Hoe and Hoare, 2013). This enabled the researcher to review the transcription for accuracy, extract themes from the original script and coding of the transcript. The process was lengthy and was performed a few times to produce an overall analysis where the interviews were mapped, and concepts and themes were derived from. The thematic analysis was done in stages and over a period, providing greater flexibility for the researcher. This approach revealed unexpected insights and highlighted similarities and differences amongst learners which could be related to the quiz results, student motivation, engagement, and the student learning experience (Braun & Clarke, 2006; Thomas & Harden, 2008; Tong et al., 2012; Braun & Clarke, 2014; Braun & Clarke, 2021).

In the field of VM and teaching, few studies include students' interview with thematic analysis, most studies include questionnaires with open-ended questions. Helle et al. (2013) reported students' perception from a qualitative perception that included interview with students in addition to an evaluation questionnaire and enable the researchers to understand the students' voice and the issues that concerned them: four students (from 126 participants) were interviewed, and these were transcribed but the number of students were too few to make a meaningful analysis.

Qualitative research that includes interviews with students to understand student's perception and experiences was the gap in the literature and the MMR approach this study aimed to address.

The six-phase guide to data analysis described by Braun and Clarke (2006) was followed for the analysis of the data provided by the interviews:

- Phase 1 – Familiarisation with the data – the researcher reviewed the notes taken during the interviews and got the interviews transcribed chronologically. The reading of the notes, the listening of the recording of the interviews and the reading of transcribed interviews allowed the researcher to gain familiarity with the topics raised by each student and the researcher gained a greater depth of the subjects raised and started thinking about ideas and words that stood out.

- Phase 2 – Generating initial codes – in this step, the ideas and words started taking shape and the researcher developed initial codes using words from the interviews. This process enabled the researcher to create a mind map of themes and separate and organise material into different areas. This process was done using highlighter pens with the printed interviews, using Microsoft Word and Excel 365 and Post-it notes as a visual support.

- Phase 3 – Searching for themes – from the ideas and codes highlighted, themes started to emerge providing a map, the name of the “themes” process started, and the ideas raised by the different students were visually seen as part of the themes. At the end of this phase, the interview texts were colour coded to highlight the different themes and a physical visual map with Post-it notes with themes and quotes were available.

- Phase 4 – Reviewing themes – this was an iterative process and allowed the researcher review and refine the process completed. It also allowed the researcher to immerse into the themes again and derive a deeper knowledge about the ideas and themes generated considering each of the students and their contexts.

- Phase 5 – Defining and naming themes – this phase allowed for a clearer definition of the codes and names developed in the previous phases and consolidated the themes; not to broad that all is included in one theme or so specific that it failed to provide students representation from the different groups. At the end of phase 5, the researcher had a clearer story, with themes that were relevant and include the perceptions, experiences, and emotions of students in the different groups.

- Phase 6 – Producing the report – when the researcher produced the written report of the findings through the analysis and could draw conclusions and recommendations from the study.

NVivo 12 was also used for the data analysis. The transcripts of the interviews were entered onto the software and code analysis was performed; however, this was not very productive to assist the researcher in understanding students' perception and experience in the study. The software was limited to searching words and, in that sense, the context of the words was not considered; the word analysis was ambiguous and additional considerations were needed to analyse the words; the findings have not added value to the manual mapping of themes thus will not be presented in the forthcoming chapter.

The attrition rate of students, not a research question, was also part of the statistical discussion as it could also be considered an indicator of the success of delivering new knowledge by using VM. Students that dropped out of the study were also be invited to complete the survey to allow a better understanding of the students' engagement with the method of learning and any other relevant considerations raised by the students.

Considering the research questions and the data collated in the study, the researcher can answer the following research questions summarised in Table 6.1.

Table 6.1 – Method used to answer the research questions.

Research Question	Quantitative method	Qualitative method
Whether processing style or memory performance impacted on student success (RQ1)	Findings related to processing style and memory performance using Pearson correlation	Thematic analysis of the interviews
Whether student motivation and stress levels were modifiable factors in learning (RQ2)	Findings related to motivation and stress using Pearson correlation and linear regressions	Online questionnaire themes and thematic analysis of the interviews
Whether VM improve learning outcomes (RQ3)	Findings related to the quiz results using IBM SPSS version 25 tests: normality of data, independent t-test statistical test with a 2-tailed distribution One-Way ANOVA, Man-Whitney U test, descriptive tests with means and Standard Deviation and Histogram and Boxplot representations	
Explore which method/s are preferred by students (RQ4)	Online questionnaire 5-point Likert style questions	Online questionnaire themes and thematic analysis of the interviews

6.3.5. Pilot study design

A pilot study was delivered prior to the intervention study. In addition to group A – microscopy and group B – Westminster Path XL, a third group was included – group C, this is a control group with tutorial session only.

The pilot study lasted for a period of four weeks in total with two tutorial sessions which students were required to attend, 20-minutes each (Figure 6.3). The students in group A and a 20-minute practical session, the students in group B and C were released after the tutorial session. Students in group B were given the access to the software after session 1 and the other two groups (groups A and C) were given access to the software two days prior to the assessment.

Students completed one assessment on week 4, the assessment was a combination between glass slides and the use of Westminster Path XL, this allowed the researcher to measure the level of knowledge at that time of completing the quiz and how students engaged with the teaching resources despite the teaching methodology. For group A, the quiz was the first encounter with using Westminster Path XL and for group C, the assessment method would be a complete novelty, both the use of microscope and glass slides and Westminster Path XL. The pilot study was smaller in scale and length of time.

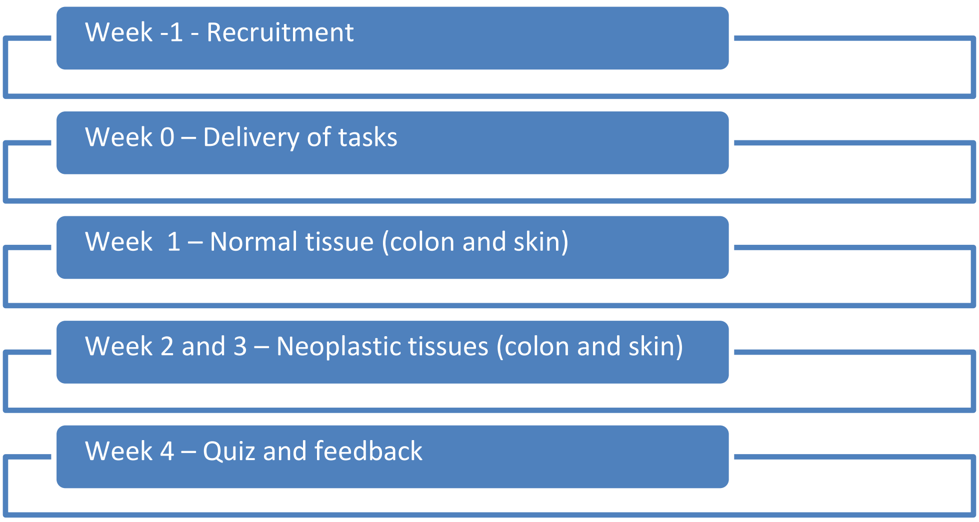

Figure 6.3 – Chronogram of the pilot study.

The assessment in the pilot study included microscope and six glass slides and four images on Westminster Path XL, students could start with whichever set they preferred. For each slide, the students had to identify the tissue, discriminate between normal/pathology, and justify their choice by means of identifying three features. If positively recognising the tissue the student was awarded 1 point, for discriminating between normal and pathology the student was awarded 1 point, and for justifying their choices the student was awarded 3 points one for each feature, this means each slide set is 5 points in a total of 50 points for the assessment.

The assessment allowed the researcher to understand how students engaged with the assessment regardless on the learning methods. In addition, it allowed the assessment if the control group was required for the intervention. Considering the students outcomes, the researcher was interested in observing if the students could discriminate morphologically the nucleus, recognise the tissue type and the pathology despite the intervention being very short and intense.

The student feedback allowed the researcher to understand the student's perception regarding the delivery of the tutorial session and the practical component of the study. The open-ended questions allowed the researcher to know students' motivation and learning experience and assist in informing the delivery of the intervention.

6.3.6. Limitations of the study

Limitations in the study that were considered were sample size which may require extending the end time of the study to include more students or multiple delivery sets if many students register their interest. Other limitations of the study were student compliance with the training cycle, and continuous engagement as the participation in the study was voluntary (Garrison & Cleveland-Innes, 2005; Arend, 2006; Salmon, et al., 2017; NSS, 2019).

The potential conflict between participation in the study and degree assessments was minimized by avoiding exam times and coursework submission deadlines; however, this may have not been possible at times. The attrition rate may have been due to disengagement in the topic or conflict between the study and other activities, this has also been considered (Garrison & Cleveland-Innes, 2005; Arend, 2006; Salmon, et al., 2017; Gregori et al., 2018).

Another area that required careful consideration was student expectation, and this was managed by having a clear line of accountability and referral processes set at the beginning of the study during the task delivery and through the documentation (PIS) available and signed by the participants (Willging & Johnson, 2004; Woodley, 2004; Gregori et al., 2018).

6.3.7. Demographics in the study

Personal characteristics such as age and gender and previous experience were some of the confounding factors that were considered alongside the technological flexibility to learning which was measured during the study. All students were still at university or were recent graduates working in the NHS without professional registration, so the role of experience in tissue recognition was less relevant in the study.

Independent variables that were discussed in the study were the speed of learning and learning style, motivation, stress, and memory capacity, which was measured and re-assessed with the psychometric tasks. Academic ability may have some role to play, and this could also have been used as an indicator of the effectiveness of VM delivery; however, this information was not available, and it was not a requirement to participate in the study, this variable was outside the scope of this study.

The new Learning Futures curriculum that was introduced at the UoW as part of the university strategy was another confounding variable. The strategy was published in the academic year 2012-13, and in the 2016-17 academic year, Westminster Path XL, and the use of mobile computing for students was introduced to the curriculum, when analysing and reviewing the data produced, these factors were considered as part of the discussion process in terms of how these can affect student learning, this was only applicable to the UoW students (UoW, 2015; UoW, 2018).

6.4. Sample selection and recruitment

The total sample that was available and was invited to partake in the study was two-hundred students in the first academic year from a range of entry routes into Higher Education at the UoW, twenty students at LMetU that were in the second year of a

Biomedical/Biological Science degree and twenty staff that were at ICNHST Cellular Pathology department, which included recent graduates or staff still completing their studies.

Interested students were invited to attend a 20-30min session with the researcher to learn about the study and how to participate in the study, it was not expected that all students would enroll in the study. The students that agree to be part of the study received a PIS containing all relevant information related to the study and a letter confirming confidentiality. A request form for consent to participate in the study was completed for eligibility to participate in the study.

Students that did not fulfil all the inclusion criteria were excluded from the study. It was not expected that all students that were invited in the study would participate, and it was likely that a small percentage of students may not complete the study considering the attrition rate in other studies.

The total number of students available to participate in the study was manageable (two-hundred and forty students in total). However, if the number of students were unmanageable, then an additional set of deliveries would have been considered.

In the UK, the average participation in a healthcare setting study was eighteen participants (Table 3.1). Considering a 10% attrition, a minimum of twenty students completing the study would be in par with other studies and allows the researcher to understand whether VM is more effective than glass slide/textbook approach.

6.4.1. Pilot study, participant recruitment and delivery

A pilot study was conducted to understand better the requirements for the intervention study and to review and highlight any areas for improvement that could be mitigated for the intervention study.

The total sample that was available and was invited to partake in the study was fifty students in the second year of the undergraduate degree in Biomedical Sciences at the UoW and ten staff at ICNHST Cellular Pathology department, recent graduates or still completing their studies. Students were invited to attend a 20-minutes session with the researcher to learn about the study and how to participate in the study.

6.5. Materials

The materials used for the study included the glass slides used by the students in group A and Westminster Path XL software used by the students in group B for the intervention and all students during the assessment.

Formalin-fixed paraffin-embedded (FFPE) blocks were retrieved from ICNHST. Case selection was done by the researcher using the specific histology reporting software to identify cases at ICNHST, blocks for the cases were retrieved, sections were cut using a microtome, and the glass slides were stained with haematoxylin-eosin (HE) by the researcher, large blocks/slides were also included in the cases. The material to be retrieved was based on the relevance for the study, and representative tissue has been collected for this.

The tissue types that were used in the current study were colon and skin, were retrieved from ICNHST and were digitised with Hamamatsu scanner. Both colon and skin pathology have a clear molecular model to demonstrate progression to cancer from a normal functioning status to a dysplastic condition to cancer. Understanding these two organs are core to the undergraduate curricula for Biomedical Scientists (Quality Assurance Agency, 2020) (Figure 6.4).

One set of the glass slides (regular slides only, not large slides) were digitised using a Hamamatsu scanner at UCL Hospital under the supervision of Prof. Novelli. All the sets of glass slides were available for the students in the cohort having the microscopy sessions for the period of the study (Figure 6.4).

Once the study was complete, the digital slides remained in the Westminster Path XL database and were available for other student cohorts through the supervision of Dr Madgwick. All glass slides became part of the training set of slides for ICNHST employees.

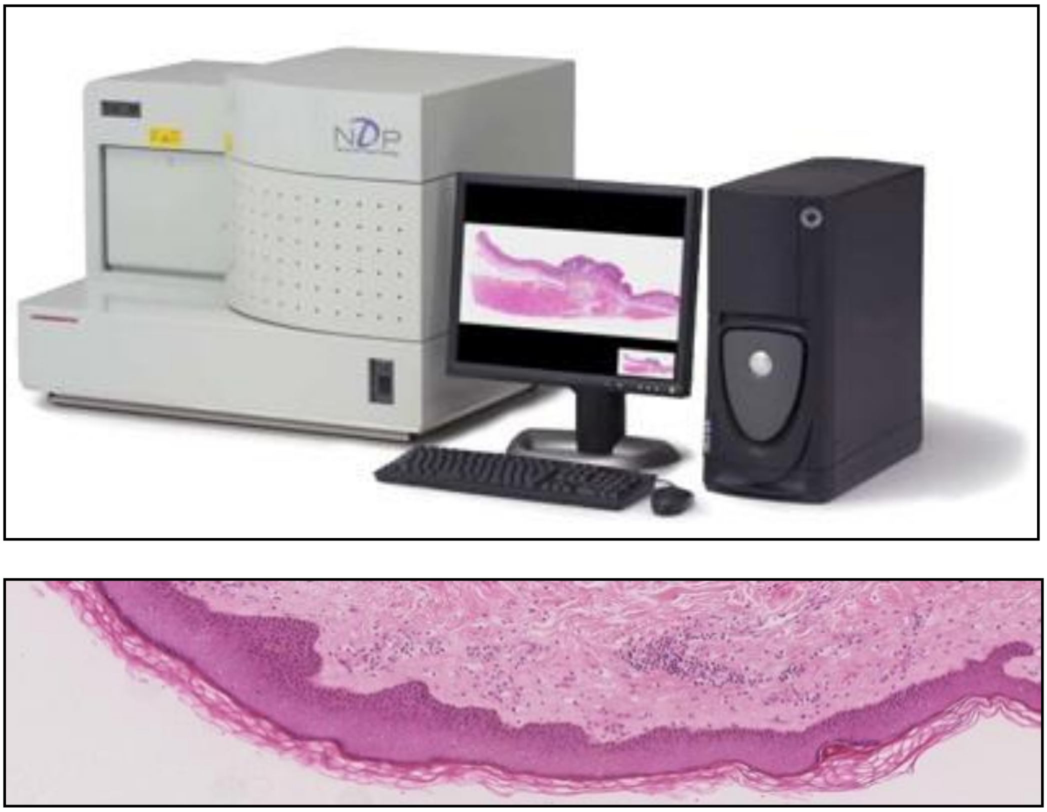

Figure 6.4 – Top of the image is Hamamatsu scanner with an image of carcinoma of the colon in the screen (TIGA Center, 2020). Bottom of the image is digital image of normal skin (taken by the researcher using the Hamamatsu scanner).

To access Westminster Path XL, UoW students used their own university login. The students from other institutions were issues with a username and a password which expired after the completion of the study. Students were only able to see the content created and organised for the purpose of this study. In Appendix 8, there are images of the viewer and assessment mode for Westminster Path XL.

6.6. Ethics and Health and Safety considerations

Consent form for the use of the glass slides was approved by ICNHST Tissue Bank in March 2013 to access any archive material for a period of five years once the study was approved (project R12125), the approval was further extended until the 31 March 2019. The practical element of the study finished in October 2018 and the renewed approval was not sought.

An application for consideration of research ethics approval has been submitted to the Faculty of Sciences and Technology - Research and Ethics Committee with the reference ETH1617-0175 in November 2016 and has been approved for the research for the duration of the Professional Doctorate. The application included the PIS was given to each student at the start of the study (see Appendix 1).

The VM software to be used for the current study was supported by the UoW – Westminster Path XL and was available for students through password protected credentials. For students at the UoW, the credentials were the same as their username and password for other programmes at the university. For students who were not at the UoW, the weblink was be provided, and the username and password were in line with the university policy for guest login details at the time of the study.

All the data collected from students has been stored by the principal researcher on the university computer. The records will be destroyed in accordance with the Data Protection Act (2018) and GDPR (2018) as per UoW policies.

All other costs for the project were funded by the principal researcher, a breakdown of most expenses will be available Appendix 18 for interest only.

Health and Safety considerations for the study were minimal and followed good laboratory practices guidelines regarding the use of microscopes and glass slides. Students in the cohort having the microscopy sessions had an induction to the use of a microscope and glass slide during the first practical session. The facilities used for the practical sessions are the Universities facilities at UoW and LMetU and the multi-header rooms for teaching at ICNHST at Charing Cross Hospital. All these three laboratories/sites had guidelines in the form of risk assessments and Standard Operating Procedures for the use of the spaces that students needed to observe.

This chapter described the methodology, underpinning of the study design and the detailed methods approach for the study.

The next chapter describes the pilot study that allowed the researcher to deliver the study to a group of students in a smaller scale, including a control group and understand in practice the delivery of psychometric tasks and the delivery of the sessions.

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7. Pilot study

This chapter describes the pilot study delivery including the delivery of the psychometric tasks, quiz students result and the outcome of the feedback questionnaire. Also, there is a review of few student profiles and a discussion on how the pilot study will be used to address shortfalls in the intervention study.

7.1. Recruitment and sessions delivery

The recruitment session was performed once at the UoW at the beginning of a tutorial session in February 2016 to all students on the second year of the undergraduate degree in Biomedical Sciences and was performed twice at ICNHST: a session at Charing Cross Hospital and another at Hammersmith Hospital to all Band 4 in the Histology department. Six students from the UoW and seven students from ICNHST were recruited, a total of thirteen individuals: five males and eight females, and the average age of the cohort was 27 years old. There was a 22% uptake for the study considering the total sample available to participate.

Students completed the psychometric tasks and were allocated a learning group: group A – tutorial and microscopy, group B – tutorial and Westminster Path XL, group C – tutorial only. Group C was a control group introduced in the pilot, these students only had tutorials sessions and no engagement with slides or technology until the assessment. The observations and findings from this group allowed the researcher to understand if any of the intervention would be significant to the student's experience and learning outcome. In the UK context, all Universities have a practical component, so this is not the practice. In remote areas, tutorial sessions may be the only learning practice so a practical session and assessment may not exist.

The delivery of the tutorial sessions and the assessment quiz for the pilot study followed a different pathway than the intervention due to time constraints (Figure 6.3); however, it still allowed the researcher to understand the most effective delivery approach and the most effective quiz method.

7.2. Tasks results

Students completed the initial tasks in a pre-booked session with the researcher and were allocated to an intervention group once all students completed the tasks, five individuals were assigned to group A (tutorial and microscopy), four individuals assigned to group B (tutorial and Westminster Path XL) and four individuals assigned to group C (tutorial only) as listed in Table 7.1. The group allocation was based on their processing style only: featural vs global, so in each group, there were students with heterogeneous processing styles. Group C had students from ICNHST only.

The delivery of the tasks was conducted following the guidelines described previous chapters: enabling environment, space, and time allocation to complete the tasks for each student. The students were at ease while the tasks were being delivered and, as appropriate the students asked clarification questions about the study during the session (see Appendix 10 for psychometric task results). All students completed all tasks prior to the start of the tutorial sessions.

One student (LUJO) in group A dropped out from the study due to long term illness on week 2, which is not included in the results, the attrition rate was 8%. This individual is not being considered henceforth for the purposes of the analysis of the results. This student was not available to provide feedback.

Table 7.1 – Group allocation of students for the pilot study performed in 2016.

Group A **Tutorial and microscopy**	**Group B** **Tutorial and Westminster Path XL**	**Group C** **Tutorial only**
RASM	SAPA	IQBI
JOAN	SABO	BECH
AYKE	RESA	JAVA
VIUJ	MOKA	JETA
(LUJO)*		

* Student that dropped out of the pilot study on week 2

According to the stress levels task, the psychometric task questionnaire revealed that students' stress levels was relatively low, and the median was 12 out of 40. Students in group C demonstrated higher stress levels - 13.75 than students in groups A and B, 11.25 and 11, respectively (Figure 7.1).

The results from the motivation psychometric task questionnaire demonstrated that students' motivation to participate in the study was variable, and the median was 151 out of 175. Students in group C and B had values of 140.74 and 141.75, respectively, these students were less motivated than students in group A with a value of 154. The results are demonstrated on in Figure 7.1.

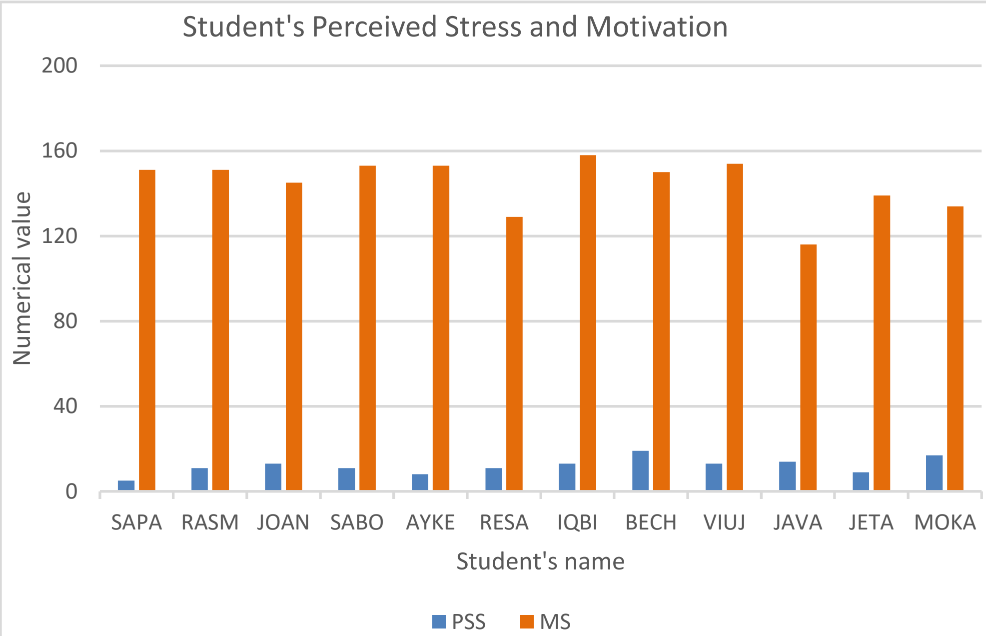

Figure 7.1 – Result from the PSS in blue and the Motivation scale (MS) in orange for each of the students that participated the pilot study.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the numerical value each student achieved. PSS maximum value is 20 and MS maximum value is 175.

Learners' processing style is demonstrated in Figure 7.2, the results for the processing style have taken account of the RO task and the Navon task. Students were distributed according to their predominant processing style – featural versus global: three students learning style were predominantly global, and no student was completely featural, but five students processed learning in a featural manner. The three students with predominantly global processing style were distributed in different groups, and the five students with featural processing style were also distributed in different groups. The remaining of the five students were assigned a group based on gender to ensure gender parity. There were less males than females in the study, including the student that dropped out. All students that had a predominantly global style were from ICNHT.

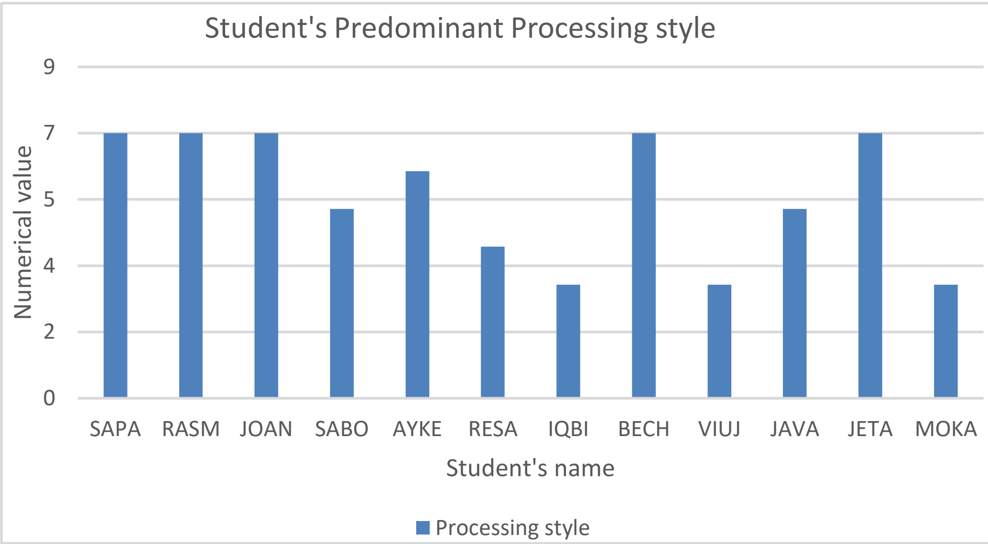

Figure 7.2 – Reveals the predominant processing style for each participant at the beginning of the pilot study.

The x axis variable is the name of all the students that participated in the study and the y axis variable determines the processing style for each student. A score meaning between 3 and 5 reveals a global processing style, the value 6 reveals a mixed processing style and a score between 7 and 9 reveals a featural processing style.

Considering the working memory of students using the digit span task, 75% of students fell within the average category, and 25% of students fell above the average notwithstanding when looking at the LNS the results were quite low (Figure 7.3), the digit span scaled score was 8 and the LNS result was 11.

Considering the TMT and that difficulty increased in TMTB and measuring similar functions in the context of this study, two students maintained their sealed scores, four students performed better in TMTA than in TMTB and six students (50%) performed better in TMTB than in TMTA which is (Figure 7.4).

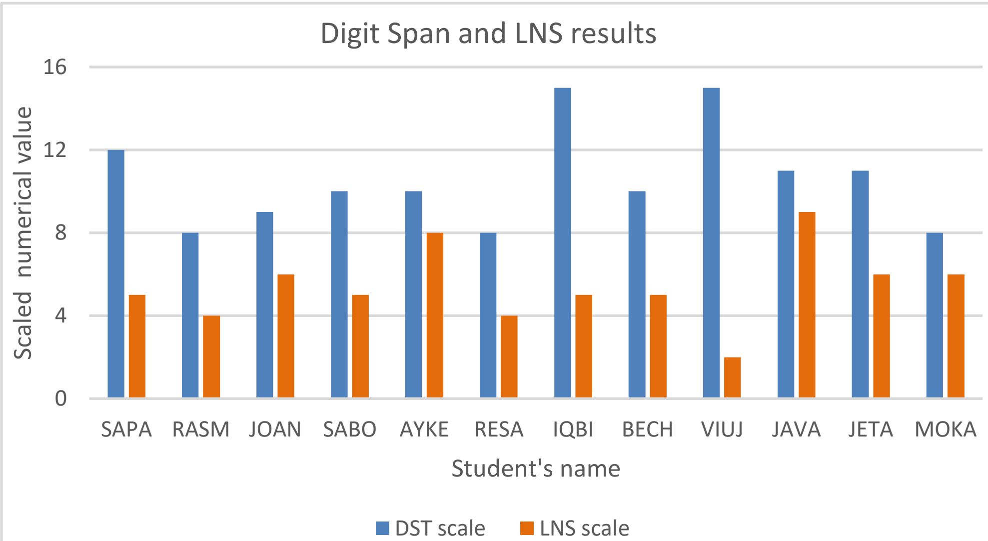

Figure 7.3 – Digit span (blue) and (orange) results for the pilot students, scaled scores average is 8 and 11 respectively, the maximum score is 16.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the scaled numerical value each student achieved for the digit span and the LNS tasks.

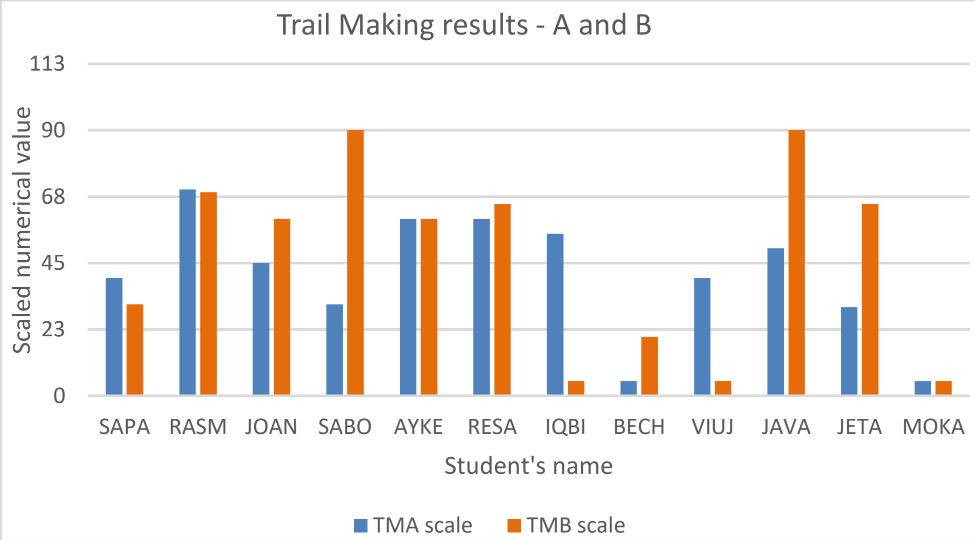

Figure 7.4 – TMTA (blue) and TMTB (orange) results for students in the pilot study.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the scaled numerical value each student achieved for the TMTA and TMTB.

7.3. Assessment of results

The pilot study started on the 11 March 2016 with one session where normal skin and colon were thought and two subsequent sessions, one on malignancies of the skin and the other on the malignancies of the colon. The summative assessment was completed on the 20 April 2016 (see Appendix 11 for students' assessment results). The students' attendance at all three sessions was 86%, and twelve students completed the practical assessment, which is a 100% assessment completion rate. Considering thirteen students started the study, the completion rate of the quiz was 92% and the attrition rate was 8% (one student).

Students were able to identify the tissue type in 90% of cases and eight students – 67% - were able to identify all slides and all images in the assessment. Students were able to discriminate between benign and malignant lesions in 60% of the cases.

Justification of their choices was variable and overall poor; no student was awarded 3 points in any slide set.

The pass rate was determined at 40% or 20 out of 50. Two students failed the assessment, they were able to identify the tissue but not the justify their choices, one student in group A and one student in group C. The remaining ten students – 83% passed the assessment, all students in group B passed the assessment.

The overall average score for the assessment was 26 out of 50, in group A the average was 28, in group B it was 27, and in group C it was 25. The individual student scores are demonstrated in Figure 7.5.

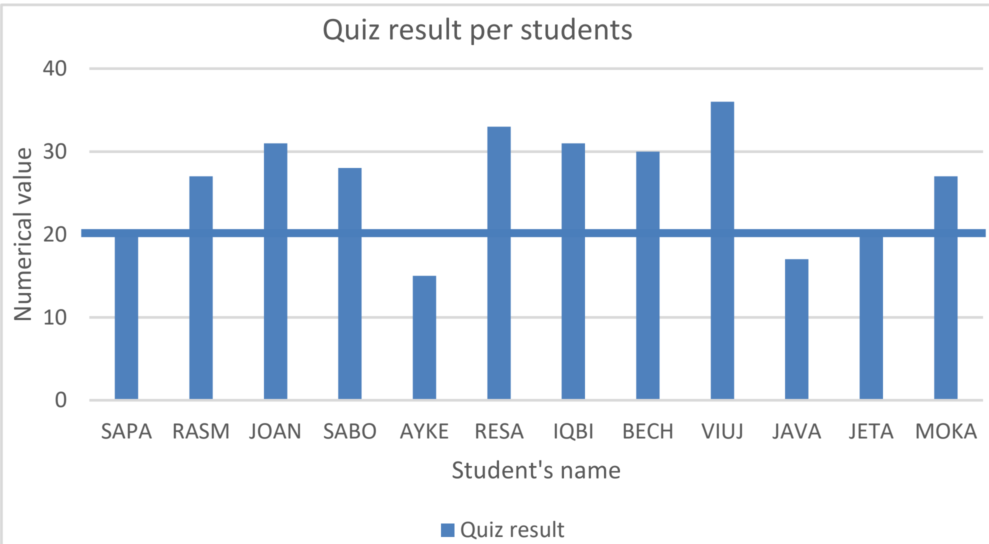

Figure 7.5 – Students' results for the quiz, the pass mark is 20 out of 50.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the quiz result each student obtained.

7.3.1. Normality test

The normality test for the pilot study using Shapiro-Wilk test demonstrates that the Sig. value is greater than 0.05, hence the data is normally distributed (Table 7.2). For the Kolmogorov-Smirnov test it is not possible determine the Sig. value as the sample if small. Parametric testing should be used to analyze the data.

Table 7.2 – Normality testing for the sample of 12 students.

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
A	.239	4	.	.947	4	.696
B	.250	4	.	.963	4	.798
C	.282	4	.	.855	4	.242

7.3.2. Parametric testing

An One-Way ANOVA was performed with the results of the quiz considering the three groups of students and the results demonstrated that the significance value is 0.842 therefore there is no statistical difference between the groups (Table 7.3).

Table 7.3 – One-Way ANOVA test results for quiz results.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18.500	2	9.250	.175	.842
Within Groups	475.750	9	52.861		
Total	494.250	11			

The range for group A was 21, group B was 13 and group C was 14. The results for group B and C were closer to the median and group A had the highest range of results. Group A has the higher median value (mean, Table 7.4, Figure 7.6).

Table 7.4 – Descriptive analysis of the pilot study sample.

					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Min**	**Max**
A	4	27.25	8.96	4.48	13.00	41.50	15.00	36.00
B	4	27.00	5.35	2.68	18.48	35.52	20.00	33.00
C	4	24.50	7.05	3.52	13.29	35.71	17.00	31.00
Total	12	26.25	6.70	1.94	21.99	30.51	15.00	36.00

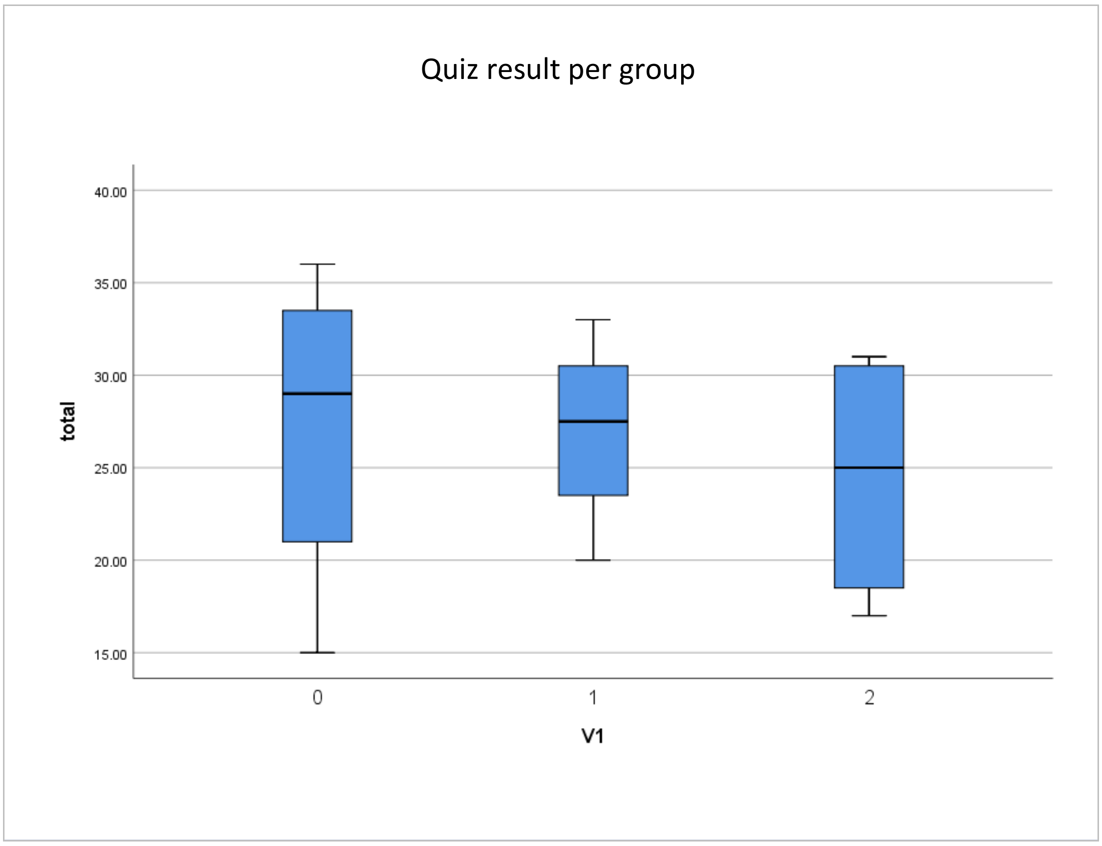

Figure 7.6 – This boxplot shows the median score of every group (thick horizontal bar) along with the $25^{th}/75^{th}$ percentile and minimum/maximum score.

The pass mark is 20. The columns are represented as 0, 1 and 2 which are groups A, B and C respectively.

7.3.3. Non-parametric testing

The normality testing demonstrated that the data is normally distributed; however, as this is a small sample, the researcher considered non-parametric K independent samples testing. The results of the Kruskal-Wallis confirmed that there is no statistical difference between the groups as the *p* value of the sample is 0.873 (Table 7.5).

Table 7.5 – Kruskal-Wallis test results.

	Total
Kruskal-Wallis H	.272
df	2
Asymp. Sig.	.873

An independent-samples median test suggested that there was no difference between the group medians as demonstrated in Table 7.3. The mean and median for group A was 27.25, group B was 27. and group C was 24.5 (Table 7.3 and Figure 7.6).

When comparing the performance of students looking at microscopy slides or Westminster Path XL images, the differences were non-significant median differences; however, there were some cases worth mentioning described in section 7.5.

One student in group A (AYKE) and a student in group C (JAVA) performed twice as better when looking at a glass slide under the microscopes compared to the use of Westminster Path XL; however, both these students failed the assessments. On the other hand, a student in group B (MOKA) and a student in group C (BECH) performed nearly twice as better when looking at Westminster Path XL compared to a glass slide, and one student in group C (IQBI) performed marginally better when looking at a glass slide compared with Westminster Path XL (Figure 7.7).

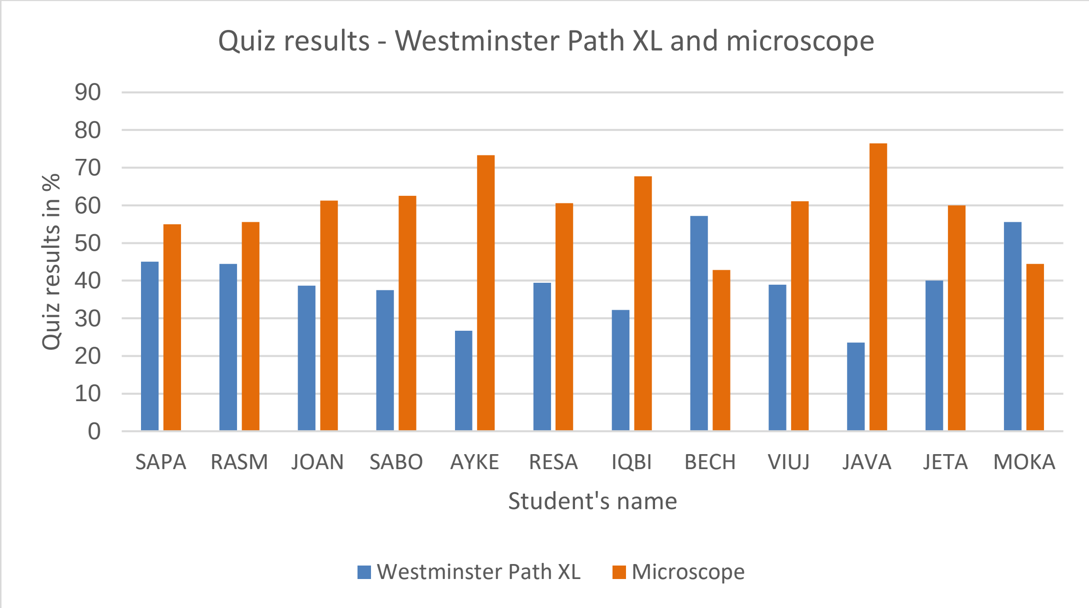

Figure 7.7 – Students' quiz results for Westminster Path XL images (blue) and microscope and glass slide (orange) in percentages (%).

The x axis variable is the name of all the students that participated in the study and the y axis variable is the quiz result in percentages for each of each assessment method for each student.

Considering the overall performance of students per group against the overall score for the glass slide and Westminster Path XL in Figure 7.8, all students performed marginally better with microscopy and glass slide than with Westminster Path XL. Group A and B results with microscopy and glass slide were 58% and 55% respectively and with Westminster Path XL, group A had 55% and group B had 52%. Group C performed equally with microscope and glass slide and Westminster Path XL (48%). The assessment method did not seem to be a factor in students' performance and overall grade, and this was not statistically significant (p=0.681, Table 7.6).

Table 7.6 – One-Way ANOVA test results for quiz results between Westminster Path XL images (blue) and microscope and glass slide.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	126.562	8	15.820	.728	.681
Within Groups	65.167	3	21.722		
Total	191.729	11			

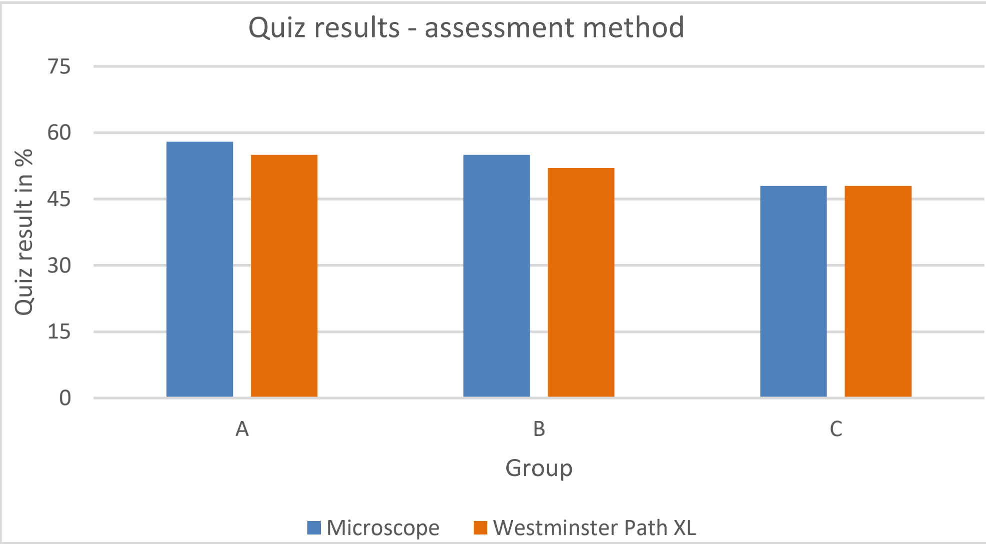

Figure 7.8 – Group quiz results by using microscope and glass slide (blue) and Westminster Path XL (orange) in percentages.

The x axis variable is the groups in the study and the y axis variable is the quiz result in percentages for each of each assessment method for each group.

7.4. Questionnaire results

All twelve students in the pilot study were invited to complete a questionnaire and seven students, this is 58% of students completed the questionnaire. One student was part of group A (AYKE), three students were part of group B (SABO, RESA, MOKA) and three students were part of group C (BECH, JAVA, JETA).

Of the responding students, 43% considered the overall training excellent (question 21) and that their knowledge increase was excellent (question 20); 57% of the respondents considered the training and their knowledge increase satisfactory. None of the students identified the training as poor or unsatisfactory nor the knowledge increase as poor or unsatisfactory (Figure 7.10). However, 14% of students strongly disagreed that the allocation time for training was sufficient (question 11) and 14% of students strongly disagreed that the course duration was right (question 12) (Figure7.9).

On the other hand, 100% of students agreed the objectives were met (question 7), 71% of students strongly agreed that the topics covered were relevant (question 3) and 71% of students strongly agreed that the trainer was knowledgeable about the training topics (question 7) (Figure 7.9).

Considering the answers provided for questions 1 to 14, question 11 and 12 had a strongly disagree respondent, the questions were related to the time allocated for the training and the duration of the course (Figure 7.9). One student in group A felt that enough time was not spent looking at the slides. One student in group B did not like the look and feel of the module (see Appendix 12). This will be addressed in the discussion and for the intervention study.

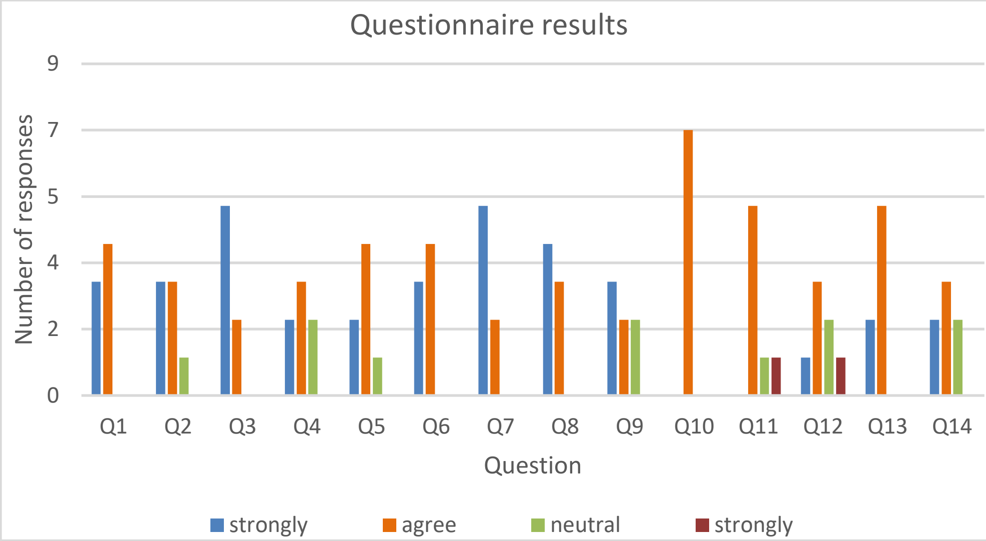

Figure 7.9 – Questionnaire results for questions 1 to 14.

The x axis variable is the question, and the y axis variable is the number of responses for each question.

Most students answered questions 15 to 19 regardless of the group allocation, except JETA who did not reply to any in these groups. One student (SABO) disagreed that there was enough time to look at the slides and the same student did not like the look and feel of Westminster Path XL. This student provided most in depth replies in questions 22 to 24.

All students would recommend the training to peers, and they considered the training overall was satisfactory/excellent, no further comments were added to the later questions to justify their choices.

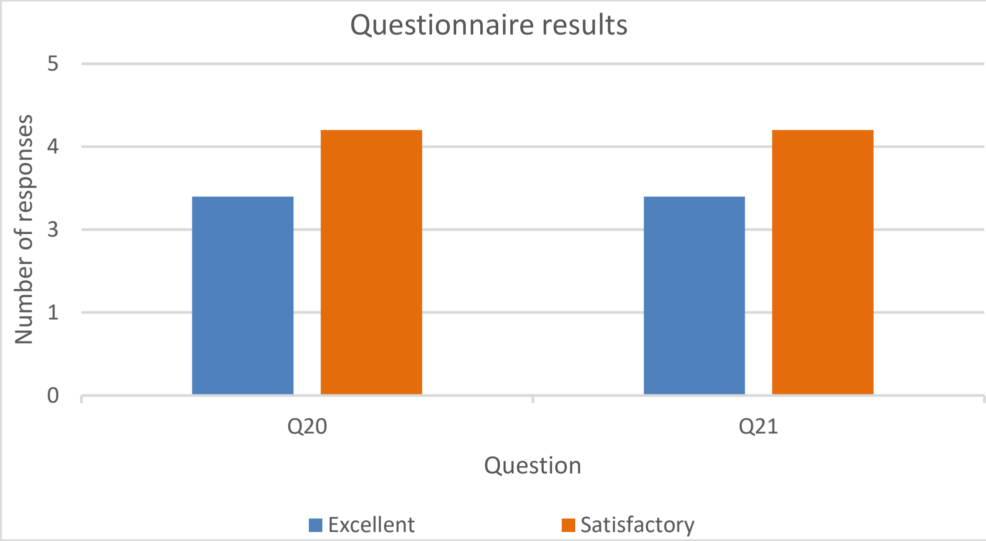

Figure 7.10 – Questionnaire results for questions 20 and 21 – overall training.

The x axis variable is the question, and the y axis variable is the number of responses for each question.

Considering the themes that arose from questions 22, 23 and 24, there were multiple topics raised by the students: 43% of students would prefer split sessions, 29% of the students would prefer longer lectures and 29% of the students agreed that Westminster Path XL gave them more freedom to learn. One student commented that Westminster Path XL was less straining to the eye - 14% (see Appendix 12).

7.5. Psychometric tasks correlations and Student profile

The study has been designed to analyse and describe the overall impact of the intervention on student outcome and to understand the role of processing style and working memory. However, as part of the discussions it may be useful to consider individual student profiles that include the results of the psychometric tasks and student outcome and understand any individual differences. Reviewing these enable the researcher to assess whether other variables needed to be considered and how these students performed against the average and each other. Table 7.7 highlights the profile of four students and their respective assessment results; these are for the top two students that had higher assessment marks and the two that had the lowest assessment marks.

Table 7.7 – Summary of four student profiles and the assessment scores.

	PS	MSS	Processing style	DS	LNS	Group	Assessment score
VIJU	13	154	Global	15	2	A	36
REZA	11	129	Global	8	4	B	30
JAVA	14	116	Global	11	9	C	17
AYKE	8	153	Featural	10	8	A	15

Students with higher assessment scores and the lowest assessment scores.

The Pearson product-moment for perceived stress score and quiz one is r=0.462 and *p*=0.131 (Table 7.8) and the Pearson product-moment for motivation and quiz one is r=0.269 and *p*=0.397 (Table 7.9), the correlations for both tests were not statistically significant. There is no correlation between quiz one and stress nor between quiz one and motivation (students VIJU and AYKE).

Table 7.8 – Correlation between quiz results and PSS.

		PSS	Quiz one
PSS	**Pearson Correlation**	1	.462
	Sig. (2-tailed)		.131
	N	12	12
Quiz one	**Pearson Correlation**	.462	1
	Sig. (2-tailed)	.131	
	N	12	12

Correlation is significant at the 0.01 level (2-tailed).

Table 7.9 – Correlation between quiz results and motivation.

		Quiz one	Motivation
Quiz one	**Pearson Correlation**	1	.269
	Sig. (2-tailed)		.397
	N	12	12
Motivation	**Pearson Correlation**	.269	1
	Sig. (2-tailed)	.397	
	N	12	12

Correlation is significant at the 0.01 level (2-tailed).

Considering Table 7.10, no statistical differences were found between the score and each of the tasks, therefore, none could be used as a predictor factor for student success (n=12, p=0.001). For example, one of the top-scoring students (REZA, group B) demonstrated stress levels slightly below the average and moderate motivation levels, the digit span results were lower than the average and students performed well. On the other hand, student JAVA had moderate stress levels and low motivation, the student was in group C (tutorial session only), and this was one of the two students that failed the assessment. Could it have been incidental or if the student was in one of the other groups (A or B), the assessment outcome would be different.

Table 7.10 – Summary table with the results for the Pearson correlation and Sig. (2 tailed) for processing style, working memory, group allocation and Quiz one.

n=12, *p*=0.001	**Pearson correlation (r)**	**Sig. (2 tailed)**
Group and Quiz one	-0.175	0.587
Group and Proc. Style	-0.319	0.312
Proc. Style and Quiz one	-0.522	0.081
Group and TMTA	-0.388	0.213
TMTA and Quiz one	-0.116	0.72
Group and TMTB	-0.046	0.886
TMTB and Quiz one	-0.43	0.163
Group and DST	0.219	0.493
DST and Quiz one	0.13	0.688
Group and LNS	0.291	0.359
LNS and Quiz one	-0.801*	0.002

* Correlation is significant at the 0.01 level (2-tailed).

Negative values have the (-) for negative correlation, the other values are positive correlations. The closer to 0 the weaker correlation, the near to -1/1 the negative/positive correlation.

7.6. Discussion

Considering this was an additional workload for students at the university and an additional activity staff completed outside working hours, the uptake was not unenthusiastic, and the attrition rate was below the predicted value and unsurprising, motivation was high, and dropout was explained by ill-health of the student who was unable to continue.

The uptake from the students from UoW was low, it could be suggested that the students were still completing their studies and had much learning to continue and hence taking on new commitments could cause challenges to them completing their university modules. The students in employment seemed keener to take on the additional training as this could be used as CPD and allowed them to progress further in their careers.

Motivation in this cohort of students was high as expected, the students volunteered to take part of the pilot study. Little motivation may have inhibiting outcomes for students. The stress levels demonstrated by the students in the pilot study was low.

When discussing what motivates students taking part in an additional workload, it could be inferred that this supports students in increasing their knowledge as well as engaging with technology to learn new materials.

The processing style tasks (RO and Navon tasks) revealed consistent results and these were used to allocate students to different intervention groups. The results for working memory using digit span for the students fell within the average as described in the literature. However, using LNS and the TMT, there was correlation considering the scaled scores for these tasks, this could be better explored when analysing the results of the intervention study.

To be able to make meaningful interpretations about the psychometric tasks, a larger cohort of students was required, particularly to explore the role of processing styles in learning and the role of working memory in the early intervention.

In the pilot study, technology-enhanced learning delivered outcomes with no negative effect. In a student-centered learning support environment, Westminster Path XL has the potential to replace the current labour-intensive pattern of work and is particularly suitable for a larger student cohort. In addition, Westminster Path XL is an equivalent to glass slide and microscope for delivering assessment bringing forth new strategies for student assessment.

The outcomes of the pilot study allowed the researcher to improve and adapt proactively the intervention study considering the feedback provided by the students and by the data produced, namely longer sessions (from 20-minutes to 30-minutes), the delivery and organization of the practical session and the delivery and design of the assessment method (only Westminster Path XL).

The outcome results of the control group (group C) demonstrated that any intervention was beneficial and produced better learning experience even in the slightness so, the intervention study will explore the role of different interventions only to teach tissue recognition.

Students started the study in February, and at this time, their workload was lighter. The feedback students provided informally was that when assignments were due and during exam periods students are busier with additional study periods and last-minute revisions, these periods should be avoided. During these periods, students' stress levels were higher, and that impacted on students' performance, this was a consideration taken when scheduling the intervention study.

Students also stated that, though were provided with the handouts and correct terminology, additional time was needed to allow students to internalise it and process the materials (questions 11 and 12 in Figure 7.9), in the pilot study, students were able to identify images, but the explanations provided were not worded correctly and not fully understood, the students raised this informally.

The follow-up assessments designed for the intervention study, were not performed on the pilot study, will be essential in understanding the role of short term and long-term memory in teaching and learning.

The pilot study demonstrated that there is a further need to explore the role of VM in teaching undergraduate students to understand how it affects learning and assessment and to better understand the student experience. The intervention study will allow the researcher to assess the persistence of learning over an extended period and further evaluate the impact of learning styles, stress, and motivation on outcomes.

In the pilot study, students only provided a fair amount of informal feedback after the study and this was only recorded by the researcher on the written notes with date and comment, and no student is identified. Students' interviews in the intervention study, will allow the researcher to further explore student's motivation and challenges with learning and assessment tools as well as the student experience.

Completing the pilot study, enabled the researcher to gauge the delivery of the psychometric tasks, the method and the interpretation of the data gathered considering the quantitative and qualitative methods and how these can be used in the intervention study.

The next chapter describes the intervention study and the findings from the psychometric tasks, the quiz results, questionnaire feedback, and interview findings in detail and how they related to each other.

8. Intervention study

This chapter covers the intervention the practical element of the thesis, the delivery of psychometric tasks to the recruited student, the quiz results and the findings from the questionnaire feedback and the interviews. In this chapter the findings of all the data collected will be analyzed as described in the methodology chapter to answer the hypothesis. Attrition rate and selected individual student profiles will be considered to understand student experience and student motivation.

8.1. Recruitment

The recruitment strategy included a 20-minute session delivered to students during the months of January and February 2017: two sessions delivered at UoW for two different student cohorts in the first academic year with fifty students approximately in each session, one session delivered at LMetU for students in a biomedical/ biological science degree in the second year with around thirty students in the classroom and three sessions delivered at the different sites at ICNHST: Charing Cross Hospital, Hammersmith Hospital and St. Mary's Hospital, the total number of students at ICNHST that attended the sessions was twenty staff. Students were given the email address of the researcher to request any additional clarifications and to register their interest in participating in the study. The uptake to participate in the study was 19% (twenty-eight students).

From the recruitment sessions, six students from the UoW and six students LMetU registered their interest and completed the tutorial sessions, twelve students in total.

Sixteen staff from ICNHST expressed their interest and completed the tutorial sessions. The total number of individuals participating in the study was twenty-eight students.

Some students expressed their interest in participating in the study through email and requested additional discussions face-to-face: three students from the UoW and two students from ICNHS, five students in total. However, they were not able to participate in the study due to time pressures and personal commitments, this was explored when they scheduled the session to complete the tasks and clarify the time commitment for the study. These students will not be mentioned after this point.

One student from ICNHST completed the psychometric tasks and attended two tutorial sessions, and after attending week 2 tutorial and microscopy sessions, the member of staff withdrew from the study (NIPA), the reason the student withdrew from the study was professional change in employment, the staff handed in their notice to leave ICNHST as the staff received a promotion and was no longer available to continue in the study, it was too early to complete the questionnaire and to participate in the interview, this student was in Group A. The student has not been included in any results and discussion unless required. The basis of the student allocation to group A was based on the results for TMT outcomes, the student had a high-stress level and high motivation, the processing style was global, and the digit span and LNS were good, the TMTA result was average and the TMTB was good. This student results will be not described in the results section and this student will not be referred to hereafter unless necessary to explain or discuss any detail, this student would have been the twenty-ninth student participating in the study.

Two students started on week 1 (UOAH and SAKA), and the tasks were completed after the first tutorial as they were not able to complete the tasks prior to the commencement of the tutorial sessions. Each student was allocated to group A and the other to group B. One of these students (UOAH) did not complete the study and withdrew after completing the five tutorial sessions, this student did not perform any quiz and was not available for a follow-up interview. The other student (SAKA) completed all tutorials and completed quiz one only.

8.2. Tasks results

A 30-minute time slot was scheduled between the researcher and the participant for the psychometric profile. The researcher had to book a room for the delivery of the tasks with the Universities and ICNHST, the room had to be a quiet and amenable to a discussion with proper lighting and with a table and chairs at a location agreed with the participant. For each session, the researcher welcomed the student and started with some lighter conversation about the aims of the study and personal and professional information about the researcher and the personal interest in the study followed by the structure of the study. The student introduced him/herself and provided any additional relevant information that he/she may have wanted to share with the researcher. If the student was interested in participating in the study, then the psychometric task was delivered following the sequence defined in chapter 6 (see Appendix 13 for psychometric tasks results).

The study included twenty-eight students in total, six males (21%) and twenty-two females (79%) (Figure 8.1), over three-quarters of the study population were women. The average student age was 27.9 years old, the age ranges from 19 to 47 years old, and the median age was 26 years old (Figure 8.2).

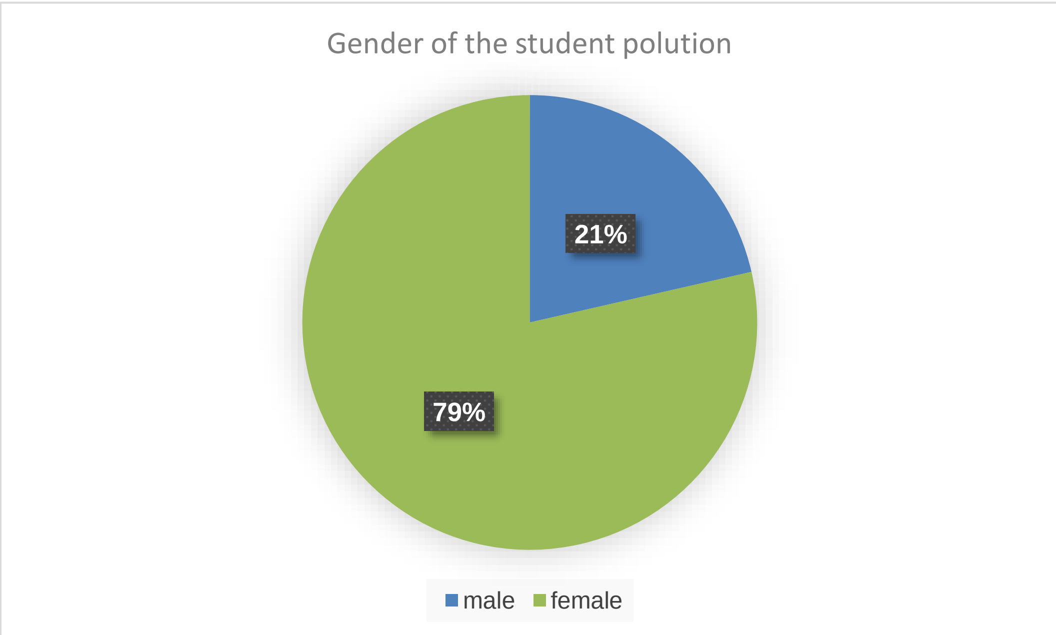

Figure 8.1 – Student population in the study considering gender.

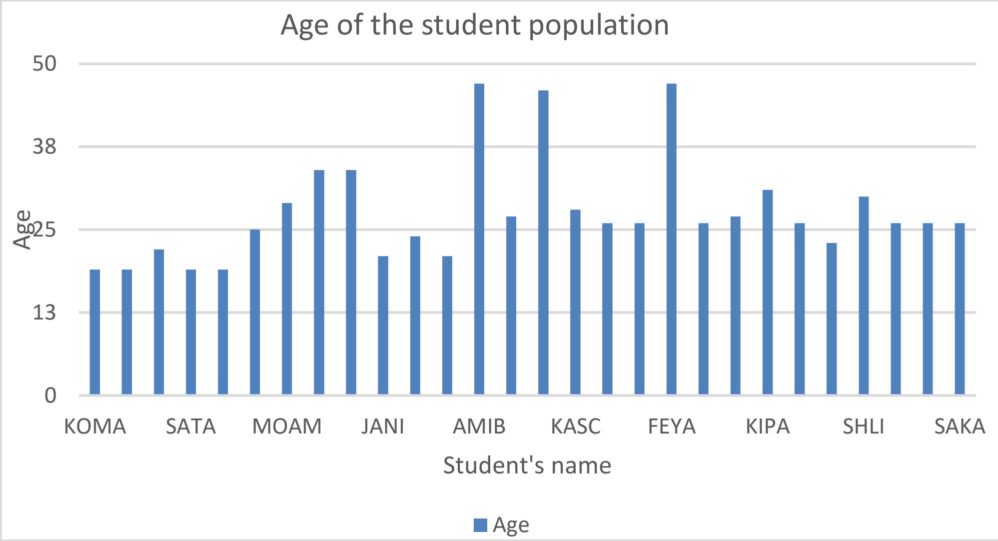

Figure 8.2 – Individual students' age participating in the study.

The average age of the students from the UoW was 20.5 years old, the average age of the students from LMetU was 27.2 years old, and the average age of the students from ICNHST was 26.2 years old. The male average age group was 28.7 years old, and the average female age was 27.4 years old. In the study group, there were no males participating from the UoW, there were three males from LMetU and three males from ICNHST.

Considering the age ranges for groups A and B, students in group A had an average age of 28.6 years old, with three males and nine females completing quiz one and group B had an average age of 27.2 years old, with three males and twelve females.

Students were allocated a group according to their processing style and their working memory, for Group A, the practical sessions delivery was glass slides using microscopy and Group B was Westminster Path XL. There were fourteen students in Group A, three males and ten females and fifteen students in Group B, three males and twelve females. The average group age for group A was 29 years old, and group B was 27 years old.

The median for the stress questionnaire reveals that the students stress levels were 19 out of 40 (moderate) and motivation to participate in the study 139 out of 175 (high). The group A median for stress levels was 20 and for motivation was 142 and, for Group B, the median for stress levels was 19 and for motivation was 137 (see Appendix 13). The results obtained by the Motivation task are considered moderate for each group and overall and the stress task is considered high for each group and overall. The results of these tasks are provided in Figure 8.3.

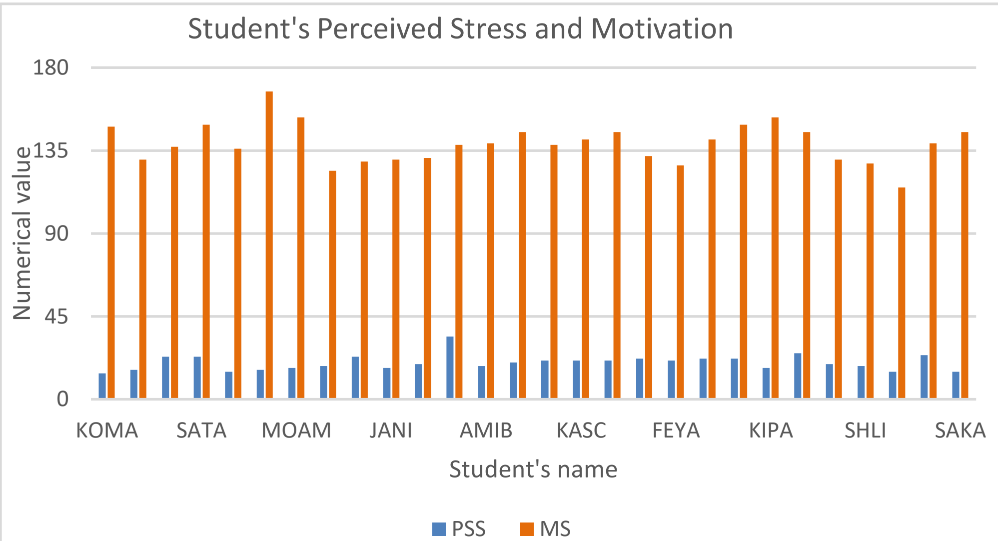

Figure 8.3 – Result from the PSS in blue and the Motivation scale (MS) in orange for each of the students that participated the study.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the numerical value each student achieved. PSS maximum value is 20 and MS maximum value is 175.

Students completed the initial tasks and were allocated to an intervention group based on the task outcomes (Table 8.1). As required, gender parity was also included as a feature for group allocation.

Table 8.1 – Group allocation of students in the intervention study based on task outcomes.

Group A **Tutorial and microscopy**		**Group B** **Tutorial and Westminster Path XL**	
SATA	SAAK	KOMA	GAWI
SAAR	HAKH	MOMU	MOAM
JANI	UOAH	PHWH	AYDA
LUJO	JOFE	AMIB	QASA
FEYA	KIPA	KASC	RUMI
FAMO	LIBA	SIKU	OSPE
SAKA	(NIPA)*	PASA	SHLI
		NAJA	

* Student dropped out on week 2

Learners were distributed heterogeneously in each group according to their processing style and their working memory, each group had a balance of students considering the preferred patterns for the RO and Navon task for processing style, and digit span and LNS scaled scores (Figures 8.4, 8.5, 8.6 and 8.7).

Figure 8.4 demonstrates the results for the processing style tasks: the RO copy, draw from memory and recall memory and the Navon Task. In Figure 8.5, the RO task was reviewed and presented as one processing style, considering the averaged results obtained in each of the tasks.

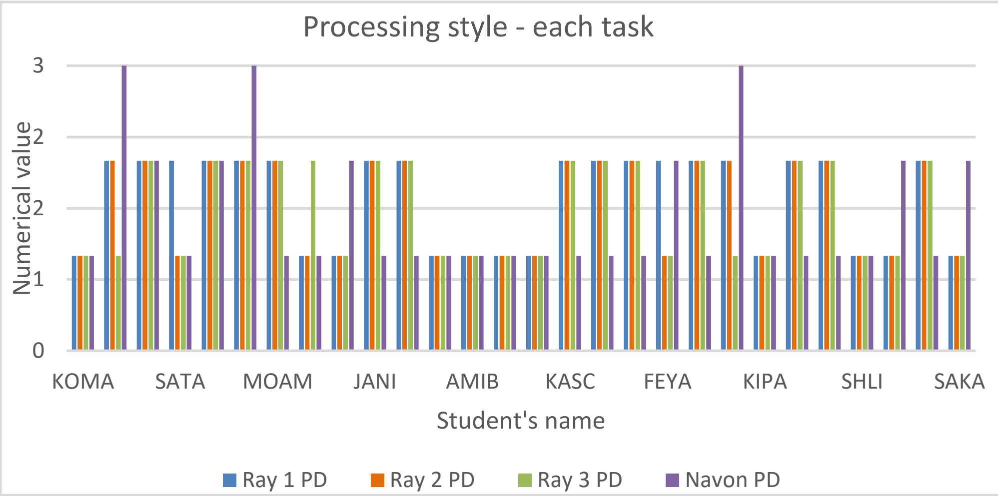

Figure 8.4 – Reveals the predominant processing style for each participant at the beginning of the study for each of the tasks – RO copy (blue), memory (orange) and delay (green) and Navon Task (purple).

The x axis variable is the name of all the students that participated in the study and the y axis variable determines the processing style for each student. A score of 1 reveals a global processing style, 2 reveals a featural processing style and 3 reveals a mixed processing style.

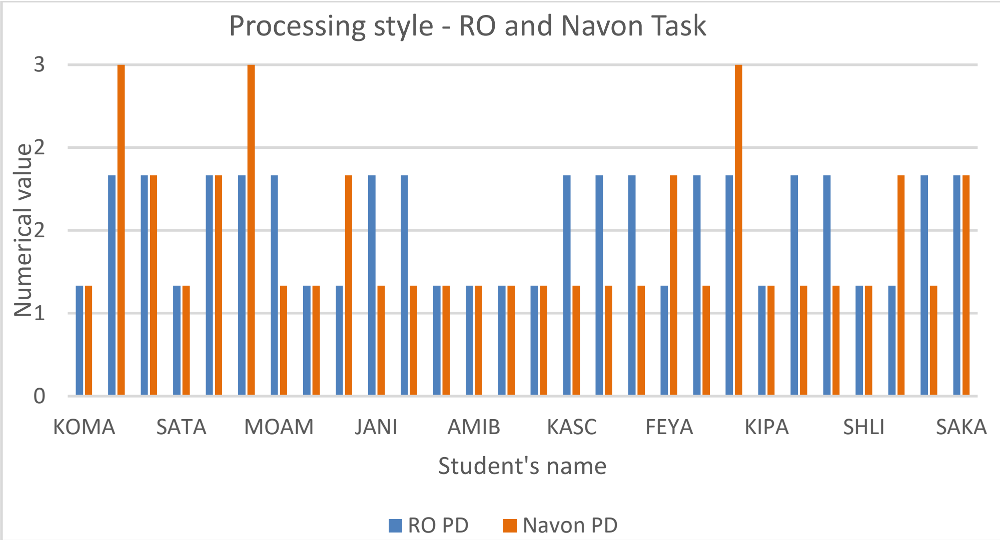

Figure 8.5 – Reveals the predominant processing style for each participant at the beginning of the study for RO task (average, blue) and Navon task (orange).

The x axis variable is the name of all the students that participated in the study and the y axis variable determines the processing style for each student. A score of 1 reveals a global processing style, 2 reveals a featural processing style and 3 reveals a mixed processing style.

Two students had a completely featural style (MOMU and SAAK) and eight students had a predominant global processing style (KOMA, SATA, PHWH, AMIB, QASA, LUJO, KIPA and SHLI), the other sixteen students had a featural processing style with three of them revealing a mixed pattern for the Navon task (GAWI, SAAR and OSPE). For the two featural students and the eight predominantly global students group allocation was easily determined: SAAK, SATA, LUJO and KIPA were allocated in group A and MOMU, KOMA, PHWH, AMIB, QASA and SHLI were allocated in group B (Figure 8.5).

The three students that had a mixed pattern were allocated a group alternately starting with Group B – tutorial and Westminster Path XL (GAWI and OSPE); SAAR was allocated group A (Table 8.1). On completing this first allocation based on the processing style, all the students from UoW had been allocated a group. There were five students in group A and eight students in group B which was not significant as the processing style was one of the main characteristics that were to be assessed in the approach with VM.

There were four students from UoW, the two featural were allocated separate groups and the other two were randomly allocated group A and B. One student was from LMetU and allocated group B and there were five students from ICNHST, two allocated group A and three allocated group B. Students from LMetU and ICNHST were left to be allocated.

When reviewing the working memory results (Digit Span tasks – Figure 8.6 and TMT – Figure 8.7), there were three males to be allocated (MOAM, JANI and FEYA), one was allocated to Group B and the other two for Group A as there was already one male in group B. Reviewing the digit span tasks, two students had a similar scaled score (8 – MOAM and 9 - FEYA) and the other had a slightly higher scaled score (20 - JANI). FEYA was allocated group A as also the other male student from ICNHST was allocated group B. MOAM was allocated to group B to be opposite to FEYA; JANI was also assigned group A. All male participants have been allocated.

For the remaining ten students to be allocated, the results for the working memory tasks were used: digit span and LNS and the TMT. On reviewing the scaled scores for the digit span and/or LNS task recorded as a low average there were five students, three of them had a lower score for both the digit span task and the LNS task and two only had the LNS task lower than average. Two students from ICNHST – FAMO and LIBA – were allocated to Group A and one student from LMetU (AYDA) were allocated to Group B. The two students that presented the LNS task lower than average only were from ICHNHST – KASC, SIKU – and were allocated to group B.

Considering the students from LMetU at that stage, there was one student in group A and three students in group B, the student HAKH was assigned group A to ensure parity of students considering the institution where they were coming from. At that point, all student from LMetU were allocated until the one that enrolled later. There were ten students in group A and twelve students in group B.

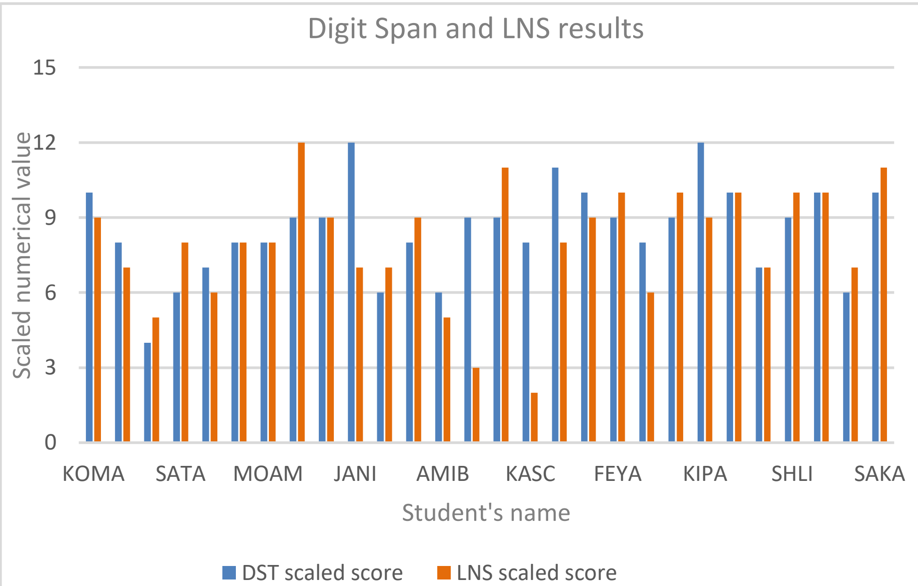

Figure 8.6 – Digit span (blue) and LNS (orange) results for each participant at the beginning of the study, the maximum score is 16.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the scaled numerical value each student achieved for the digit span and the LNS tasks.

The remaining five were allocated considering the TMT, the students with the better TMT result were allocated group A (JOFE and NIPA), and the remaining three students allocated to group B (RUMI, PASA and NAJA). On completion of the student allocation, there were twelve students in group A and fifteen students in group B.

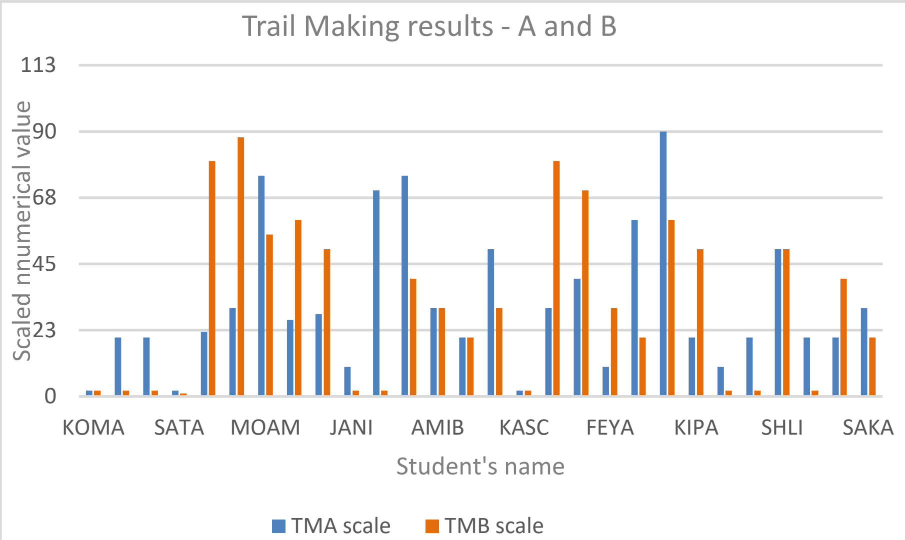

Figure 8.7 – TMTA (blue) and TMTB (orange) results for students in the pilot study.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the scaled numerical value each student achieved for the TMTA and TMTB.

The two students that completed the tasks after the session and after the original allocation was performed were allocated by gender parity and the group that had less students: UOAH and SAKA were assigned to group A (Table 8.1), bringing group A to have fourteen students and group B fifteen students.

The total number of students that completed the tasks and attended week 1 was twenty-nine students, with fourteen students in group A and fifteen students in group B. There were three students from the UoW and three students from LMetU in each group, and there were three males in each group. On week 3, there were twenty-eight students, with one student withdrawing from the study, this student was in group A, female, from ICNHST. On attendance to complete quiz one there were twenty-seven students, one student from group A did not attend quiz one, this student enrolled one week later, male, from LMetU. All these will be discussed in further detail in the following sections and the next chapter.

Creating groups as described in the methodology chapter was ideal, and this was the criteria used for the student's allocation. In practice other considerations were included as gender parity and ensuring that for each of the students' physical location there was an even number of students in group A and B as much as possible.

8.3. Sessions' delivery

The student groups were divided into four cohorts: one cohort delivered at the UoW, one cohort delivered at LMetU and two cohorts delivered at ICNHST. The aim of having several delivery sessions was to suit students' location, availability to participate in the study, also, to ensure that there were enough microscopes for students in each of the cohorts for group A.

The intervention started in February 2017 with cohort one at the UoW, and the last assessment was completed in October 2017 for the cohort from ICNHST. The students from UoW started in February 2017 and completed quiz three in May 2017, the students from LMetU started in March 2017 and completed quiz three in June 2017 and the students from ICNHST started in April 2017 and completed quiz three in October 2017, this last cohort took slightly longer to complete quiz two and three due to workload pressures.

When the five tutorial sessions were complete, the students completed the quizzes. The feedback questionnaire was sent to all twenty-eight students after the last assessment, whether they had completed the quizzes or not. In August 2018, ten students were invited to participate in a semi-structured interview, and nine students participated, one student was not available to participate due to personal commitments.

The students' attendance at all five sessions was 90%, attendance was recorded anonymously by the researcher using an informal attendance record, students did not have to sign in, this was collected for health and safety purposes and monitoring attendance informally. Students' punctuality was overall excellent. Students had the mobile number and the email of the researcher and were very prompt in communicating with the researcher if there were any issues regarding attendance, time keeping, and any other issues related to the study.

Due to university commitments (assignments and exams) and change in academic pursuit, one student (UOAH) dropped out of the study after completing all the tutorials sessions, this information was provided informally, and there was no formal withdrawing of the study, the student was invited to complete the feedback questionnaire and attend an interview, the researcher did not hear from the student again.

The completion rate for the twenty-eight students attending tutorials and completing quiz one was 96.4% and the attrition rate after completing the five tutorials was 3.6%.

8.4. Assessment of results

To understand and interpret the results obtained by the students as individuals, in groups and overall results in the assessments, the researcher has considered the research questions and has used the tools described in the methodology chapter to examine the data.

Considering twenty-seven students as sample size, all students that completed any of the quizzes, passed them, twenty-seven students passed quiz one (100%), twenty-two students (81.5%) completed quiz two and passed and seventeen (63%) students completed quiz three and passed (Table 8.2, see Appendix 14 for students' assessment results).

Three students left ICNHST for external promotions after quiz one, a further three students left ICNHST for external promotions after quiz two. These six students never withdrew formally from the study. The final pool of students that could have completed quiz three, considering the six students that dropped out due to employment reasons was twenty-one students, that was a completion rate of 78% related to the total number that completed quiz one; however, 63% of students completed quiz three, this was lower than expected. The other four students (15%) did not provide any reasoning formally or informally for dropping out of the study.

In group A, twelve students completed quiz one, ten students completed quiz two and seven students completed quiz three, in group B, fifteen students completed quiz one, twelve students completed quiz two and ten students completed quiz three (Table 8.2). There was no difference in the dropout of students when comparing group A and B.

Table 8.2 – Summary of the number of students in the study that completed the assessment, the feedback, and the interview: total number, group A and B.

	Quiz one	**Quiz two**	**Quiz three**	**Feedback**	**Interview**
Total	27 *1	22 *2	17*2	14	9
Group A	12	10	7	8	4
Group B	15	12	10	6	5

Considering 28 students, *1 – one student withdrew informally, *2 – three students withdrew informally, and two students did not provide any information.

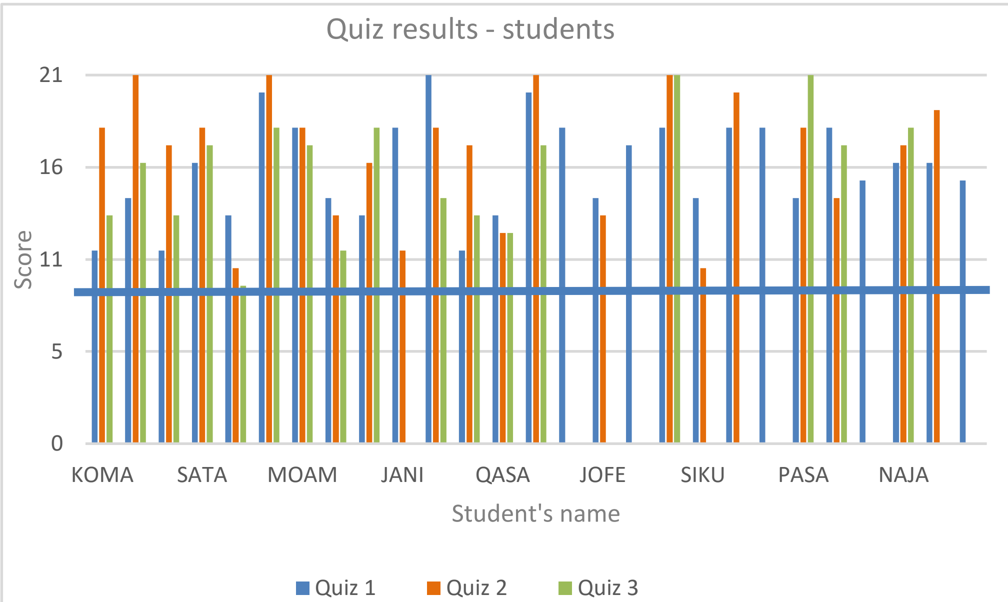

Figure 8.8 – Students' results for each of the quizzes, the pass mark is 8.4 out of 21, quiz one is in blue, quiz two in orange and quiz three in green.

The x axis variable is the name of all the students that participated in the study and the y axis variable is the quiz score each student obtained.

Figure 8.8 demonstrates the overall quiz results for each student individually, Table 8.2 provides a summary of the results overall and per group, including the number of students that completed each quiz and Figure 8.9 illustrates the quiz results for all students overall, group A and B. Reviewing Figure 8.8, all students passed all the quizzes.

The student (AYDA) that had the highest result on quiz one and the highest possible mark has progressively decreased the quiz results, this student was in group B. Two other students, one in each group, decreased their quiz results gradually: SAAK in group A and PHWH in group B.

One of the students that had the lowest result on quiz one – 11, belonged to group B (AMIB), the students improved in quiz two with 17 and then decreased on quiz three had 13. There were a few students that had a similar pattern: in group A there were the following students - SATA, SAAR and LUJO and in group B there were the following students – KOMA, GAWI and MOMU.

There were a few students that increasingly improved their results, in group A – HAKH and FEYA, the latter had 21 on quiz two and three, in group B there is PASA and NAJA, the earlier had 21 on quiz three.

On quiz one there was one student that has 21 – AYDA, in quiz two there were three students that had 21 – GAWI, SAAR and FEYA and in quiz three there were two students that had 21 – FEYA and PASA.

In quiz one, there were three students with the lowest score was 11– KOMA, MOMU and AMIB, in quiz two there were two students that had 10 – SAAK and SIKU, and in quiz three there was one student with 9 – SAAK which was still a pass for the quiz.

Reviewing the results in Table 8.3 the overall quiz results were 75% on quiz one, 79% on quiz two and 74% on quiz three, despite the consistency in the dropout of students completing the quiz – five students in Group A and five students in Group B. quiz two had the highest average score.

Table 8.3 – Summary of quiz results, overall and per group (numerically), including the number of students completing the quiz.

	Quiz one	Quiz two	Quiz three	Average
Overall results	15.7	16.5	15.6	15.9
No of students completing	27	22	17	22
Group A overall results	16.4	16.4	16.7	16.5
No of students completing	12	10	7	9.7
Group B overall results	15	16.6	14.8	15.5
No of students completing	15	12	10	12.3

Group A had higher quiz results than group B, and the quiz results improved very slightly over the period (quiz two – same and quiz three – 0.3), the quiz result average for group A was 16.5. Group B had a more fluctuating pattern (quiz two – 1.6, quiz three – -1.8), the quiz result average was 15.5 (Figure 8.9).

In quiz two there was the least variation between group A and B, Quiz one there was a 1.4 variation in average, and in quiz three there was a variation of 1.9. Group A performed better in quiz one (16.4) and three (16.7) having a higher average - 16.5 –

for the three assessments. Group B performed better in quiz two (16.6) having an average of 15.5 for the three assessments (Table 8.3).

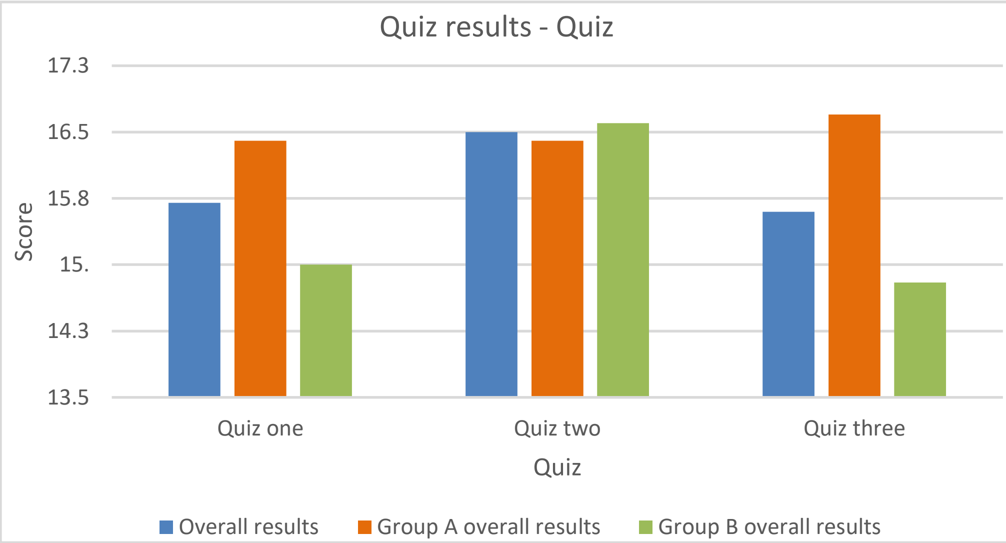

Figure 8.9 – Summary of the quiz results, overall and per group A and B, numerically.

In blue is the overall average for all students, in orange are the students in group A and in green are the students in group B. The pass mark is 8.4 out of 21. The x axis variable are the groups considered in the study and the y axis variable is the quiz score per group and per quiz.

Group A had twelve students completing quiz one (Table 8.3 and Figure 8.10), two students did not complete quiz two, and five students did not complete quiz three. The range for quiz one was 13 to 20, and the average was 16.4 with six students reaching over 17. In quiz two, the average was 16.4, and six students had 16 or over, and three students achieved 21, and the lowest score was 10. In quiz three, the average was 16.7 with seven students completing the quiz, one of the students that achieved 21 in quiz two achieved 21, and the student that scored 10 on quiz two had 9 on quiz three. All other six students had 17 points or over on quiz three. 50% of students completing quiz one achieved 14 or over in quiz two and 17 or over in quiz three.

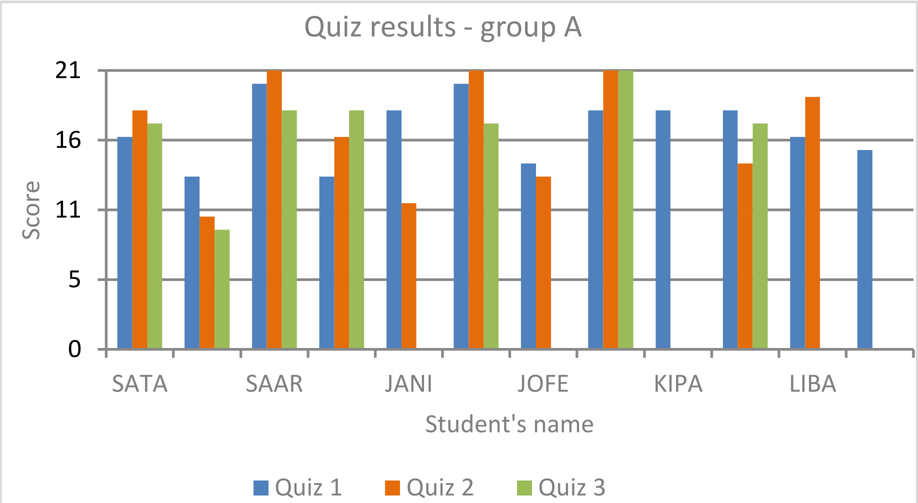

Figure 8.10 – Quiz results for the three quizzes for group A, the pass mark is 8.4 out of 21.

All students passed the quizzes, quiz one is in blue, quiz two in orange and quiz three in green. The x axis variable is the name of all the students that were in group A and the y axis variable is the quiz score each student obtained for each of the quizzes.

Group B had fifteen students completing quiz one (Figure 8.11), three students did not complete quiz two, and five students did not complete quiz three. The range for quiz one was 11 to 21, and the average was 15 with seven students reaching 15 or over, one of the students achieved 21. In quiz two, the average was 16.6, one student achieved 21, and the lowest score was 10, nine students had 17 or over. In quiz three, the average was 14.8 with ten students completing the quiz, with four students achieving 15 or above, one student had progressively increased their results since quiz one and had achieved 21 in quiz three (PASA), and one other student increased their results (NAJA) whilst most of the students achieved lower scores in quiz three than in quiz two; the lowest score was 11. The student that achieved 21 in quiz one had 14 in quiz three, which was the greater negative range.

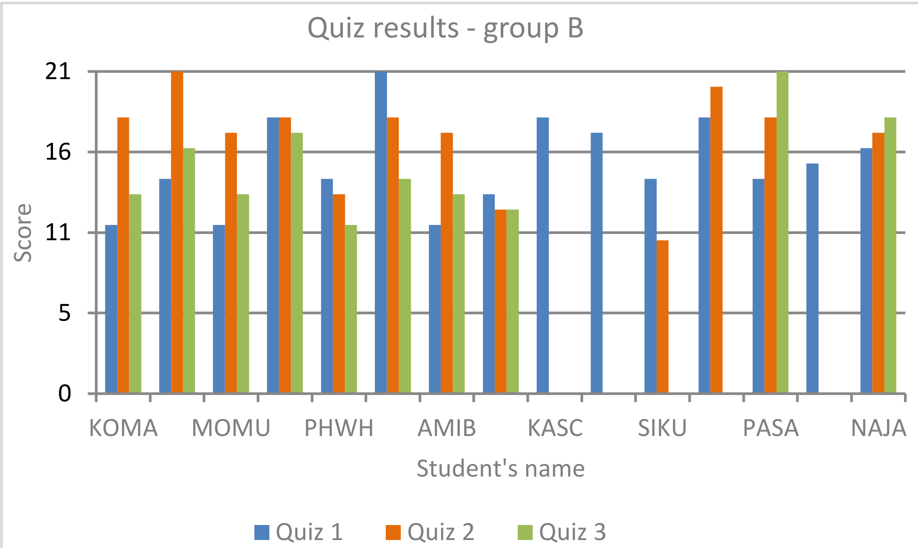

Figure 8.11 - Quiz results for the three quizzes for group B, the pass mark is 8.4 out of 21.

All students passed the quizzes, quiz one is in blue, quiz two in orange and quiz three in green. The x axis variable is the name of all the students that were in group B and the y axis variable is the quiz score each student obtained for each of the quizzes.

Students were able to identify the tissue type accurately 89% of the time, students were able to identify the condition in 78% and provide a justification in 66% respectively (Table 8.4). In quiz one the overall average results were 77%, in quiz two the students slightly improved their results to 80% and on quiz three the results were 76% (Tables 8.4 and 8.5 and Figure 8.12, 8.13, 8.14 and 8.15). When reviewing the questions independently: tissue type, condition, and justification in the quizzes, they follow the same pattern consistently, in quiz two the performance was slightly better.

Table 8.4 – Table of results, in percentages, considering the answers provided by the students overall regarding the questions asked in all the quizzes.

	Quiz one			Quiz two			Quiz three		
	Slide 1 C N	Slide 2 C M	Slide 3 S M	Slide 1 S N	Slide 2 C M	Slide 3 S M	Slide 1 C M	Slide 2 S M	Slide 3 S M
Tissue type	96	81	93	95	93	82	88	97	74
Condition	80	81.5	66.7	91	70.5	80	82	76	74
Justification	72	70	49	79	61	70	75	65	53

C – colon, S – skin, N – normal, M – malignant

When reviewing the overall results and considering the different questions, identifying the tissue type was the most constant followed by the condition, students were more challenged when identifying malignant skins conditions and providing overall justifications for their choices (Table 8.4). In quiz two, students' performance was better, followed by quiz one, and in quiz three, the results were worse (Figure 8.12).

Students could recognise better tissue type colon than skin, the condition and justify their choices was better for colon than skin (Figure 8.13). Group A performed overall better than group B (Figure 8.14), group A recognised better the colon as a tissue type, the condition, and at providing better justifications. Group A performed the same as group B in identifying the tissue type and group A was better than group B in identifying the condition and justifying their choices. (Figure 8.15).

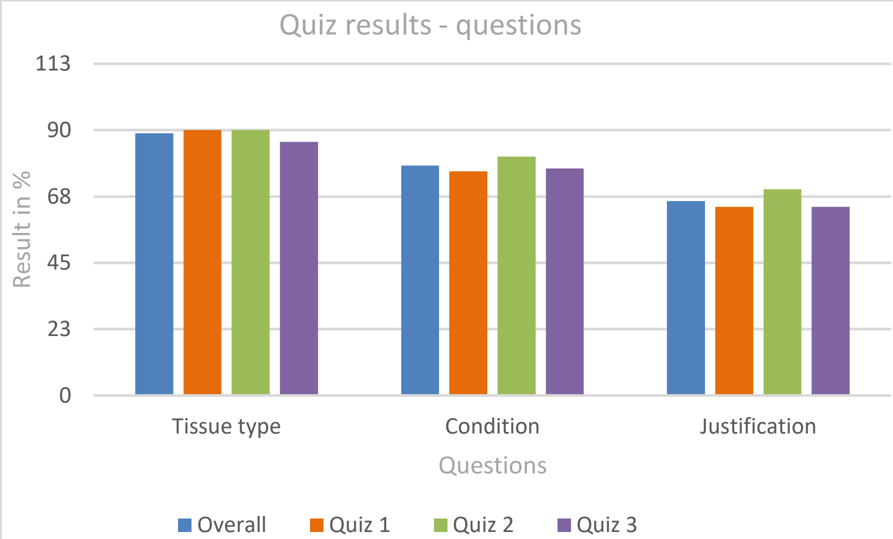

Figure 8.12 – Results of quizzes in the function of the answers, in percentages, overall and for each of the quizzes.

Overall results are in blue, quiz one in orange, quiz two in green and quiz three in purple. The x axis variable are the questions asked to students and the y axis variable is the quiz result in percentages for each of the quizzes.

Reviewing Table 8.5, group B performed overall better than group A in identifying the tissue type (question 1) across the three quizzes, quiz three, group A and B performed identically for tissue type. For question 2 (determining the condition) group A was better than group B for quiz one and three, group A and B performance in quiz two for question 2 was alike. In question 3 – justifying their choices – group A was overall better than group B, and in quiz three, group A improved their results for justification regarding the previous results.

Table 8.5 – Numerical representation of the results obtained in each question an: overall, group A and B (in percentages).

	Quiz one			Quiz two			Quiz three		
	Overall	**A**	**B**	**Overall**	**A**	**B**	**Overall**	**A**	**B**
Tissue type	90	89	92	90	88	92	86	86	87
Condition	76	82	71	80	80	81	77	81	75
Justification	64	70	59	70	70	69	64	75	57
Average	76.7	80.3	74	80	79.3	80.7	75.7	80.7	73

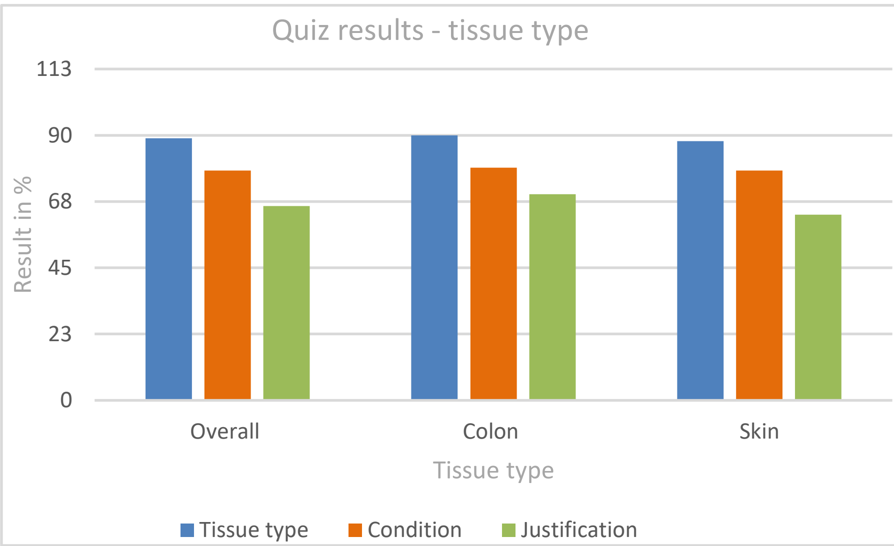

Figure 8.13 – Results of all quizzes in the function of the tissue type, in percentages, overall and for each of the questions.

Tissue type in blue, condition in orange and justification in green. The x axis variable is the tissue types, and the y axis variable are the quiz result in percentages for each of the tissue types.

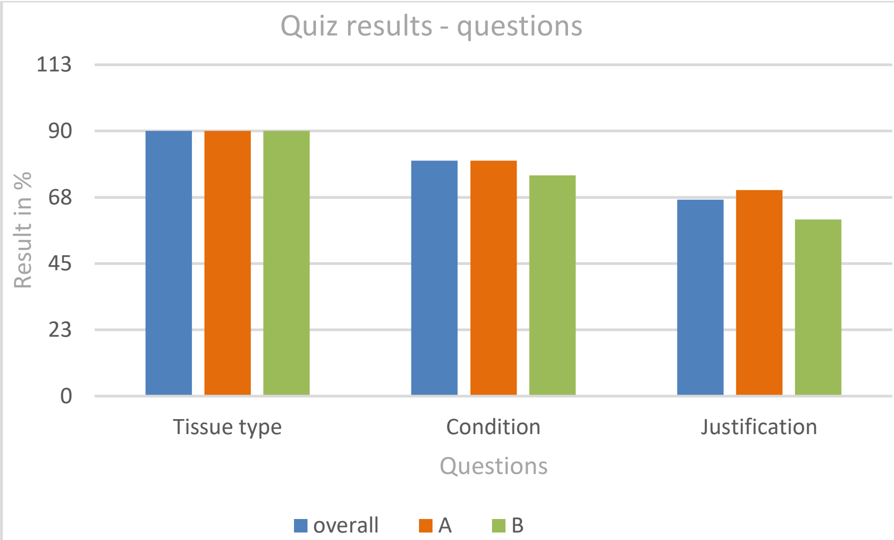

Figure 8.14 – Results of all quizzes for each group in function of the questions, in percentages.

Overall results are blue, group A in orange and group B in green. The x axis variable is the questions, and the y axis variable are the quiz result in percentages.

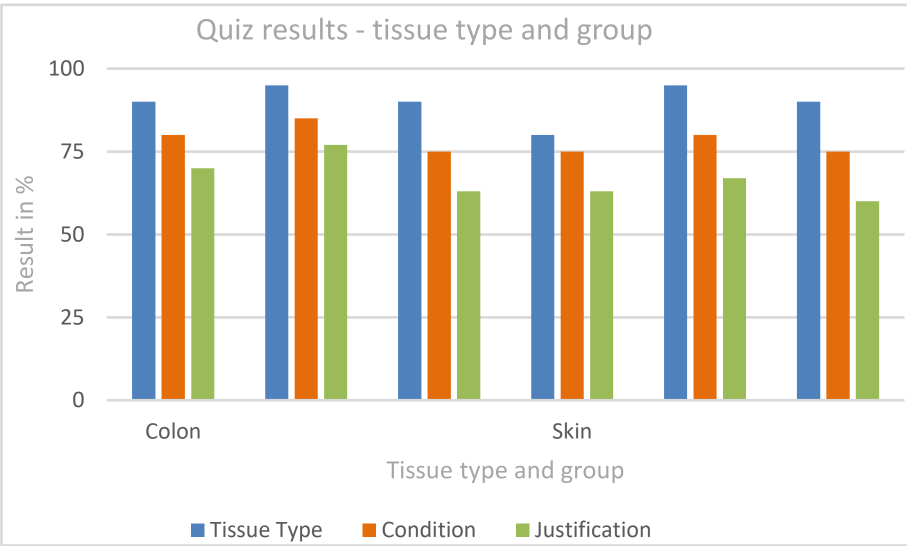

Figure 8.15 – Results of all quizzes in the function of the tissue type and group allocation, in percentages, for each of the questions.

Tissue type in blue, condition 1 in orange and justification in green. The x axis variable are the tissue types and group allocation, and the y axis variable are the quiz result in percentages for each of the tissue types.

The variation of results between quiz three and quiz one (Table 8.6, Figure 8.16, 8.17 and 8.18) demonstrated that memory seems to decay over time when identifying the tissue type (question 1), group A was marginally better than group B (Figure 28.16), there was no pattern of memory decay. Group B could determine (i.e., name) the condition much better than group A (question 2, Figure 8.17). Group A was better at articulating and using the terminology for their justifications more appropriately than group B (question 3, Figure 8.18).

Table 8.6 – Variation of results between quiz three and quiz one per question.

	Question 1	**Question 2**	**Question 3**
Overall	-4	1	0
Group A	-3	-1	4
Group B	-5	4	-1

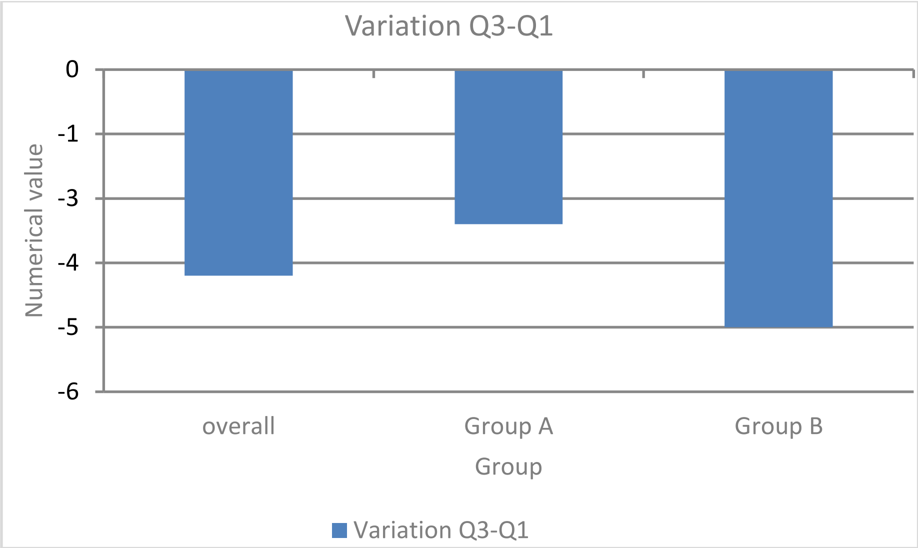

Figure 8.16 – Variation of results between quiz three and quiz one for question 1) identification of tissue type (colon or skin).

The x axis variable is the group, and the y axis variable are the difference between the quizzes result.

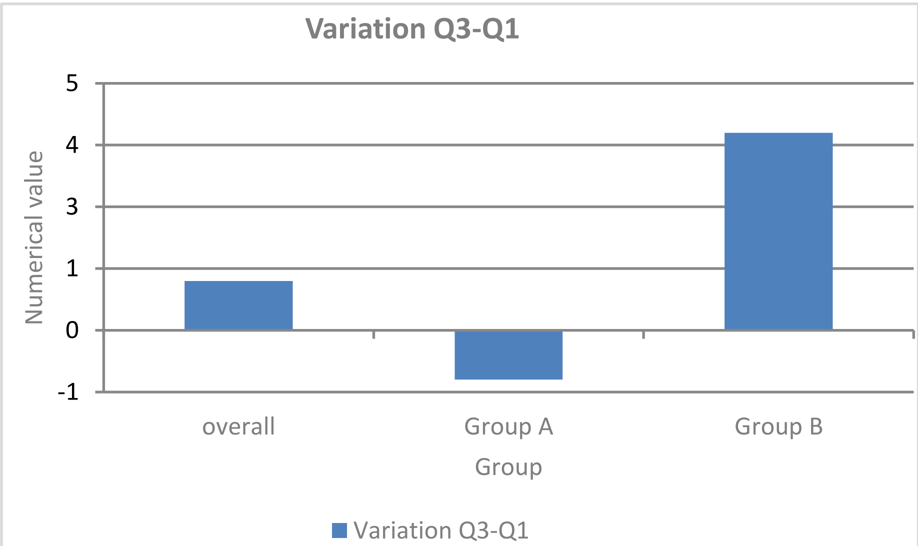

Figure 8.17 – Variation of results between quiz three and quiz one for question 2) identification of the condition (normal and malignant).

The x axis variable is the group, and the y axis variable are the difference between the quizzes result.

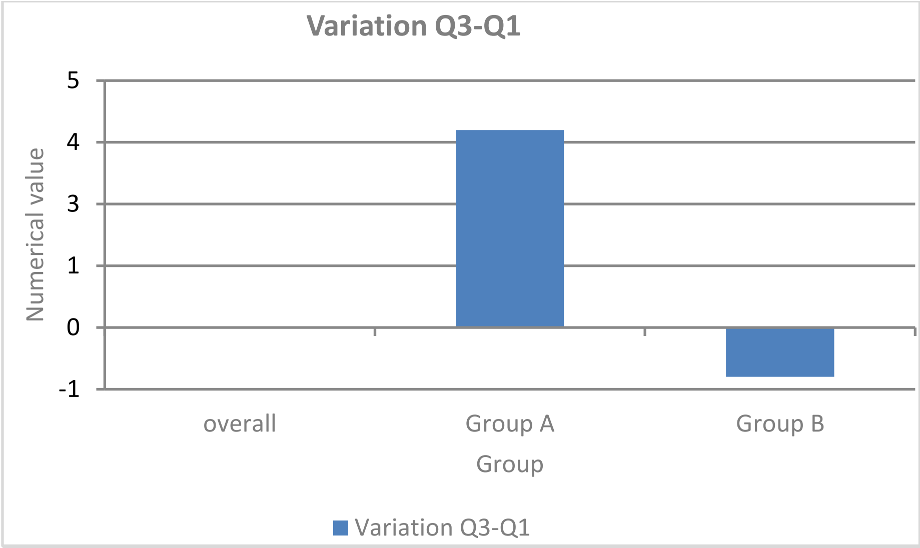

Figure 8.18 – Variation of results between quiz three and quiz one for question 3) justifying the choice (3 features).

The x axis variable is the group, and the y axis variable are the difference between the quizzes result.

On reviewing the results considering the difference between quiz three and quiz one overall was -4, Group A was -1 and Group B was 5. Table 8.7 notes the students that performed at the extremes. HAKH in group A and PASA in group B increasingly improved their quiz results. The other four students (SAAK, SAAR, AYDA and PHWH) had worse results in quiz three, notably SAAK in group A that had a result of 9 and AYDA in group B who had achieved 21 in quiz one. The pass score for the quiz was 8.4 (40%).

Table 8.7 – Variation of results between quiz three and quiz one for students that demonstrated extreme differences for Group A and B.

Student	Group	Difference (Q3 – Q1)	Results in quiz three
HAKH	A	5	18
SAAK	A	-4	9
SAAR	A	-2	18
PASA	B	7	21
AYDA	B	-7	14
PHWH	B	-3	11

8.4.1. Quiz one results

8.4.1.1. Normality testing

The results for quiz one was first reviewed for normality using IBM SPSS version 25. Shapiro-Wilk (SW) test and Kolmogorov-Smirnov (KS) test were performed. Shapiro-Wilk test is most appropriate for small sample sizes (under 50 samples). The Sig. values are KS=0.123 and 0.200 and SW=0.240 and 0.337 (Table 8.8) The null hypothesis was greater than 0.05 therefore not rejected, the results of quiz one were normally distributed and did not deviate from a normal distribution (Figure 8.19). The analysis of the quiz results should be considered using parametric testing.

Table 8.8 – Normality testing for the sample of 27 students.

	V1	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
TOTAL	A	.217	12	.123	.914	12	.240
	B	.165	15	.200*	.936	15	.337

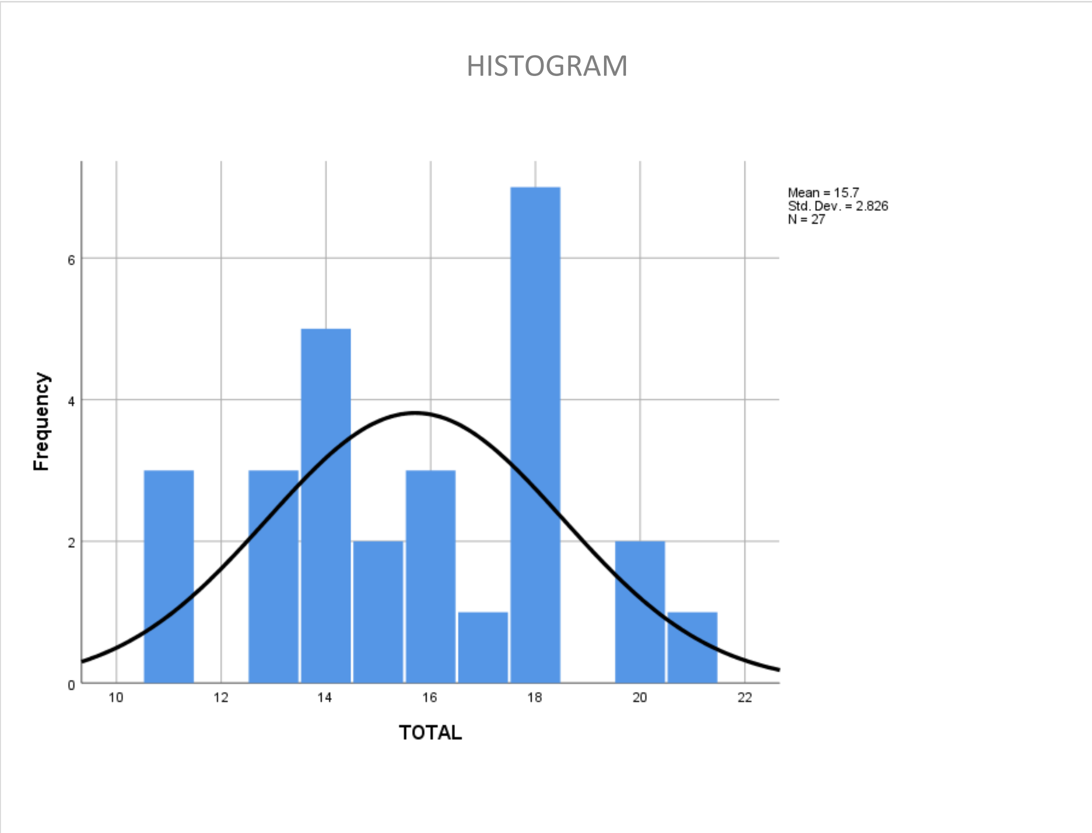

Figure 8.19 – Histogram distribution of the sample.

8.4.1.2. Parametric testing

Using IBMS SPSS version 25 and Microsoft Excel 365 statistical tools and by using independent t-test statistical test with a 2-tailed distribution and two sample using the data from Table 8.10, the equal variance is 0.152. The *p* value was 0.15 therefore the null hypothesis has been rejected: blended learning with VM more effective than glass slide/textbook approaches in training Biomedical Science undergraduate students?

All students passed the assessment in quiz one. The range for group A was 7 and group B was 10, the mean and median for group A are 16.6 and 17 respectively, and for group B are 15 and 14 respectively (independent-samples median). The results for group A were more concentrated and nearer the median and the results for group B were more spread including the values for quartiles one and four (Table 8.9 and Figure 8.20).

Table 8.9 – Descriptive analysis of the sample.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
A	12	16.58	2.47	.71	15.02	18.15	13	20
B	15	15.00	2.98	.77	13.35	16.65	11	21
Total	27	15.70	2.823	.54	14.59	16.82	11	21

Table 8.10 – Independent Samples test results.

						95% Confidence Interval of the Difference	
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
Equal variances assumed	1.48	25	.15	1.58	1.07	-.62	3.79
Equal variances not assumed	1.51	24.95	.14	1.58	1.05	-.57	3.74

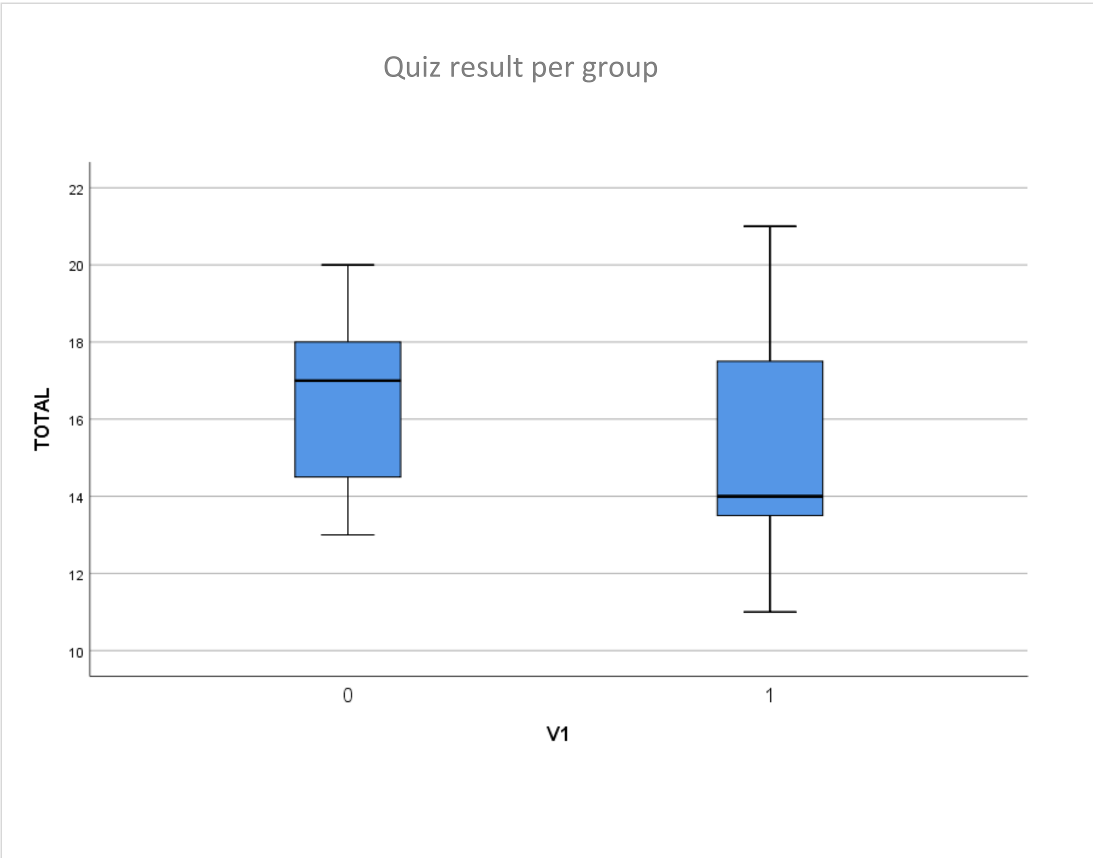

Figure 8.20 – This boxplot shows the median score of every group (thick horizontal bar) along with the 25th/75th percentile and minimum/maximum score considering the score results for quiz one.

The pass mark is 8.4. The columns are represented as 0 and 1 which are groups A and B respectively. In group B, the dot at the top represents an outlier, one student achieved the maximum score – 21.

Quiz one was completed by the twenty-seven students, Table 8.9 demonstrates the mean and standard variation. The standard deviation allows the researcher to understand the spread of results obtained by the students. Group A had a higher mean at 16.6 and group B was 15. The standard deviation between the groups is close, group A is 2.5 and group B is 3. Considering Table 8.9 and Figure 8.21, most students fall within the standard deviation window considering the overall results for quiz one, there are three students – SAAR, AYDA and LUJO – that obtained results higher than the standard deviation window, they had 20, 21 and 20 respectively for quiz one, and three students – KOMA, MOMU and AMIB – that obtained results lower than the standard deviation window; however, they still passed the assessment, these three students had 11.

Considering the students in group A, all students fell within the standard deviation values (Figure 8.22). Considering group B, most students fell within the standard deviation values, one student (AYDA) achieved 21 in quiz one results and represents an outlier (Figure 8.23).

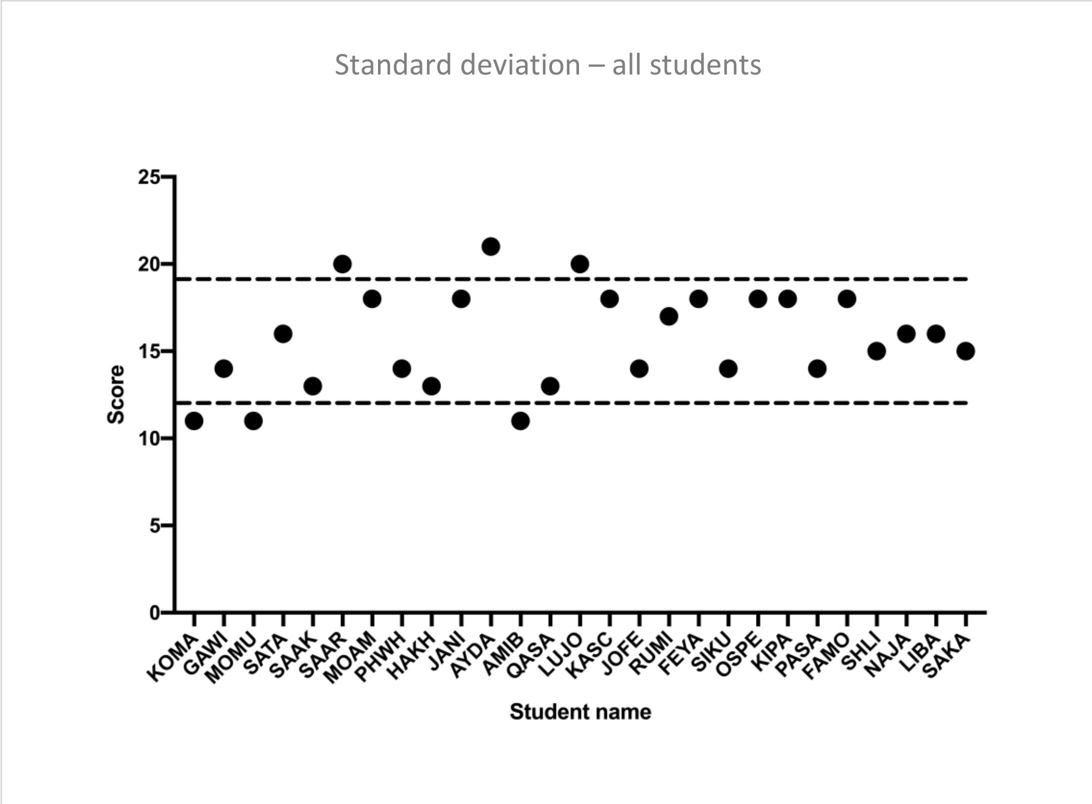

Figure 8.21 – Standard deviation considering all students completing quiz one.

The x axis variable are all the students name and the y axis variable score result.

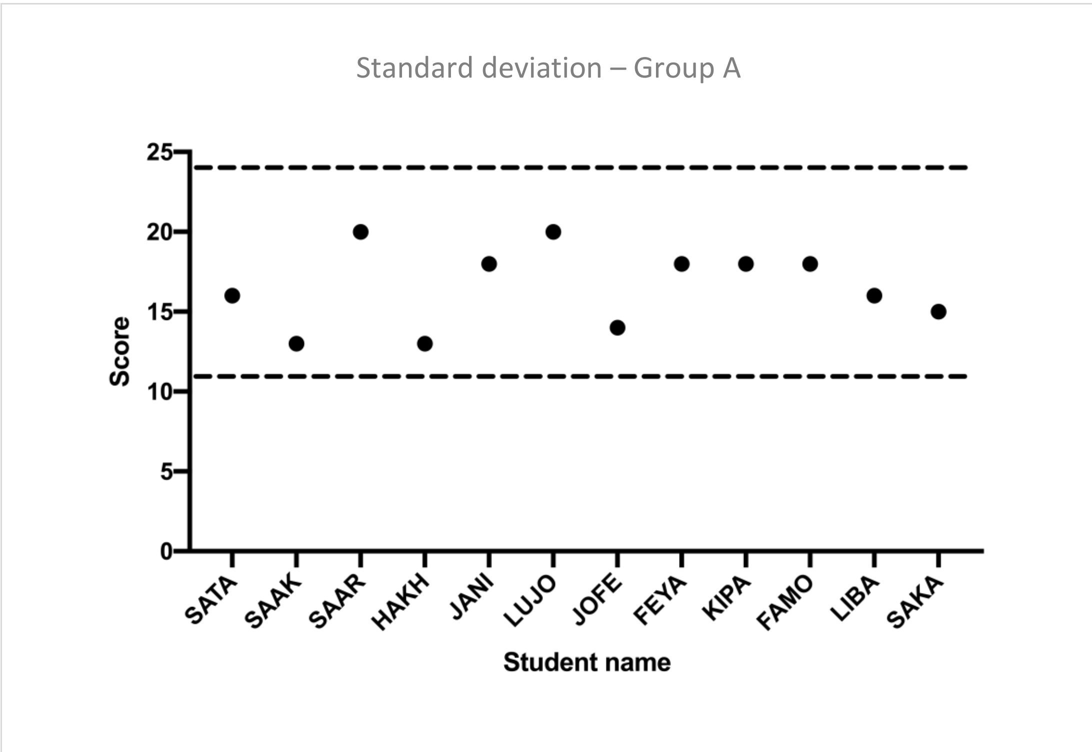

Figure 8.22 – Standard deviation considering students in group A completing quiz one.

The x axis variable are the students in group A and the y axis variable score result.

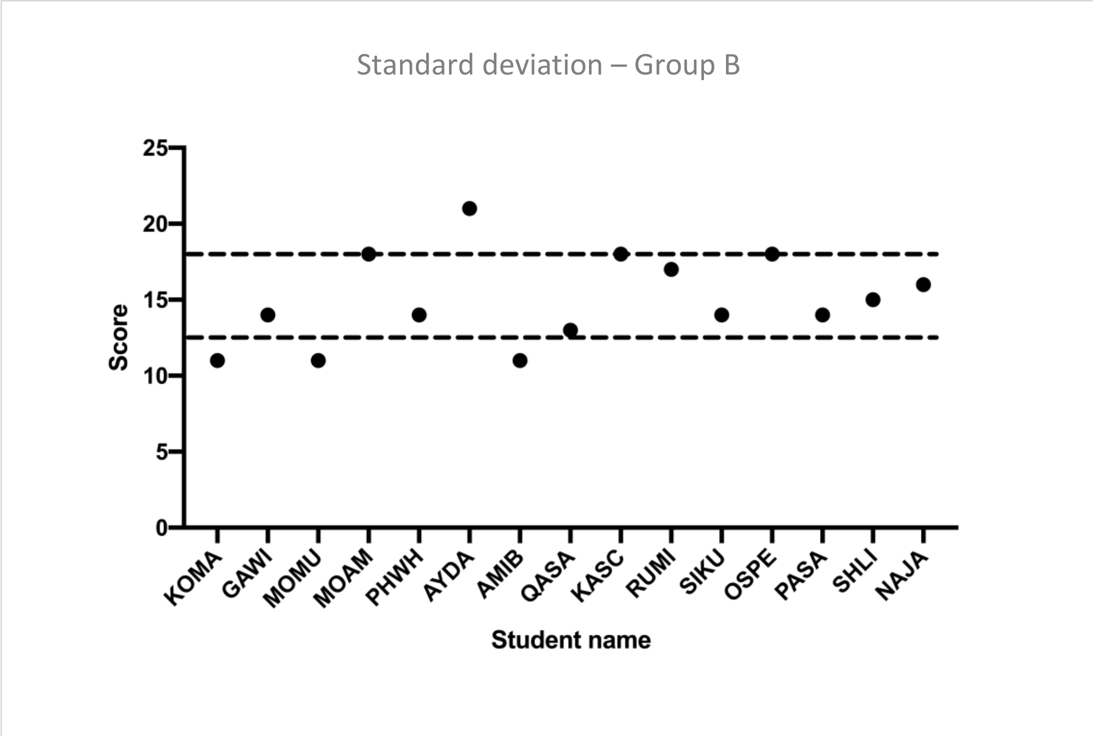

Figure 8.23 – Standard deviation considering students in group B, completing quiz one.

The x axis variable are the students in group B and the y axis variable score result.

Crosstabulations were used to express the students answers in quiz one compared to the training method. The results suggested that there were no differences when students identified the tissue type (question 1, colon tissue type) between group A and B as presented in Table 8.11.

Table 8.11 – Crosstabulation Training method * colon (tissue type) for quiz one, Question 1.

		Colon		Total
		Tissue incorrect	Tissue correct	
Training Method	Microscopy	1	11	12
	Path XL	1	14	15
Total		2	25	27

Reviewing Table 8.12 there was a higher number of students identifying the correct disease (question 2, identification of the condition) in group A than in group B, in group B there was nearly the same number of students identifying the disease correctly and incorrectly.

Applying weighting to the crosstabulations to adjust the values regarding the training methods and the condition (question 2, identification of the condition), there were no differences or patterns identified (Table 8.13 and Table 8.14).

Table 8.12 – Crosstabulation Training method * normal tissue (tissue type) for quiz one, Question 2.

		Normal		**Total**
		Disease incorrect	**Disease correct**	
Training Method	**Microscopy**	3	9	12
	Path XL	7	8	15
Total		10	17	27

Table 8.13 – Crosstabulation Training method * weighted normal (condition) for quiz one, Question 2.

		weightednormal1			**Total**
		.00	**2.00**	**4.00**	
Training Method	**Microscopy**	4	0	8	12
	Path XL	6	2	7	15
Total		10	2	15	27

Table 8.14 – Crosstabulation Training method * weighted normal (condition), expressed as percentages for each cohort for quiz one, Question 2.

		weightednormal1			N
		.00	2.00	4.00	
Training Method	Microscopy	33	0	67	12
	Path XL	40	13	47	15
Total		n/a	n/a	n/a	n/a

8.4.1.3. Non-parametric testing

The normality testing demonstrated that the data is normally distributed; however, as this was a small sample, non-parametric 2-independent samples Mann-Whitney U testing was considered. The results of the Mann-Whitney U confirmed that there was no statistical difference between the groups as p=0.158 (Table 8.15).

Table 8.15 – Mann-Whitney U test results.

	Total
Mann-Whitney U	61.500
Wilcoxon W	181.500
Z	-1.410
Asymp. Sig. (2-tailed)	.158
Exact Sig. [2*(1-tailed Sig.)]	.167[b]

8.4.2. Quiz two and Quiz three

The overall mean for quiz two was 16.50 which was higher than quiz one – 15.70 (Table 8.16). One-way ANOVA and Mann-Whitney U tests were performed for quiz two and the group allocation. There was no significant difference between the quiz two results and group allocation considering One-way ANOVA p=0.357 and Mann-Whitney U p=0.872 (Tables 8.17 and 8.18 respectively).

Table 8.16 – Descriptive analysis of the sample of students that completed quiz two.

	N	Mean	Std. Deviation	Minimum	Maximum
Quiz two	22	16.50	3.635	10	21
Group	22	.55	.510	0	1

Table 8.17 – One-way ANOVA for quiz two and group allocation.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.905	10	.290	1.253	.357
Within Groups	2.550	11	.232		
Total	5.455	21			

Table 8.18 – Mann-Whitney U test results for quiz two.

	Quiz two
Mann-Whitney U	57.500
Wilcoxon W	135.500
Z	-.167
Asymp. Sig. (2-tailed)	.868
Exact Sig. [2*(1-tailed Sig.)]	.872[b]

The overall mean for quiz three was 15.59 which was lower than quiz one – 15.70 (Table 8.19). One-way ANOVA and Mann-Whitney U tests were performed for quiz two and the group allocation. There was no significant difference between the quiz three results and group allocation considering One-way ANOVA p=0.425, Mann-Whitney U p=0.193 (Tables 8.20 and 8.21 respectively).

Table 8.19 – Descriptive analysis of the sample of students that completed quiz three.

	N	Mean	Std. Deviation	Minimum	Maximum
Quiz three	17	15.59	3.392	9	21
Group	17	.59	.507	0	1

Table 8.20 – One-way ANOVA for quiz three and group allocation.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.201	8	.275	1.148	.425
Within Groups	1.917	8	.240		
Total	4.118	16			

Table 8.21 – Mann-Whitney U test results for quiz three.

	Quiz three
Mann-Whitney U	21.000
Wilcoxon W	76.000
Z	-1.382
Asymp. Sig. (2-tailed)	.167
Exact Sig. [2*(1-tailed Sig.)]	.193[b]

The results obtained in quiz one, two and quiz three are independent from the group allocation, this has been demonstrated by using parametric and non-parametric tests. There is no significant difference between the quiz results in group A and B.

8.5. Questionnaires results

After quiz three, twenty-eight students were invited to complete a feedback questionnaire. The student that did only attend the tutorial sessions and did not complete the quiz (UOAH) was invited to complete the questionnaire and the interview, this student did not reply to the email and will not be included further in this section.

Fifteen students (54%) completed the feedback, eight students (53%) in group A and seven students (47%) in group B (Table 8.22). The quiz was sent electronically to each student, the students could return the questionnaire via email, it was challenging to return anonymous questionnaires, the students could leave unanswered questions. Students could send feedback to the main supervisor to ensure anonymity, but no feedback was received by Dr Madgwick.

Table 8.22 – Students that participated in questionnaire according to the intervention group.

Group A **Tutorial and microscopy**		**Group B** **Tutorial and Path XL**	
SATA	HAKH	KOMA	QASA
SAAK	LUJI	MOAM	SIKU
SAAR	FEYA	PHWH	SAKA
KIPA	FAMO	AMIB	

Considering the generic questions on the questionnaire, the questions 1 to 14 and the overall questions 20 and 21 are more generic, the results are included in Appendix 15 and in Figure 8.24 and Figure 8.27, respectively. Figures 8.25 and 8.26 demonstrate the results for the specific questions for group A and B respectively and Figure 8.28 demonstrates the emerging themes from the open questions in questions 22, 23 and 24.

The result of the questionnaire revealed that 80% of students that completed the feedback strongly agreed that the trainer was knowledgeable and prepared (question 7), and 67% of students strongly agreed the objectives were clearly defined as well as the topics covered were relevant (question 1 and 3). 47% of respondent students strongly agreed that the objectives were met and another 47% of respondent students agreed that the objectives were met, one student was neutral replied neutral in this question (question 10). One student stated that the trainer was not available outside the training time (question 9) but no further comments were made about this in the later questions.

Considering whether the allocation of time and course duration was right, 73% of students agreed/strongly agreed the allocation of time was sufficient; however, two students (13%) disagreed/strongly disagreed this was the case (question 11). 80% of students agreed/strongly agreed the duration was right; however, two students (13%) disagreed that the duration of the course was right (question 12).

One student in group A (FAMO) disagreed that the trainer was not available outside the training time (question 9). One student in group B (QASA) strongly disagreed that the meeting room and facilities were adequate and comfortable (question 13). No comments were added on the feedback form by any of the students.

Two students disagreed/strongly disagreed that the time allocated for the training was sufficient (question 11) and that the duration of the course was right (question 12), one in group A (SAAK) and one student in group B (AMIB) and they both expressed that more time was required to learn, the tutorials and the practical element.

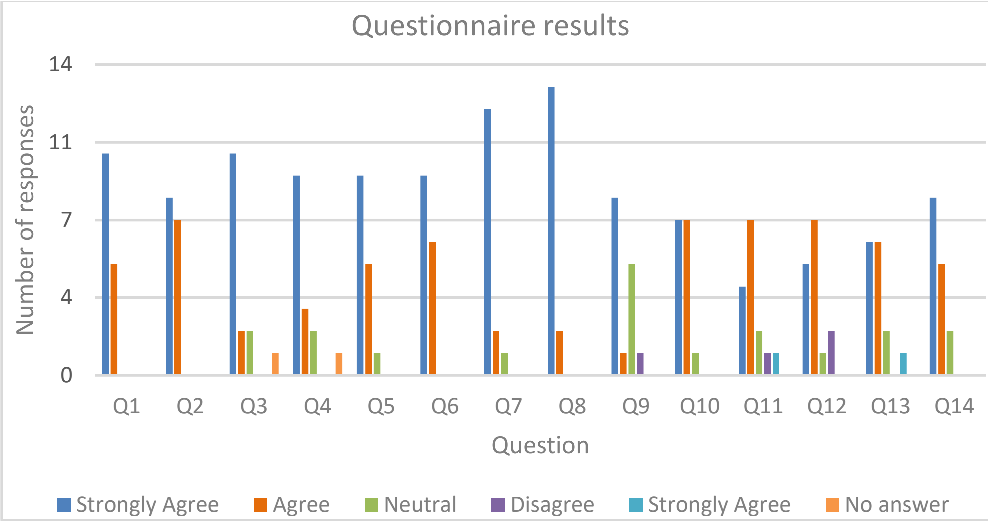

Figure 8.24 – Questionnaire results for questions 1 to 14.

The x axis variable is the question, and the y axis variable are the number of responses for each question.

Considering Figure 8.25, 87.5% of students in Group A agreed/strongly agreed that the microscope slides were useful (question 15), only 25% of students agreed/strongly agreed that there was enough time to look at slides and 37.5% of students (SAAK, KIPA, SAKH) disagreed that there was enough time to look at slides (question 16).

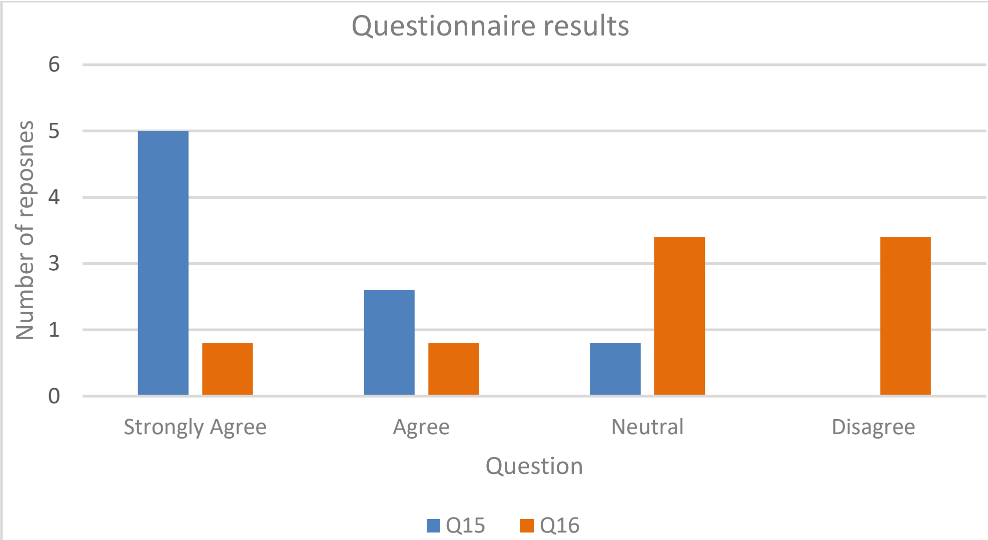

Figure 8.25 – Questionnaire results for specific questions for group A, questions 15 and 16.

The x axis variable is the question, and the y axis variable are the number of responses for each question.

Considering group B and Figure 8.26, 75% of students (6) agreed/strongly agreed that the cases on Westminster Path XL were useful (question 17), students stated that they could navigate the module very easily (question 18) and they liked the feel and look of the module (question 19).

Considering questions 15 and 17 respectively (Figure 8.25 and 8.26), 87.5% of students strongly agreed/agreed that slides/microscopy sessions were useful and 86% of students strongly agreed/agreed that the cases studies on Westminster Path XL were useful, this is 87% of the students found the study useful/very useful.

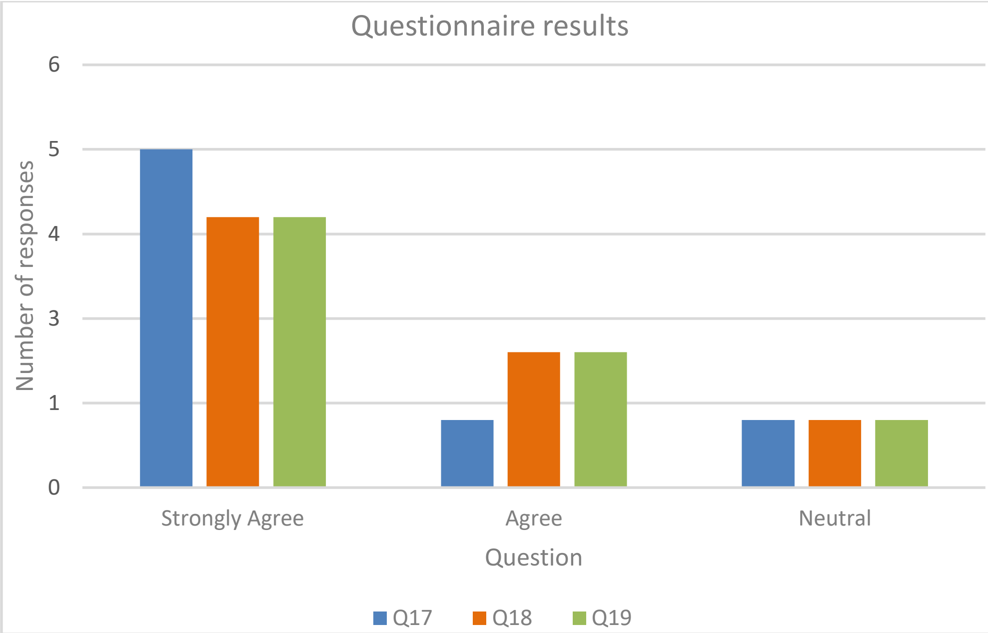

Figure 8.26 – Questionnaire results for specific questions for group B, questions 17, 18 and 19.

The x axis variable is the question, and the y axis variable are the number of responses for each question.

The feedback whether they would likely recommend the study to colleagues, 60% stated the training was excellent and 40% of students stated the training was satisfactory (question 20), i.e., all the students who answered the questionnaire (100%) would recommend the study. To question 21, “how do you rate the training”, 53% answered excellent and 33% satisfactory and two students did not answer.

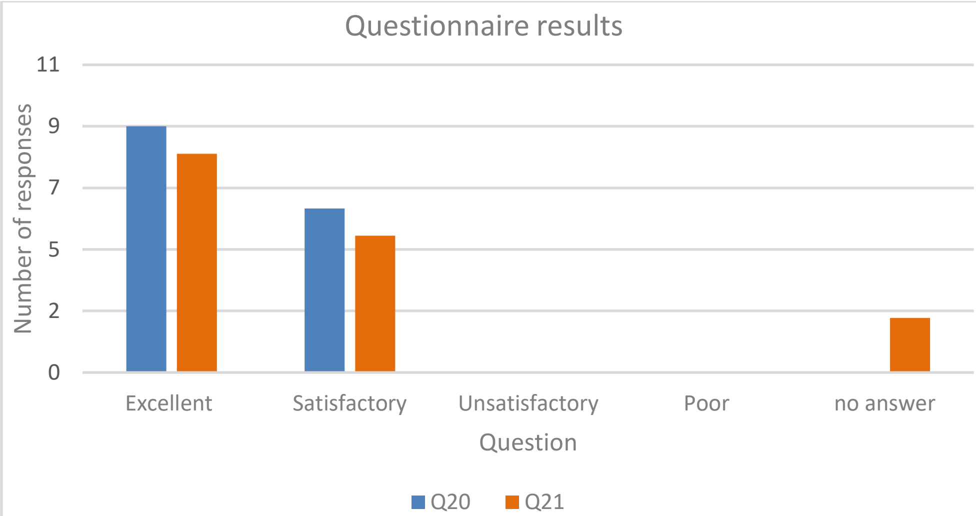

Figure 8.27 – Questionnaire results for questions 20 and 21 – overall training.

The x axis variable is the question, and the y axis variable are the number of responses for each question.

In the questionnaire there were three open questions (Figure 428), the themes that emerged from these are varied, to highlight: students felt that the study increased the students' knowledge and contributed to pathology understanding in 80% of the students and 40% of students would prefer more extended sessions. 33% of students appreciated the use of the microscope and considering that these students were in group A, this represented 62.5% of the students that completed the questionnaire in group A. 20% of students commented on the use of the software and this was reflected in two areas: ease of use of the software and challenges with the password.

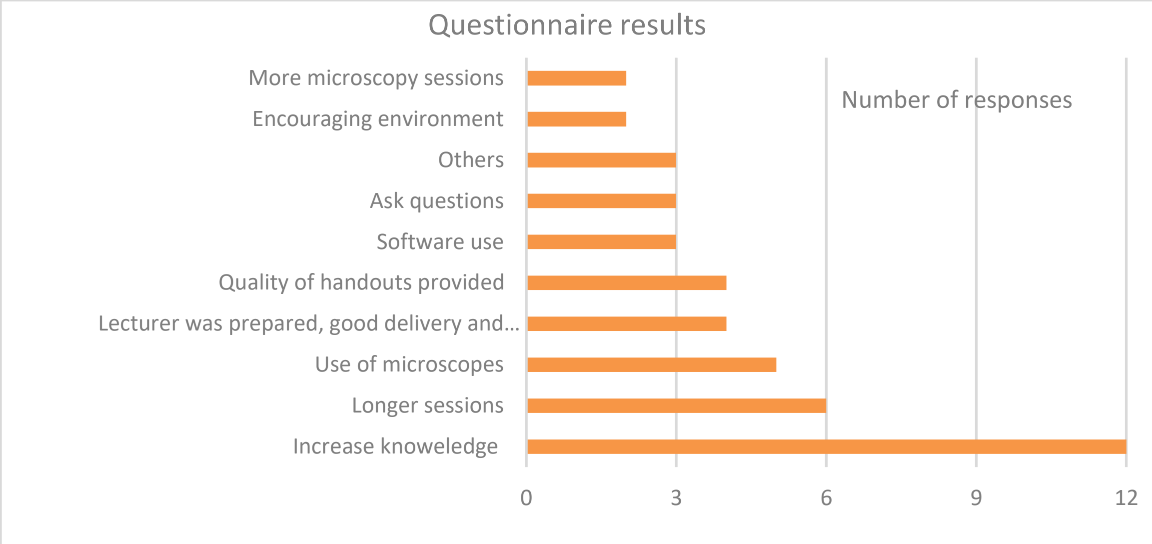

Figure 8.28 – Questionnaire results for questions 22, 23 and 24 – emerging themes.

The x axis variable is the number of responses for each theme raised and the y axis variable are the themes raised by the students.

Considering the students that completed the feedback, all students provided an answer to all questions except two students in group A (HAKH, FAMO) for question 21. Three students in group A expressed disagreement with the time allocation for the microscopy session and no student in group B disagreed the time allocation for Westminster Path XL was insufficient. All students provided additional information on questions 22, 23 and 24 and the data gathered from these are insufficient to draw conclusions as there are many themes raised by different students, the one theme raised by most students is that participating in the study increased their knowledge (80%). The feedback provided by students was overall positive and provided insights from the students' perspective.

8.6. Interviews results

Ten students that completed the questionnaires were invited to participate in a semi-structured interview, five in group A and five in group B. One student was not available to participate in the interview as they were out of the country during the time scheduled for the interviews, all other nine participated in the interviews: four in group A and five in group B (Table 8.23). The student who withdrew in the earlier stages (2 tutorials) and the student who only attended tutorials and did not complete quiz one was not available to participate in the interview.

Table 8.23 – Students that participated in the interviews according to the intervention group.

Group A **Tutorial and microscopy**		**Group B** **Tutorial and Path XL**	
SAAR	HAKH	PHWH	GAWI
FEYA	KIPA	AMIB	MOAM
(SATA)*		PASA	

* This student was not available

The interviews were scheduled on a one-to-one basis, at the convenience of the student: time and place agreed with the students providing they were conducive for an open and honest discussion, aimed at creating a relaxed, enabling, and exploratory environment so students could talk freely. The interviews were schedule to last up to one hour. At the beginning of each interview, the researcher started with a light conversation and then led into the formal interview starting with requesting permission to record the interview. The researcher assured the students that the recording would be kept confidential and anonymised in any writings. This introduction took approximately 10 minutes. These recording have been kept as per the PIS described earlier and in line with the approval given by students. Each interview recording was unique and ranged from 10 to 40 minutes. Some students provided informal feedback after the end of the interview, and this would not be included as permission was not given, these comments did not affect the outcome of the study and were related with the teaching of tissue recognition at universities. Some informal comments were provided by students and consent to publish them was agreed, this was excluded from the formal interview process. There were some guiding questions (see Appendix 16) for the researcher to ensure that all the relevant topics were covered. Students were invited to bring any topic and issues related to their experiences using blended learning and some students required more prompting.

The interviews were transcribed verbatim by the researcher as available in Appendix 17 in Microsoft Word 365. The thematic analysis was performed as described in the methodology chapter and the findings are described below.

8.6.1. Manual mapping

Considering manual mapping, common words in each interview were counted; conjunctions words, linking words and verbs were discounted. These common words allowed the researcher to group the words in themes and the associated paragraphs linked to each theme on Microsoft Excel 365, and the percentages were then calculated for each theme. The initial themes were reduced into broader categories as described below and in Figure 8.29:

1. Usability of Westminster Path XL – 32%
2. Training delivery – 22%
3. Application of the intervention study – 14%
4. Use of technology – 11%
5. Use of microscope – 11%
6. Others – 10%

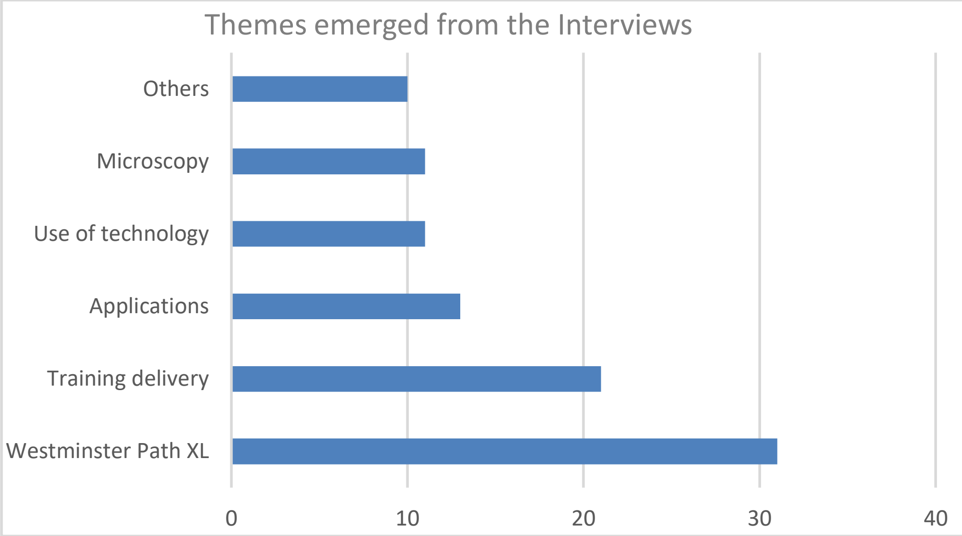

Figure 8.29 – Number of entries per comment from the interview.

The x axis variable are the themes raised in the interviews and the y axis variable are the number of entries for each theme.

8.6.1.1. Usability of Westminster Path XL

In this theme, students discussed how they used Westminster Path XL and the way they engaged with this software as a learning tool and as an assessment strategy. The experiences of students stated advantages and challenges of this in using the software for learning are presented below:

1) <u>Flexibility of movement, ease of manipulation</u>

It was clear that flexibility of movement and ease of manipulation were key to the students liking the software. The ability of zoom in and out, to see the image in more detail were mentioned by this student as some of the important features:

'Certainly giving clear image and more freedom to move around, less fidgety, to the point, amazing resolution. I felt that I had more benefit as I

looked across the whole image on Westminster Path XL than microscope, being able to zoom in/out of the zoom features made it more simple than using the microscope'. MOAM, group B

Clarity of image was a repeated claim, one student reported it as an - 'amazing resolution' and was noted as an important feature to them. Compared to a microscope image it was easier to get a detailed picture and allowed for manipulation of the whole image to aid understanding. It made the task simpler, this student reported, and more effective, it gave the student a good (secure) result without needing to have had much experience with a microscope:

'Technology is easier, it makes the picture clearer. For example, any nuclear changes, you just assume, with the microscope you need more experience, looking at it digitally you can see in a bigger screen and zoom in/out, with a microscope, it needs experienced eyes'. KIPA, group A

2) <u>Convenience of use</u>

Another key theme was the convenience of using the software, it could be used in a variety of settings which expanded its use; this was raised by a few students:

'Westminster Path XL was more convenient, anywhere, microscope I could only use at work, not at home, so I am restricted at work and only at certain times'. KIPA, group A

Time and place flexibility was also an advantage highlighted by students:

'If we do digital it is easier, you can have different stains and compare. You can do it in your own time or a microscope, you only need a computer anywhere anytime'. AMIB, group B

However, there were also some problems with the software that impacted on its convenience of use, this student explains her issues with the software in terms of usability:

'Sometimes the pictures would not load, and I had to wait until they got clear and not pixelated'. PASA, group B

It was clear from this sample, that when students completed the assessment, many students in both groups were comfortable with the use of technology (AMIB, GAWI, MOAM, SAAR).

3) Password issues

A further theme was the issue with logging in as the passwords - password complexity, and in the assessment environment students felt the added pressure:

'There were many issues with the website and the password'.

AMIB, group B

This student was specific about his reservations with the use of Westminster Path XL and his preference in using traditional methods:

'The assessment initially was challenging, especially the password, also, I could not go back with Westminster Path XL, and if it is a paper I can go back later'. FEYA, group A

Coping with more than one thing at a time also presented problems, this was mostly stated by students in group A which were less familiar with Westminster Path XL:

'The assessment via Westminster Path XL was more difficult for me, when I am looking at different things, it starts getting confusing, paper and microscope is easier for me to concentrate and to recognise'. HAKH, group A

4) <u>Features of Westminster Path XL</u>

Some students highlighted features of the software that were particularly useful for them during the learning process:

'Looking at it digitally you can see in a bigger screen and zoom in/out'. KIPA, group A

'Need to find it first unless you mark it, with the computer you can screenshot it and if you find another area, a normal and an abnormal area you can screenshot it'. PASA, group B

There was a comment from a student on which features would be helpful for their learning:

'I think that the slide should have been labelled, this would help a lot to identify specific areas that we should look at'. AMIB, group B

And another student made a comment about using Westminster Path XL for the assessment:

'The first assessment I did I was not very familiar with the layout'. PHWH, group B

The theme "usability of Westminster Path XL" was raised by many students in varying degrees. Students in group B made more comments as they were exposed to the software for longer, the intervention and assessment. It is important; however, not to lose sight of the finding that most reviews were positive about the use of Westminster Path XL as a learning tool and as an assessment software.

8.6.1.2. Training delivery

The training delivery was the second theme most raised by all students, these were mostly positive. The topics that were mentioned were related to the length and the content of the tutorial sessions and there were a few occasional comments about the delivery. Their experiences are described below:

1) <u>Length of tutorial sessions</u>

In relation to the duration of the course, some students expressed that the length of the course and the content were suitable as that the length was appropriate and the content delivered was at the right level. This is described below:

‘The lectures were interesting, they were straight to the point and easy to follow. The terminology was ok and easy to follow, and the length of the sessions’. FEYA, group A

‘The lectures were informative, and they were quite short, not drawn out and boring. The language was ok, and the frequency of the sessions was good and just before the first assessments, the length was fine and the terminology when I did not understand I could ask you’. PHWH, group B

In contrast, two students (AMIB and GAWI) stated that longer sessions would be more beneficial so this would allow more depth in content to enable them to gain more knowledge from the sessions:

‘The lectures were interesting, I remember the slides on the iPad, and we had everything printed as well. Maybe we could have had more time to go more in-depth, not more sessions but longer sessions, we could go deeper on the subject’. GAWI, group B

The student (AMIB) that raised that time allocated for the study in the feedback questionnaire for questions 11 and 12 (Figure 8.24) raised the same concern during the interview. In this comment there is some self-reflection.

‘The tissue recognition sessions, I found it useful. I wish it had more sessions, the tutorials were very short, we were given the material, but I did not have enough time to do my own work on it.’ AMIB, group B

2) <u>Content of the sessions and learning style</u>

The content of the lectures seemed to be appreciated by the students that highlights the use of handouts provided to students and the mode of delivery by the researcher:

'I think you explained very thoroughly, normally there is only a power-point presentation, and they will only read some bullet points, and you expanded and made detours'. PASA, group B

Below is a very specific comment from a student relating to the delivery mode by the researcher, the student's learning preference and the idea of using pictures as a mind map are relevant in the context of tissue recognition which is preferred by the student:

'Lectures were very neatly done, they (handout) were all in boxes, they were all in one sheet (print style) which gives me a mind map, the kind of information which makes me satisfied after I read it. About the people in the room, it was quite good. We were all females and more comfortable actually and made me speak out more and ask more questions with things that I am stuck with. The length of the session was 30min was very good, not tiring, and the terminology was good'. SAAR, group A

The quote below is from a student who recognises the role of images and memory and how it affects their own learning needs:

'if you take an image it will hit your memory far better than using a pre-stained slide whether as a microscope or Westminster Path XL, it helps kick start the memory'. MOAM, group B

In this theme, the students stated that overall, the sessions were informative, and the materials provided of quality, some would prefer longer or more sessions to discuss the topics in greater details whilst others were satisfied with the sessions. In this topic there was an attempt to recognise the role of memory when learning patterns through discussions of learning styles and students' learning preferences.

8.6.1.3. Application of the intervention study

The application of the learnt content from the intervention study was discussed by all students. In this section, the students demonstrated the positive impact of participating in the study.

1) <u>University assignments</u>

The two students below were completing their degrees and, by attending the intervention study, they have been able to perform better at university:

'The training was useful, especially for the university portfolio that I had to get together. We did coursework where we had to work on slides and find our own diagnosis on a case study, we had slides and online'. GAWI, group B

This student was at a different university than the former, despite having different topics and assignments, the student was able to apply the content learnt.

> *I was able to implement what I learnt here, at the same time we were having the same topics at university and in the last homework I was asked which was a melanoma and I was able to answer it very quickly because we had just seen them with you.* SAAR, group A

2) Transferable skills - at work

Some students stated how completing the study provided them with better opportunities at work and how they were able to use this newly gained skills as they transferred directly to the workplace. The student below described staining and then visualizing his own sections under the microscope and being able to identify the structure and features of cells and tissues.

> *'I have started implementing what I learnt when I am staining, I can look at the stains and see the difference in the cell components'.* FEYA, group A

The student below described how learning tissue recognition enabled her to transfer the skill of tissue analysis under the microscope to orientate the specimen and recognize different features when performing a different task in the laboratory:

> *'One thinks that the training has helped me with, is that I am more curious when I am embedding if I don't recognise the tissue I go and look at the form to check what the tissue type it is'.* AMIB, group B

3) Longer term advantages - job opportunities

Taking part in the study had, for some participants, a longer-term positive impact. This was a specific comment made by one student about the opportunities that she gained by being part of the study. This student was undertaking a Biological Sciences course with common lectures as the peers in this study; however, the job opportunities were different on completion of the degree. By completing this study, the student felt that she was at an advantage over other candidates as she had gained more practical microscopy skills than other applicants and was able to understand better her opportunities:

> *'Now looking for jobs, I can use that experience of being on that environment, when I read the documents, I do understand what they say, otherwise, I wouldn't have a clue'.* HAKH, group A

The applications of the study were not a direct measurable outcome for the study; however, students appreciated the learning and the skills gained by participating in the study and understood how those skills could be applied in different contexts.

8.6.1.4. Use of technology

The use of technology has it advantages and disadvantages, in this theme, students highlighted their views on alternative technologies, using both methods for teaching and the disadvantages of reliance on technology.

1) Alternatives

The use of technology/equipment was mentioned by few of the students outside the context of using Westminster Path XL, whether is by using an equivalent to a microscope at home or taking static images with a camera/phone:

'I think if a microscope is not available, Westminster Path XL is the 2nd best option, I actually bought myself a Nurugo to look at my skin, but it is not exactly a microscope'. SAAR, group A

'The use of photographs, if you are on a microscope and can take pictures, if you are staining a slide, if you take an image it will hit your memory far better than using a pre-stained slide'. MOAM, group B

2) Both methods

Interestingly, some students stated that they would prefer both methods and they proposed ways of using them alongside. This sub-theme is expressed by students in group A and B. The students below stated that with technology demonstrating a feature is easier as this can be marked and saved using the labelling and coordinate features in the software and easily retrieved as opposed to when using a microscope as this will not retain coordinates.

'Technology is easier, it makes the picture clearer. For example, any nuclear changes, you just assume, with the microscope you need more experience, looking at it digitally you can see in a bigger screen and zoom in/out, with a microscope, it needs experienced eyes'. KIPA, group A

'Technology yes, because it is easier, if you got a microscope and you are showing your students a certain area, you need to find it first unless you mark it, with the computer you can screenshot it and if you find another area, a normal and an abnormal area you can screenshot it, both of them and compare and show to the students, there is a limit amount of things you can do with the microscope than with a computer'. PASA, group B

This student highlights the notion that once you have learnt it properly with the use of technology, recognizing features using any software or a microscope should not make a difference:

'We should use technology. However, we cannot solely do it, when you know it so well, you can recognise it on the paper, microscope or the computer'. HAKH, group A

3) Limitations

There was one comment that stated the limitations of using technology alone and alluded to challenges in student-teacher engagement and technology:

'Technology should definitely be used but not replacing the current method, technology can sometimes push teaching away, some teachers may be so dependent on technology that they lose the ability to engage and teach students, you have to have a balance and offer the best of both worlds'. MOAM, group B

It was interesting to explore with the students the use of technology outside the scope of Westminster Path XL and realize that students had developed their own ways to learn using different technology that suited their needs.

8.6.1.5. Use of microscope

There were fewer comments overall related to the use of microscope, these were explored by all the students that completed the practical sessions with the microscope and glass slides (group A). The students highlighted the challenge of accessing the material outside the practical sessions and how that affects learning:

> *'I had the microscopy practical sessions, the microscope was not readily available, and I cannot always go back to the slides, it was a one-off practical session. With the University Path XL, I can always go back'.* FEYA, group A

> *'I had the microscope practical, we had to do self-study, we were provided with the slides, and I used to look at the slides at the workplace under the microscope. Because we were learning, the microscope was very useful, the disadvantages were a limit with the magnification, with the digital, you could go high power, for example, look at the nuclei, sometimes we had to convince that it is there'.* KIPA, group A

> *'I preferred the microscope, hands-on, I learn better with paper that way. Not stressful as I found the areas that I was expecting'.* HAKH, group A

It was interesting to note that three students in group B made comments on the use of microscopy as a skill and an interest:

> *'I think technology has a place, but I would like to use the microscope sometimes, so I know how to use it'.* PHWH, group B

> *'If I had used the microscope, I would have improved the microscopy skills'.* GAWI, group B

Students in group A demonstrated that they were satisfied with the learning method; however, there were challenges and limitations. The use of a microscope is discussed in the context of a skill by students in group A and B.

8.6.1.6. Additional themes raised by fewer participants

There were a few themes raised by a smaller number of students but are worth reporting here.

1. Skill development and teaching

Four commented on skills development. One of these related to microscopy skills:

> *'The use of a microscope is good; however, using Westminster Path XL, the skill of using a microscope is lost'.* FEYA, group A

Another student commented on how being part of the training developed other skills related to their ability of tissue recognition that would be relevant during the later university years:

'The training gave me better analytical skills, it was new, and I spent a lot of time playing with it, and when I was in the 3rd year, I could recognise tissue features on a very quick basis, and it was specific due to this, I had not done this before'. MOAM, group B.

Gaps in the teaching were also noted. A few students commented on how the practical element of teaching should include both microscopy and Westminster Path XL as this would enable them to learn the cellular features when using technology and learn microscopy skills that were required in the workplace.

'If I had a choice, I would do both to see the difference, routinely I would use the microscope, but digital would be useful also'. KIPA, group A

'I think microscopy needs to be there, the basics, I remember you saying that to understand what is abnormal we first need to know what is normal, so I first learnt what is normal on Westminster Path XL, then I could carry on using microscopy and my eye would be sharper'. GAWI, group B

2. <u>Recruitment</u>

The other themes that were only raised by two students relates to the recruitment process (HAKH, group A and GAWI, group B). The student below describes how taking part of the study gave her advantages when applying for jobs.

'Now looking for jobs, I can use that experience of being on that environment, when I read the documents, I do understand what they say, otherwise, I wouldn't have a clue'. HAKH, group A

The comments about skills development and the teaching methods are important to note as they demonstrate that the students understand the importance of learning tissue recognition which is the driver for the study which they were participating.

8.6.1.7. Emotions generated during the learning process

The emotional engagement of students is important to consider. This may be reflected on the words that the students said and were transcribed as part of the interviews. These enabled the researcher to re-create the students' experience and explore the context that the students experienced and on the other hand, it allowed the researcher to reflect on the intervention delivery (Brookfield, 1998; Reed, 2014; Brookfield, 2017). The emotions are categorised as either positive or negative emotions.

1) Positive emotions

Most of the emotions encountered in the transcripts were positive and playful and during the interviews, students felt happy and light-hearted. The happy emotions are stated in quotes as described below, the first one denotes appreciation, and the following two quotes demonstrate awareness and enjoyment, the latter goes to the extent of stating the success of the study in the student's view:

'I was really happy to be a part of the training, you didn't come to my lectures, you went to the tissue sciences lecture for the recruitment and my friend told me about it, and when I contacted you and asked if I could be part of it'. HAKH, group A

'Westminster Path XL suited me better especially for the purpose of the study'. GAWI, group B

'The training was very enjoyable, and it was very engaging and certainly lots of positive outcomes for me… The training was a brilliant experience'. MOAM, group B

The following statement demonstrates respect and thankfulness that the student received during the study and the researcher's availability and trust in the process that the student would attain the desired knowledge.

'*The training was good, we went through all the stages, lectures, slides, it was useful, and we could put the puzzle together, you were always there to answer any questions'.* KIPA, group A

There were other positive emotions demonstrated by students when discussing the tutorials, the microscopy sessions, the use of Westminster Path XL and the assessment, below are some quotes respectively:

'The lectures were informative, and they were quite short, not drawn out and boring'. PHWH, group B

'I had the microscope sessions, they were really good'. HAKH, group A

'I never got to use anything like this, and seeing the big range of slides, to zoom in/out gives the true definition of something'. MOAM, group B

'The assessment was good, …, as technology goes it was good, we looked at the different slides, zoom in and see the features'. KIPA, group A

The comment below is very interesting, besides providing the student's view on the length of the sessions, the handouts, and the content, it provides insights on cultural constraints that are important for her:

> *'Lectures were very neatly done, they (handout) were all in boxes, they were all in one sheet (print style) which gives me a mind map, the kind of information which makes me satisfied after I read it… We were all females and more comfortable actually and made me speak out more and ask more questions with things that I am stuck with. The length of the session was 30min was very good, not tiring, and the terminology was good'.* SAAR, group A

Considering the students availability to attend the interviews, students were readily available to assist the researcher in attending the interviews and were conscious in providing accurate and honest views. Even when the comments were not so positive, students were candid in providing feedback.

The students were joyful and thankful for being part of the study, that they appreciated the learning and they felt optimistic about tissue recognition, the use of microscopes and glass slides and the use of technology for learning. Some students felt confident in the knowledge they gained as an asset for the future and the researcher felt successful with the students' achievements. The statements provided in this section concur with the researcher's views.

2) <u>Negative emotions</u>

There were some negative emotions, mainly frustration with certain aspects of the study, namely, disadvantages or limitations of the teaching methods. Considering glass slide and microscopy, the students highlighted the following:

'With the microscope, I am restricted to the laboratory practical. The disadvantage is that you can only see what is uploaded there'. GAWI, group B

Because we were learning, the microscope was very useful, the disadvantages were a limit with the magnification, with the digital, you could go high power, for example, look at the nuclei, sometimes we had to convince that it is there'. KIPA, group A

Whilst the former quotes relate to the microscope, the next quote relates to how microscopy is taught:

'… If you got a microscope and you are showing your students a certain area, you need to find it first unless you mark it, … there is a limit amount of things you can do with the microscope than with a computer'. PASA, group B

One recurring comment that was raised by some students related to the use of Westminster Path XL log in/password and the unfamiliarity with the assessment, on the statements below, students disclose their feelings:

'The assessment initially was challenging, especially the password, also, I could not go back with Westminster Path XL, and if it is a paper I can go back later'. FEYA, group A

'The first assessment I did I was not very familiar with the layout, some of them I had to guess'. PHWH, group B

This statement from the student goes further and reveals student's distress and state during the assessment, under pressure:

'The assessment via Westminster Path XL was more difficult for me, when I am looking at different things, it starts getting confusing, paper and microscope is easier for me to concentrate and to recognise'. HAKH, group A

One of the students provided quite a few insights and was expressive about the challenges that she faced with the study, her frustrations with the length of the sessions, the Westminster Path XL software, and her own learning needs:

'There were many issues with the website and the passwords…I would have liked longer sessions or more sessions … there were a lot of details, and they were going quickly, we could ask questions, but the time was short, there was so much to ask… the slides (Westminster Path XL) were not identified, the learning material was good, but when we had the test it was difficult to identify, to be honest, I should have spent more time with the learning material but the issue with the log in made it difficult'. AMIB, group B

The negative emotions were related to the study and the challenges students faced during the intervention study as described above, the feelings were mostly frustration, unfamiliarity with Westminster Path XL and the assessment.

Considering the interview analysis, it could be highlighted that students' felt empowered by the technology; however, they noted some challenges with the use of the software. On the other hand, students feared becoming isolated if only Westminster Path XL was used exclusively thus creating a skill gap in their training. The face-to-face, teacher and student sessions offered valuable experience to students' who found it reassuring. It could be argued that the use of new technology offered convenience, speed, accuracy, and flexibility of use providing good diagnostic skills – it worked well with the 'factual' aspects of the process. But the face-to-face and paper methods allowed for reassurance and a slower, more effective longer term learning experience due to a slower consideration of the same content.

The thematic analysis allowed an in-depth understanding of the students' motivations and experiences during the study. The students were very supportive during the intervention study and students provided great insights during the interviews. Some expressed gratitude at being able to disclose how the experience was for them.

8.7. Others result findings: attrition rate, psychometric tasks and quiz results and individual student profiles

8.7.1. Attrition rate

Attrition rate is the number of students that did not complete the study. This was not considered during the design; however, this is an indicator of success (Gregori et al., 2018).

Only one student dropped out completing the five tutorials – 3.6%. This was lower than the average 10% considered in other studies. The low attrition rate is an excellent indicator of the success of the intervention, 27 students completed the intervention study and completed quiz one, which is in parity with other studies performed in the UK and other countries. This is a positive outcome as there was no financial commitment associated with the study for the students and the study was an additional episode that students could voluntarily opt-in in addition to their own regular work.

When reviewing the results of the psychometric tasks, there were students that presented outliers, UOAH presented high levels of stress (34/40), UOAH was the only student that dropped out of the study after completing the five tutorial sessions and not completing any quiz. The student did not formally withdraw, and the student did not reply to any follow-up emails, so a reason for not continuing cannot be assessed as well as discuss the reasons for the high-stress levels. Informally, colleagues from LMetU commented that he had decided to follow a different career pathway.

All twenty-seven students (sample size) – 100% of students - completed quiz one with an overall result of 75%. Completion of quiz two was completed by 81.5% of the students, and the average result was 79%, quiz three was completed by 63% of students, and the average result was 74%. Ten students did not complete quiz three, six students (22%) were no longer available to complete the quizzes as their personal and professional circumstances changed, three after quiz one and three after quiz three.

Three students that worked at ICNHST left the Trust after quiz one, the three students were in group B (KASC, RUMI and SHLI). A further three students left the Trust after quiz two, one student in group A (JOFE) and two students in group B (SIKU and OSPE), these students left the Trust for new roles in different hospitals, these students were not able to complete the quizzes as this was not a priority considering the demands on their new roles. These six students never withdrew formally from the study. Two students in group A completed quiz one and did not complete the remaining quizzes (KIPA and SAKA) and no reason was available to the researcher, formally or informally. Two students completed quiz one and quiz two and did not complete quiz three (JANI and LIBA), one from LMetU and another from ICNHST, these students were in group A.

The final pool of students that could have completed quiz three considering the six students that dropped out due to employment reasons was twenty-one students, this was a completion rate of 78% related to the total number that completed quiz one, 63% of students completed Quiz three which was lower than expected.

The overall attrition rate from completion on quiz one to quiz three is 37%, twenty-seven students completed quiz one and seventeen students completed quiz three. The first students dropping out of the study were in group B and where in employment at ICNHST, in total nine students from ICNHST did not complete quiz two and quiz three, only one student from LMetU dropped out of the study, the student was in group A. Five students in group B and five students from group A left the study after completing quiz one.

Seventeen students completing quiz three was still considered positive as the average participation in VM studies in the healthcare setting is 18 (Table 3.1).

8.7.2. Psychometric tasks and quiz results

Thirteen students scored below the average for the motivation questionnaire; however, overall, this is still considered moderate motivation (see Appendix 3), the lowest was 115; however, all these students completed quiz one (Figure 8.3). This was not a core module, so students' motivation is expected to be higher than a random group. On the other hand, the results from the stress questionnaire revealed that students had moderate/high levels of stress (see Appendix 2).

On reviewing the stress questionnaire scores and motivation questionnaire scores, there was no association between each of these tasks and the results obtained in quiz one respectively (Tables 8.24 and 8.25, Figure 8.30 and 8.31). There was no association between student motivation and dropout. The motivation and the stress levels for the student that dropped out was high (138/175 and 38/40 respectively), this student did not complete quiz one.

The Pearson product-moment demonstrate a very weak correlation between quiz one and stress ($r=0.07$, $p=0.971$) which is not statistically significant (Table 8.24). The Pearson product-moment demonstrate no correlation between quiz one and motivation ($r=0.111$, $p=0.580$) which is not statistically significant (Table 8.25). In both cases a linear representation was performed; however, the relation between the score and stress and the score and motivation do not follow this pattern (Figure

8.30 and 8.31). One student presented moderate stress levels, and low quiz one result (KOMA, PSS – 14, quiz one- 11) and another student had high motivation and high result in quiz one (SAAR, MS – 167, quiz one - 20).

Table 8.24 – Correlation between quiz one results and PSS.

		Quiz one	PSS
Quiz one	**Pearson Correlation**	1	.007
	Sig. (2-tailed)		.971
	N	27	27
PSS	**Pearson Correlation**	.007	1
	Sig. (2-tailed)	.971	
	N	27	27

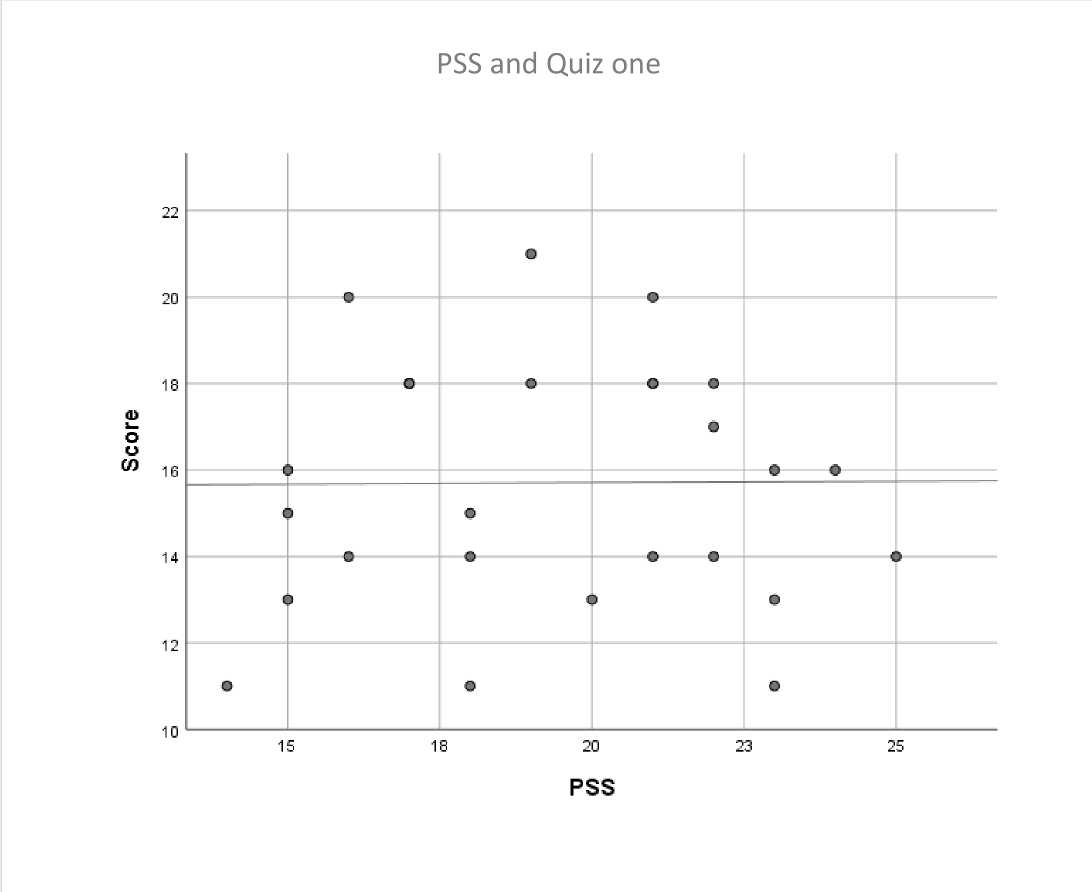

Figure 8.30 – Representation of the results of the PSS task and quiz one.

The x axis variable is the PSS result (out of 40) and the y axis variable is the score for quiz one (out of 21).

Table 8.25 – Correlation between quiz results and Motivation.

		Quiz one	Motivation
Quiz one	**Pearson Correlation**	1	.111
	Sig. (2-tailed)		.580
	N	27	27
Motivation	**Pearson Correlation**	.111	1
	Sig. (2-tailed)	.580	
	N	27	27

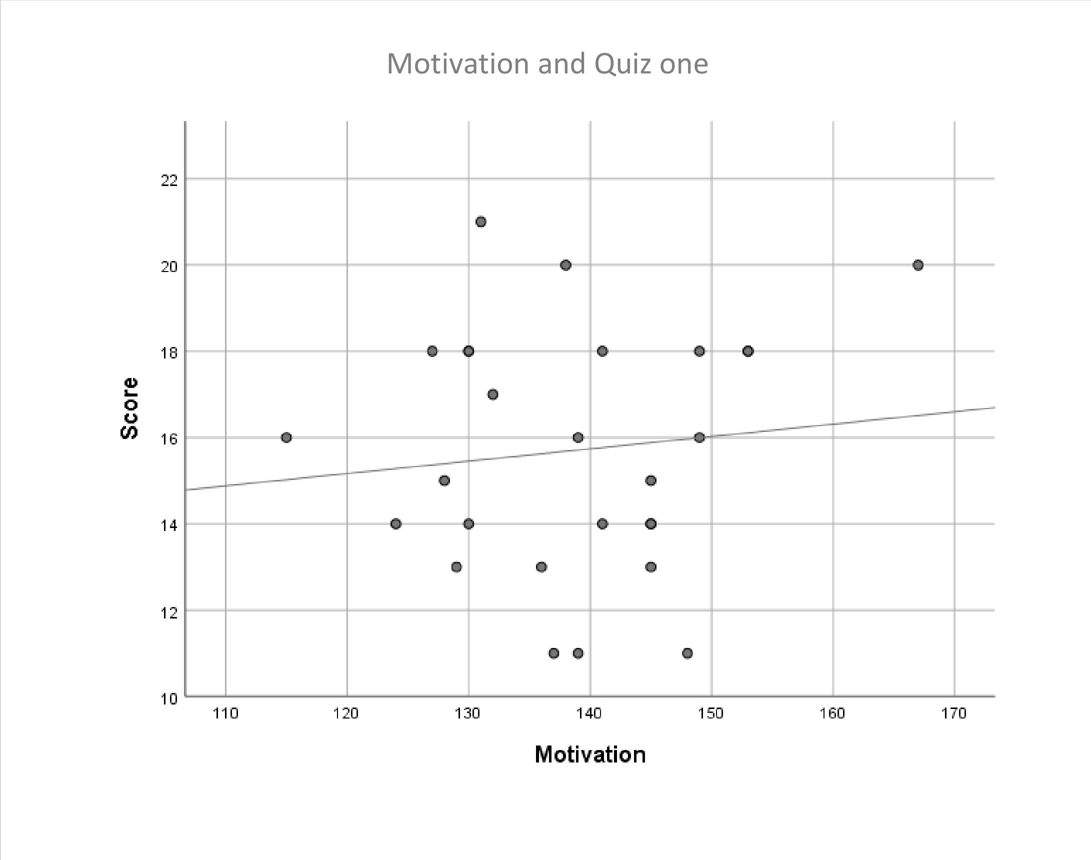

Figure 8.31 – Representation of the results of the motivation task and quiz one.

The x axis variable is the PSS result (out of 175) and the y axis variable is the score for quiz one (out of 21).

According to the results obtained, it can be inferred that stress levels and motivation could not be definite predictors of student performance; however, they may be conditioning factors that affect student's outcome. Stress levels and motivation have been demonstrated in the literature as varying over time for the same individual, and in the study the stress levels and motivation were only measured at the beginning of the study. The other opportunities to obtain information regarding student stress levels and motivation was the questionnaire feedback after quiz three which allowed the researcher to analyse the feedback provided and later during the interviews which allowed the researcher to inquire the students about their stress levels and motivation during the study. These provided less quantifiable information, yet it was essential to understand the students' perception.

One student (UOAH) that presented high motivation and high stress withdrew from the study due to high academic workload (Figure 8.3). The student completed the psychometric tasks after attending the first tutorial. The student attended the five tutorial sessions and did not complete any of the quizzes. The student did not email the researcher, this was informally conveyed by his peers.

The other student that completed the psychometric tasks after the first tutorial only completed quiz one and completed the feedback questionnaire, this student presented moderate stress levels and high motivation. These two students presented the different stress and motivation levels and had in common the completion of the tasks after the first tutorial, the attendance to the tutorial and the tutorial environment may have influenced the completion of the psychometric tasks, but this was not possible to assess as these students were not available for the interview.

Two students with raised stress levels did not complete quiz two, and five students with elevated stress levels did not complete quiz three, the motivational levels for the seven students mentioned above are in the higher motivational range. On the other hand, there are three other students that presented with higher stress levels, and that did not deter them from completing the tutorial sessions and pass the three quizzes. It has been postulated that some degree of stress drives students to perform better; however, the quiz results obtained are not significant to infer either the role of stress in student performance.

A theme that was raised by the students during the interviews informally was that, as it got closer to handing in university assignments or got busier at work, the students' availability to continue with the study was compromised. However, as the students were able to appreciate the academic and professional benefit in continuing being part of the study, these students persisted.

Students' motivation was varied, and most seem to indicate that students wanted to increase their knowledge in histology whether to better understand the subject at university or to assist them in their professional development. Some students in the feedback questionnaire and during the interviews stated how the study contributed to their increase in knowledge and gave practical examples of how they applied the learnings from the study to their environments. Literature suggested that self-determination, intrinsic motivation, teacher support and peer interaction support affect student learning, all these themes have been raised by the students in the interviews, and the researcher accepted these facts considering the number of students completing the study (Jonassen et al., 1999; Mason, 2001; Huang, 2002; Garrison & Cleveland-Innes, 2005; Vonderwell et al., 2007; Deci & Ryan, 2008; Snyder 2009; Moore et al., 2011; Gibbs, 2013; Kattoua et al., 2016; Pritchard & Morrow, 2017).

In the study, there was no evidence that stress and motivation were related to the dropout of students from the study, the students that withdrew or did not complete were not available to complete the feedback, but an informal discussion with the students and peers. Students did not complete the study due to professional and personal circumstances unrelated to the study.

Reviewing the results from the processing style tasks: featural, global or mixed patterns, twenty-eight students had a predominant style which was consistent throughout the tasks, no student had a mixed pattern in the RO task, and three students had a mixed pattern when reviewing their Navon task.

The working memory results were more complex as there were multiple tasks to be considered. For the Digit span task and the LNS task, the results were average with some students scoring lower than average results: MOMU, SAAK, AYDA, AMIB, all completed the three quizzes with variable results, SAAK failed quiz three. There were two students with low results for the LNS task: QASA and KASC, QASA results on the quiz were low, and KASC had a high score on quiz one and then did not complete the study. The Digit span task and the LNS task may be able to predict student success; however, larger cohorts are required.

The TMT enabled a review of the executive function of the students, both working memory and processing speed, also TMTB measured the attentional flexibility of students. The results for the TMT were generally poor, particularly for some students who did not seem to complete the task in a timely manner, this could be associated with the increased stress levels or by being the later tasks performed by the students.

A two-tailed correlation coefficient with Pearson product was plotted for processing style with quiz one result and group one, there is no correlation between the processing style (RO and Navon task combined), quiz results and group assigned (Table 8.26).

Table 8.26 – Summary table with the results for the Pearson correlation and Sig. (2 tailed) for processing style, working memory, group allocation and quiz one.

n=27, *p*=0.001	**Pearson correlation (r)**	**Sig. (2 tailed)**
Group and Quiz one	-0.284	0.152
Group and Proc. Style	-0.027	0.893
Proc. Style and Quiz one	0.274	0.167
Group and TMTA	-0.290	0.142
TMTA and Quiz one	0.337	0.086
Group and TMTB	-0.247	0.214
TMTB and Quiz one	0.089	0.661
Group and DST	0.079	0.695
DST and Quiz one	-0.281	0.156
Group and LNS	0.279	0.158
LNS and Quiz one	-0.168	0.401

Negative values have the (-) for negative correlation, the other values are positive correlations. The closer to 0 the weaker correlation, the near to -1/1 the negative/positive correlation.

A two-tailed correlation coefficient with Pearson product was plotted for working memory, DST, LNS, TMTA and TMTB independently, with quiz one result and group allocation and there is no correlation between any of the working memory tasks performed, quiz results and group assigned (Table 8.26).

The assessments were not timed, so the time element to complete the assessment was not so relevant in the study. Two students performed consistently better in the task: MOAM and OSPE and both achieved high results on the quizzes, OSPE only completed two quizzes. The role of attentional flexibility as an important executive function in tissue recognition was reviewed considering the results obtained in the TMTB, ten students had a scaled score above borderline and seven students (25%) scored over the average, this may have been of relevance when considering tissue recognition. The study did not include the completion of the tasks post-intervention to assess any changes, it could be hypothesised than an intervention could improve attentional flexibility.

The overall results in group A and B were very similar, and no group pattern could be deducted; however, there was a marginal increase of overall results in group A compared to group B, and it was not significant to imply that VM is more effective than in teaching students than glass slide/textbook approach. On the contrary, group A results were marginally better than group B and the students experience brought to light in the interviews highlighted some areas that required careful consideration when implementing a VM system: the human factor as a bridge to learning and engaging students as well as individual learning styles. The notion that students learn better by doing was clearly shown in this context – using the microscope to view slides rather than using technology to view pre-arranged images (Vygotsky, 1978; Gaytan & McEwen, 2007; Snyder, 2009).

The purpose of the research did not include an analysis of the role of age and gender and previous experience in the tissue recognition pathway. However, there were some observations worth highlighting. Students from the UoW had an average of 20.5 years old and was composed of women only. The quiz results were 14.2, 17.5, 14.3, respectively. The students from LMetU had an average of 27.2 years old and had an equal distribution of male and females. The quiz results were 16.8, 15.2, 15, respectively. The students from ICNHST had an average of 26.2 years old, and there was 18.75% male. The quiz results were 15.7, 16.7, 17, respectively.

In the study, there was a disparity between the number of male and female in the study, this was not unusual as seen in other studies (Figure 8.1). There was an age difference between the cohort of students and that did not seem to have affected the quiz results both considering group A and B and from location where they were recruited.

The students from the UoW had marginally lower results than the other two cohorts in the three quizzes (Table 8.27). The variable that seemed to have made more impact was the role of experience and exposure to the topic as the students from ICNHST were already in the workplace and many were graduates, i.e., working in a histology laboratory with a qualified degree, and that provided them with some advantage over the other students particularly when considering that their results improved over time. The students from LMetU were mature students and had wider life experiences, also, students from LMetU were in their second year and those at UoW were in the first year. In quiz one, LMetU students performed better than ICNHST, on quiz two and three, students from ICNHST performed better. Overall, the students that performed better considering their origin is ICNHST were better than the students from LMetU which were better than UoW.

Table 8.27 – Quiz results considering the cohort of students' location.

	UOW	**LM**	**ICNHST**
Quiz one	14.2	16.8	15.9
Quiz two	17.5	15.2	16.6
Quiz three	14.3	15	17
Average	15.3	15.7	16.5

To deliver the intervention study, the researcher organised the time most effectively to be able to deliver sessions with students at different days and in different locations, preparing for the tutorial and the practical sessions and troubleshooting issues with Westminster Path XL. The first semester of 2017 was intense with the delivery and data gathering and very limited time was available to review the data produced. The following twelve months provided the opportunity for the researcher to review and analyse the data obtained from the psychometric tasks, the online quizzes, and the feedback questionnaire. The researcher had some personal challenging circumstances that delayed the interview sessions. In hindsight, this provided the opportunity for students to use Westminster Path XL and internalise the learning from the intervention, it also allowed students to make use of the learnings to support their academic and professional development.

The statistical analysis of the data produced was reviewed all multiple stages after it was first drafted, and many questions were asked multiple times and looked through different lenses to ensure the results were consistent and reproducible.

The thematic analysis of the results from the questionnaires (questions 22, 23 and 24) and the interviews were also reviewed multiple times, including the listening and the transcripts of the interviews, to ensure that all the themes were identified regardless of the filters used, i.e., considering the origin of students, personal characteristics, data from the psychometric tasks and the quiz results and the intervention group: microscopy practical and glass slides or Westminster Path XL.

8.7.2.1. Quiz two and three and psychometric tasks

A two-tailed correlation coefficient with Pearson product was plotted for working memory including all the tasks: RO, DST, LNS, TMTA and TMTB independently, with quiz two and quiz three results and group allocation. The results in Table 8.28 demonstrate that there is no correlation between any of the working memory tasks performed, quiz two results and group assigned and, Table 8.29 demonstrate that there is no correlation between any of the working memory tasks performed, quiz three results and group assigned.

Table 8.28 – Summary table with the results for the Pearson correlation and Sig. (2 tailed) for working memory, group allocation and quiz two.

n=22, *p*=0.001	**Pearson correlation (r)**	**Sig. (2 tailed)**
Group and Quiz two	0.26	0.91
Group and RO	-0.017	0.941
Quiz two and DST	-0.117	0.604
Group and DST	0.026	0.908
Quiz two and DST	0.071	0.754
Group and LNS	0.245	0.272
Quiz two and LNS	-0.247	0.268
Group and TMTA	0.315	0.155
Quiz two and TMTA	0.107	0.625
Group and TMTB	-0.323	0.142
Quiz two and TMTB	-0.077	0.732

Negative values have the (-) for negative correlation, the other values are positive correlations. The closer to 0 the weaker correlation, the near to -1/1 the negative/positive correlation.

Table 8.29 – Summary table with the results for the Pearson correlation and Sig. (2 tailed) for working memory, group allocation and quiz three.

n=17, *p*=0.001	**Pearson correlation (r)**	**Sig. (2 tailed)**
Group and Quiz three	-0.286	0.265
Group and RO	0.07	0.788
Quiz three and DST	0.011	0.969
Group and DST	-0.023	0.929
Quiz three and DST	-0.391	0.121
Group and LNS	0.26	0.314
Quiz three and LNS	-0.42	0.093
Group and TMTA	0.152	0.562
Quiz three and TMTA	-0.062	0.812
Group and TMTB	-0.384	0.128
Quiz three and TMTB	-0.205	0.431

Negative values have the (-) for negative correlation, the other values are positive correlations. The closer to 0 the weaker correlation, the near to -1/1 the negative/positive correlation.

8.7.3. Individual student profile

Each student could be reviewed individually but there is little benefit in that analysis as the researcher is evaluating the effectiveness of VM as an online strategy for blended learning although there are some student profiles that are noteworthy discussing, to review the task results and the assessment outcomes.

Student FEYA was in group A, the student was one of the eldest one in the study (47), the student was from ICNHST and was a student placement completing their Biomedical Science training. The stress questionnaire result at the time of completing the tasks was 21 and motivation was 127. The results for quiz one was 18, and for quiz two and three it was 21. The result for the motivation level was lower than the average group, and the stress level was average. The processing style was global, and the normed processing speed and working memory was average (digit span task was average, and TMT was below average). This student had a high score in quiz one and achieved top marks in quiz two and three. In the informal discussion after the interview the student stated that there were challenges in completing the study as while working, the student had to complete the Certificate of Competence for professional registration, and the student persevered in completing the study.

Student SAAK was in group A from the UoW, the student was one of the youngest on the cohort of students (19). The stress questionnaire result at the time of completing the tasks was 15 and motivation was 136. The stress levels and motivation were lower than the group average. This student was one of two with featural processing style, the normed processing speed and the working memory are averages (digit span task was average, and TMT was below average). The student completed three quizzes and the feedback questionnaire, the results for the quizzes were relatively low: 13, 10 and 9, respectively. The student persevered in completing the study despite moderate stress and motivation levels.

The other student that had a featural processing style was in group B – MOMU. The student was from the UoW and was 22 years old, the stress levels were 23, which is higher than the average, and the motivation was 137, slightly below the average. The working memory (digit span and TMT were below average) and normed processing speed were below the average, and the attentional flexibility was poor. The quiz results for this student were inconsistent: 11 on quiz one, 17 on quiz two and 13 on quiz three. Featural processing style did not seem to be an advantageous characteristic in tissue recognition which is concurrent with the literature reviewed. SAAK and MOMU were in the first year of their undergraduate studies, hence less experience and novice in the field of study.

Student AYDA was from LMetU was in group B, the student was 24 years old, the stress questionnaire result at the time of completing the tasks was 19 and motivation was 131. In the first quiz AYDA achieved the highest mark of 21 and over time the results were lower, 18 and 14 respectively. The stress levels and motivation were lower than the group average. The working memory was good (digit span and TMT were average), the normed processing speed for TMTA was average, and the attentional flexibility was below the average. This student did not complete the feedback questionnaire for the study. This result was not consistent with the outcomes for all students, could other external factors contribute for this outcome?

Student PASA was in group B and was employed by ICNHST, the student was 26 years old, the stress questionnaire result at the time of completing the tasks was 25 and motivation was 145. The stress levels were higher than the average, and the motivation levels were on par with the group. The processing style was predominantly global with some mixed features, the working memory was good (digit span task was good, and TMT was below average). However, the processing speed particularly for the TMTB the results were poor which indicates low attentional flexibility. The first quiz PASA scored 14, then 18 and on the last quizzes 21, the highest score. While a complete featural processing style may not be advantageous, some featural style may be useful in the context of low attentional flexibility.

Attentional flexibility is the capability of switching processing styles within a context, and the literature described that this may affect learning (Arbuthnott & Frank 2000; Kortte et al., 2002). This characteristic seems important in tissue recognition and may have a role to play in this context; however, there was not enough evidence in this study or on the broader literature to make valid assumptions (cases MOMU, AYDA, PASA).

Student MOAM was in group B and from LMetU, the student was 29 years old, the stress questionnaire result at the time of completing the tasks was 17 and motivation was 153, moderate stress and high motivation. The processing style was global, and the student presented average working memory (digit span and TMT were average) and processing speed. The quiz results were constant over time: 18, 18 and 17.

Student HAKH was in group A and from LMetU doing a Biological Science course, the student was 34 years old, the stress questionnaire result at the time of completing the tasks was 23 and motivation was 129, higher than average stress and lower than average motivation. The processing style was global, and the student presented average working memory (digit span task average good and TMT is average) and processing speed. The quiz results improved significantly over time: 13, 16, 18.

The student MOAM had a very strong opinion about the use of VM for teaching and learning; however, the quiz results did not improve over time, unlike student HAKH who appreciated the role of VM particularly after completing the three quizzes using Westminster Path XL but preferred the microscopy with glass slide approach to teaching and education, this raises another question related to the method of teaching and the assessment mode, if the teaching is effective, the assessment mode should not interfere with the outcome.

Reviewing individual profiles allowed the researcher to reflect on the questions in the study and provide an opportunity to consider different areas not originally considered that can be explored further in different studies.

This chapter allowed the presentation of the finding in the intervention study and the analysis of the quantitative and qualitative data that it produced, from the analysis of the psychometric tasks, the quiz results, the feedback questionnaire, and the interviews.

The next chapter summarises the study findings considering the research questions proposed for the study. It also provides insights on the use of technology at UoW and how it has shaped curriculum development and the role of VM in the workplace.

9. Discussion

This chapter provides a summary of the findings of the study in light on the research questions posed and how they contribute to existing knowledge in the field. The curriculum at UoW and the role and application of VM in the workplace will also be discussed.

As discussed in chapter 6, the aim of the study was *to address whether blended learning with VM is more effective in training Biomedical Science undergraduate students compared with glass slide/textbook approaches.* This was supported by four specific questions which are addressed below in relation to the research findings and existing literature.

9.1. The role of processing style and working memory on student success

Research question 1 aimed at understanding the impact of processing style and memory on student outcome. The findings of this study demonstrated that processing style and working memory had no significant impact on student success.

Processing style and working memory are cognitive abilities described in the literature when considering memory. For example, there are studies associating autism and other disorders with processing styles: featural and holistic (DeGutis et al.; 2014; McKenzie et al., 2018; Metcalfe et al., 2019). However, the impact of processing style and working memory on student success in the context of education in Biomedical Sciences is innovative.

Metcalfe et al. (2019) findings show that processing style did not impact emotion recognition in children with autism spectrum disorders and McKenzie et al. (2018) designed a study using a Navon Task variant for adults with autism spectrum disorders and the study showed that there was no significant relationship between processing style and autistic-like traits. The findings of these studies support the findings of the current study.

Tso et al. (2021) considered the holistic processing of Chinese characters in college students with dyslexia considering visuospatial deficit. This in an interesting study where students were exposed to sets of images to measure holistic processing with congruent and incongruent paradigms considering a variant of the Navon task. It was found that Chinese adults with dyslexia had persistently below average performances in Chinese literacy than the control group. These findings differ from the findings in the current study and more research is needed to further investigate the role of processing style in teaching histology.

Further, there are several studies on learning styles and how these could impact student outcome considering different approaches (Terrel & Dringus, 2000; Gibbons & Wentworth, 2001; Aragon et at., 2002; Olson & Hergenhahn, 2012; Gatumu et al., 2014; Khaw & Raw, 2016; İlçin et al., 2018). Aragon et al. (2002) used three learning style instruments: motivation, task engagement and cognitive control functions to compare face-to-face and online training and though there was a difference in learning styles for the students' cohorts, the motivation did not impact students' outcome and online learning was as effective as face-to-face learning. In the intervention study, motivation did not affect student outcome and blended learning with VM was equivalent to conventional methods; these findings are in agreement with the findings from Aragon et al (2002).

İlçin et al. (2018) used the Grasha-Riechmann students learning style scale to compare learning styles and academic performance in physiotherapy students. The scale includes independent, dependent, competitive, collaborative, avoidant and participative styles. In their study, they demonstrated the most common style was collaborative and the students that had a participative learning style had a significantly higher academic performance than compared to other groups. The feedback from the interviews and the engagement in the sessions during the intervention study demonstrated that students actively participated in the learning process. Considering these finding, it could be suggested that participative learning style are more advantageous for students' performance.

Studies were also identified which address the role of working memory and students' teaching and outcome in the broader sense in which working memory play a role in students' success particularly at younger ages (Crowe, 2000; Tombaugh, 2004). In more recent studies, it was demonstrated that specific interventions assisted students in improving working memory and students' test results (Blankenship et al., 2015; Tourva et al., 2016; Maehler & Schuchardt, 2016; Nutley & Söderqvist, 2017; Friso-van den Bos & van de Weijer-Bergsma, 2020); however, this was not found across all studies in the literature (Cowan, 2014; Maehler et al., 2019). In the current study, working memory was not found to have a role to play in students' outcome.

As the tasks were not performed at the end of the sessions, it was not possible to assess whether the teaching delivery impacted students' working memory.

In the literature working memory has been linked to stress, motivation, and student outcome. Justicia-Galiano et al. (2017) linked students' performance and anxiety in maths and suggested that working memory and self-concept should be considered when supporting students with maths anxiety. Two studies in 2018 (Abduh & Tahar, 2018; Nelwan et al., 2018) described that stimulus, proper training and positive reinforcement could support students' learning and improve outcome; however, there is not enough evidence to support how working memory could affect performance in students attending university.

In summary, the literature has shown progress in understanding of the role of processing style and working memory; however, these were not conclusive and the full impact of processing style and working memory on student' outcome is not yet understood. The findings of the intervention study demonstrated that students' improved outcome is not affected by working memory nor processing style.

In this study, students did not complete the psychometric tasks post-delivery of the sessions, which would have enabled the researcher to understand if the psychometric scores had a different profile after the intervention, this information may have provided different insights for processing style and working memory. Also, few students had a predominant featural processing style, and it would have been valuable if there was a larger and more heterogeneous population, enabling the researcher to generalize the results to a wider population.

This study intended to be quite encompassing by assessing the role of psychometric tasks as predictors of student success. It did not consider the students' learning styles nor pre-university results and whether this could predict student success as these were outside its scope. Finally, the number of students in the study was satisfactory to answer the proposed aim and it was in line with other studies in the field of healthcare.

9.2. The role of stress and motivation on student outcome

Research question 2 aimed at understanding the impact of stress and motivation on student outcome. The literature reviewed demonstrated that these do have a role to play in supporting students' improved outcome (Joels et al., 2006; Salmon et al., 2009; Jovanovic & Matejevic, 2014; Stangor & Walinga, 2014; Woolfolk, 2014; NSS, 2019). The findings in this study demonstrated that students' outcome is not impacted by stress nor motivation.

Stress has been described as disruptive for student success; however, Joels et al. (2006), Stangor and Walinga (2014) and Woolfolk (2014) demonstrated that a healthy amount of stress has a positive effect on student success. Stangor & Walinga (2014) also demonstrated that motivation has a positive impact of student learning outcome, this was also described by Salmon et al. (2009) and Jovanovic and Matejevic (2014). The use of motivation and stress assessment is not novel when considering students' learning outcome. Recent studies demonstrated the negative impact of stress in academic achievement and in students' lives (Ícaro et al., 2018; Pascoe et al., 2019). Other studies demonstrated that coping strategies including mindfulness and cognitive interventions, student feedback and continuous student support can assist students in improving their learning outcomes and reduce stress (Moffat et al., 2004; Regehr et at., 2013; Galante et al., 2018).

COVID-19 has also brought a new challenge to the teaching landscape and the full effects of stress and student well-being are still being studied. Most studies in this period concluded that stress had hindered learning and that targeted support and well-being interventions could be used to support students' achievement (Son et al., 2020; Schwartz et al., 2021; Schröpfer et al., 2021). The themes raised in the studies above were not considered by students during the interviews in the current study.

Self-motivation is fundamental when discussing the role of motivation in students' learning outcome (Knowles, 1973; Ryan & Deci, 2000; Bandura, 1986 in Brentham, 2002; Deci & Ryan, 2008). The literature reviewed demonstrated that motivation and engagement are important for improved student outcome (Özen, 2017; Edgar et al., 2019; NSS, 2019); however, the role of self-motivation alone has not been able to demonstrate improvement in students' learning outcome (Howard et al., 2021). Bonem et at. (2019) argued that the way learning takes place is most important and that good student-teacher interaction are necessary for learning and improved student outcomes. Also, more studies demonstrated that student-teacher interaction have a positive impact on students' learning outcome (Goldberg & Dintzis, 2007; Gatumu et al., 2014; Khaw & Raw, 2016) and Bardach and Klassen (2021) reiterated that teacher support and student engagement are essential for students improved outcome. In the current study, motivation was considered generally so it was not possible to distinguish students' extrinsic and intrinsic motivation, this could have provided further insights.

With the onset of COVID-19, it was reported that students' motivation followed a different trend than stress. Despite the challenges faced with lockdown and online teaching, students demonstrated positive emotions and engagement which supported their learning (Baber, 2020). Also, motivation and well-being strategies were reported to have supported students during this period (Holzer et al., 2021). Finally, teacher support and the use of technology were stated as supporting students learning (Capon-Sieber et al., 2022).

The findings of the intervention study differ from some of the literature described above. In this study students' outcome was not linked to stress nor motivation; however, students expressed positive emotions regarding the study during the interviews.

It is possible that the students who participated were already motivated to gain more knowledge and understood the benefits from the study (Jovanovic & Matejevic, 2014). In that sense, their motivational levels may have been higher than the total sample of students, which could account for the low attrition rate in the study. The students reported feeling supported during the study as they were in smaller groups.

It would have been beneficial to directly assess the outcomes of the motivation and stress tasks after the intervention study; however, the online questionnaire and the analysis of the interviews provided great insights about stress and motivation such as students felt more stressed nearer the periods when assignments or exams were closer, and students were motivated and satisfied with the learning method and were engaged throughout the study.

The tasks used to assess stress and motivation have been cited and used successfully in other educational and healthcare studies and have a role to play in education; however, it may be useful to consider other factors such as student-teacher interaction and student engagement and differentiation between extrinsic and intrinsic motivation in improved student outcome.

9.3. Students learning outcome in blended learning as a teaching strategy

Research question 3 aimed at measuring whether VM improved learning outcomes. The use of VM in teaching histology to undergraduate students did not proved advantageous over microscope and glass slide statistically.

A meta-analysis conducted by Wilson et al. (2016) that included the screening of 725 records, of which 12 studies were viable for meta-analysis, demonstrated a small positive effect in learning with VM compared to OM. However, the outcome of the quizzes in the intervention study did not demonstrate that the students using Westminster Path XL had better results than the students having the lab-based practical sessions.

The findings in this study are supported in recent literature which suggests that the value of VM alone is still arguable. A study conducted by Hande et al. (2017) demonstrated that the use of both LM and VM are more beneficial than each of them used individually. In the current study, there was no group of students exposed to both teaching strategies alongside and this could be considered in further research; however, with the role of VM in education, this strategy may become regular practice.

Further, a study by McDaniel et al. (2018) included the use of technology and conventional teaching with a switch over of methods mid-point during the study. The students' outcome that was exposed to VM had slight better results; however, the students' outcome at the end of the study showed no difference between the groups. The literature reviewed demonstrated that students have a positive engagement with VM; however, there are few studies that showed an improved outcome using VM compared to traditional methods (Dee, 2009; Hamilton et al., 2009; Simavalai et al., 2011; Diaz-Perez et al., 2014; Brinson, 2015; Gopalan et al., 2018).

In the last few years, several studies have been published which demonstrated the value of VM in improved learning outcomes for students. Nauhria and Hangfu (2019) published a summary of the findings of five studies and provided tips for the implementation of VM in teaching undergraduate histopathology curriculum based on the outcomes of the studies and their own experience with implementing and using VM for teaching. Nauhria and Ramdass (2019) conducted a study in which sixty-two students were divided equally in two groups: VM and LM; half-way through the study, the students were crossed over. The students performed better when they were in the VM group in both cases. Also, students prefer VM as a teaching strategy. This was a study with a bigger student cohort and provided acceptable evidence for the use of VM in histopathology.

Somera dos Santos et al. (2021) conducted a study and compared the students' results exposed to VM (2019) and LM (2015) and demonstrated that no differences were found in the two cohorts and that students' preferred VM. These results support those found in the intervention study here in which students performed similarly regardless of the teaching method.

Interestingly, Amer and Nemenqani (2020) and Lee at al. (2020) discussed that better learning outcomes could be associated with prior experience using VM platforms and that students at different learning stages comprehend knowledge and internalize it in different ways. This was not considered in this study, and it could provide valuable insights for future studies.

Waugh et al. (2022) compared students learning outcome in the 2nd year (2020) using VM and the same students in the 1st year (2019) using LM and found no difference between the students learning outcome. However, when comparing the 2nd year students that completed exams in 2019 using LM and the cohort in 2020 using VM, there were differences favouring VM. Waugh et al. postulated that this could have been due to the factors related to the onset of COVID-19, the support from teachers, positive emotions, motivation and engagement from students and the full integration of online methods in teaching pathology. It could be inferred that COVID-19 has supported the implementation of online strategies which have gained momentum with students and teachers thus creating another variable that needs to be considering in teaching and education.

Considering the literature reviewed, there are a variety of approaches taken to measure whether VM improves learning outcomes in education and there is no one approach that fits all unlike the approach that is available for the diagnostic use of VM.

For diagnostic purposes, in the UK, the digital scanners that are considered are CE marked. Each organisation completes their own validation processes for diagnostic purposes based on entitled the "Best practice recommendations for implementing digital pathology" document published by the RCPath (Cross et al., 2018) as a two-stagged approach to verification and validation pathway for implementing digital pathology in the workplace for primary reporting of histopathology (Weinstein et al., 2009; Huisman et al., 2010; Paulsen et al., 2010; Park et al., 2013, Cross et al., 2018; RCPath, 2020). Recently, a digital pathology Committee was created to discuss relevant topics and advances in VM (RCPath, 2020) and there is the International Organisation for Standardisation (ISO) applicable to the laboratory practices that assist in creating a valid and robust environment for the use of VM in primary reporting (Cross et al., 2018; RCPath, 2020). All these support addressing issues relating to malpractice, liability, insurance of professionals, GDPR guidelines and privacy and security issues (RCPath, 2013; Cornish & McClintock, 2014).

Reviewing the literature on teaching students in Higher Education there are no guidelines per se for teaching using VM, i.e., there is no single document outlining the best practice. There are multiple books and articles on the topic, and each university produces their own guidelines to effectively deliver blended learning using VM to students (Nauhria and Hangfu, 2019). The literature reviewed suggests that each entity of learning can create an independent strategy for the use of VM. A finding from this research is that it would be innovative to have some guidelines developed for the use of VM as a blended learning approach in Higher Education. This is something that the UoW or other universities could consider.

Over the last ten years, the role of blended learning has been explored as a teaching and learning strategy and it was in the last five years that most studies have been published. The onset of COVID-19 has accelerated the importance of online learning as a learning and assessment tool. This study highlights some areas already considered in the literature and further work is required to understand student-teacher interactions, different online tools for teaching VM and how students' prior experience affects learning outcomes. Considering the role of technology in teaching, guidelines, and best practices for the use of VM as a blended learning approach should also be recommended.

9.4. VM as a tool to enhance students' experience

Research question 4 explored which method/s were preferred by students. The students appreciated and enjoyed the use of technology for learning. The experience of using Westminster Path XL was overall positive and a blended approach which also included microscope and glass slide and the use of technology were preferred by students. In this section, the feedback to Westminster Path XL will also be considered as part of the students' feedback on the use of the software.

The literature reviewed was rich in providing research on students' experiences of using blended learning. Blended learning is a more inclusive approach to teaching encompassing traditional learning approaches and the use of technology for teaching

(Masson, 2001; Huang, 2002; Rovai & Jordan, 2004; Farah & Maybury, 2009; Triola & Holloway, 2011; Ordi et al., 2015; Kattoua et al., 2016). The use of blended learning approaches for teaching Biomedical Scientists has become an effective and cost beneficial alternative to the use of microscope and glass slides.

Technology has been invaluable for a positive student experience and better learning outcomes, peer learning and different opportunities for student-teacher interactions and an improvement to the use of microscopy and glass slides which is well accepted by students (Wilson et al., 2016; Hande et al., 2017; McDaniel et al., 2018; Nauhria & Ramdass, 2019) and this is expressed by the students in the intervention study during the interviews. However, there are pragmatic issues that need to be considered as well as using underpinning theories on online instruction design need to be taken into consideration (Salmon, 2009). The online system needs to be well-organised and easy to access, and strategies need to be in place to encourage students to use blended approaches where both LM and VM are essential for learning to occur, these strategies should include peer learning and facilitated support (Vonderwell et al., 2007; Cambrón-Carmona et al., 2016; Pritchard & Morrow, 2017). This argument is consistent the with the results in this study particularly from students' feedback of Westminster Path XL functionalities. An additional consideration to ensure that the implementation of technology is successful, includes investment in dedicated staff to manage the online system and engagement which considers feedback from all the users: student, teacher, university, and compliance (Vainer et al., 2017). In the intervention study, students provided valuable feedback to enhance their experience. As part of the university strategy, it is important that all those involved in teaching actively participate in designing the delivery; in the section "Learning futures” below, the role of the UoW is discussed, and the challenges related to the implementation of a VM system are explored including human and financial resources.

The skill gained when learning the use of a microscope and glass slide when introducing VM in a balanced approach should be considered. Reports by teachers and students both highlighted the need to ensure that students are still able to use LM and understand the basic principles of microscopy, lenses and magnification and tissue preparation (Nauhria & Ramdass, 2019). The technical skills required to produce suitable glass slides and staining sections need the use of LM, therefore, using microscopes is essential in the laboratory and is a skill that should not be taken from the undergraduate curricula in healthcare (Blake et al., 2003; Evered & Dudding, 2011; Hamilton, et al.; 2012; Wang et al., 2012; Barbeau, 2013; Craig et al., 2014; Gatumu et al., 2014; Appasamy, 2018; Zarella et al., 2019). All these were raised by the students during the interviews as skills required to be learnt and maintained.

Students who rated their VM experience positively had a more inclusive and far-reaching approach to learning, even when the outcomes favoured microscope and glass slide approach over VM (Blake et al., 2003; Colis & Moonen, 2001 in Rovai & Jordan, 2004; Bloodgood & Ogilvie, 2006; Braun & Kearns, 2008; Wang et al., 2012; Fonseca et al., 2015; Alotaibi & AlQahtani, 2016; Achuthan et al., 2017). The literature reviewed demonstrated that students are enthusiastic about using VM; however, the use of both teaching strategies is preferred (Wilson et al., 2016; Hande et al., 2017; McDaniel et al., 2018; Nauhria & Ramdass, 2019).

This study supports these findings, that is, students expressed positive experiences when using VM. The analysis of the feedback provided by students during the interviews conducted on the student experience using VM and microscope and glass slide approaches, demonstrated it clearly. It is important also to highlight that the students appreciated and found very convenient the use of technology for teaching and learning – the idea that the images are available anytime, anywhere is particularly appealing to students who worked from different locations.

In the practical sessions at university and in the workplace, students are encouraged to take digital photos with cameras attached to microscopes or using their own smartphone cameras. Students are more inclined to use a blended learning approach where they can use a microscope and see glass slides and then apply the learning to an online format. During the interviews, students confirmed their role as active agents of learning and inquisition and appreciated the role of both LM and VM in their learning process. Students also provided feedback on the teaching strategy, the assessment, and their learning overall during the study which showed that VM as a blended learning strategy was preferred.

It is important not to underestimate that Westminster Path XL and the functionalities that the software provided in enhancing students' experience. Westminster Path XL as a product changed after the study was completed. The original product was developed by Prof Hamilton and Dr Diamond at Queen's University in Belfast, Northern Ireland (2004). In 2016, Phillips purchased the software and in the following years, software changes with additional features and a different branding were introduced. These changes were implemented after the completion of the intervention study, so the feedback provided below is for completeness to address students' experience and comments.

The feedback received from students from the online questionnaires and the analysis of the interviews regarding Westminster Path XL was that viewing the slides in the screen viewer was less straining to the eye in comparison to the microscope. However, at times, the images would not appear or take too long to compose, this issue could be related to the internet speed and connectivity that the students were using. The other reason for the image to form that longer could be due to the image size. The new software is faster, and the university storage capacity has increased to accommodate the increased number of students using Westminster Path XL. The internet connection was dependent on the speed the student was using and the type of connection, at UoW these variables were checked, and there were no reported issues with the image quality and composition.

The students also stated they preferred that image slides that were labelled, this was not directed to the supplier when setting the system, this was not considered an essential criterion for student success. The notion of labelling images created a paradox as glass slides were not labelled or marked and it could be hypothesised that the use of VM potentially deskills students in using the microscope and in identifying areas of interest prior to being shown the tagged images.

There were other areas identified for improvement not considered by the students such as course menu to allow filtering options, graticule option, back button enabled, more tools for statistical analysis for tutors, easier system for adding images to the database and coding the images and plug in to allow to automatic feedback for the

MCQ questions. Other areas that should be considered when delivering blended learning in healthcare is the used of gross pathology and a multidisciplinary approach including imaging and others pathology disciplines when teaching students using the full capabilities of VM to create a complete simulation for clinical practice for students (Merk et al., 2010; Thomas et al., 2014; Gopalan et al., 2018) and this is available on Westminster Path XL. Also, using near-peer learning in the classroom setting with collaborative annotation of a slide in a synchronous environment are ways to create an enabling environment for learning (Vonderwell et al., 2007; Saco et al., 2016; Pritchard & Morrow, 2017), this has been supported at UoW with the development of the VM suite.

Some students in the study reported preferring the use of pen and pencil and the use of microscope and glass slides to learn so this cannot be disregarded entirely as a preferred learning style. This is supported in the literature when several studies claim that to provide the best experience to the students, it is essential to consider that both skills are still required in the workplace, dexterity using the microscope and glass slide plus the use of digital technology (Garrison & Cleveland-Innes, 2005; Vonderwell et al., 2007; Moore et al., 2011; Kattoua et al., 2016; Wilson et al., 2016; Hande et al., 2017; Pritchard & Morrow, 2017; McDaniel et al., 2018; Nauhria & Ramdass, 2019).

Feedback is an essential element for learning which guides students on how they achieved the learning outcomes. The literature described feedback in detail, and the context of VM, instant feedback or personalised feedback was better appreciated by students (Haladyna et al., 2002; Ramsden, 2003; Heinrich et al., 2009; Llamas-Nistal et al., 2013; The University of Edinburgh, 2020). More recently, video feedback has demonstrated improved motivation and improved students learning outcome (Donkin et al., 2019).

Student feedback in the study was an element that could have been improved. When setting up the quizzes for this study, instant feedback for questions 1 and 2 was not included, in hindsight, this could have contributed to the improvement of students' outcomes in the following quizzes and could have provided opportunity for students' development and the improvement of the Westminster Path XL quizzes. Also, only one group feedback session was held with the students for each of the cohorts due to the ease of the processes, time, and location and individual face-to-face feedback sessions was more challenging. The number of students attending the feedback session was low and it seemed that the lack of presence might have impacted student performance in quiz two and three; however, this was not measurable.

At the design stage of this study, group feedback seemed the most appropriate approach. However, student feedback in the questionnaire and interviews demonstrated that students preferred personalised feedback, and this has been shown to have exponentially positive outcomes for students. This was not considered essential by the researcher, and it was not raised by students in the pilot study. It was only later that it became clear that one-to-one feedback after the summative assessment was preferred by students than group feedback. Other research found similar results as described earlier (Arend, 2006; Heinrich et al., 2009; Biggs & Tang, 2011).

Most of the teaching in this study was done face-to-face during the tutorial sessions but there was a different type of engagement with the practical element of the intervention. Whilst students in group A had presential practical sessions with microscope and glass slides, the students in group B engaged with the material online, which had been set up previously and the tutor was not necessarily online at the same time because the studying of the slides was outside the teaching schedule. In this sense, there was a combination of synchronous and asynchronous learning, this is much in keeping with the strategies used for online learning (Vonderwell et al., 2007; Saco et al., 2016; Pritchard & Morrow, 2017).

On researching the literature, four stages of students' engagement were described by Higher Education Agency (HEA) and National Union of Students (NUS), 2011: consultation, involvement, participation, and partnership (Gibbs, 2013; Healey et al., 2014). While this model was not knowingly considered at the time, consultation with the students in the pilot study as a feedback mechanism was present to review the intervention study accordingly. In this study, there were moments where student engagement was valuable, during the practical session students in group A contributed to the smooth running of the sessions with their participation and input, both in the pilot and intervention study. The feedback provided by the students after the intervention study was very useful in suggesting areas to consider for future research such as the features of Westminster Path XL, the use of different functions of the software and the training delivery.

The intervention study employed a blended learning approach using face-to-face training, practical laboratory sessions and VM with asynchronous methodology. Assessment methods which were carefully designed considered theoretical underpinnings and practical methodological approaches to good effect, the students expressed their positive views and areas of strength and areas for improvement during the interviews.

Some literature reviewed questioned the use of VM exclusively to teach students (Pratt, 2009; Donnelly et al., 2012; McDaniel et al., 2018). A survey by Pratt (2009) states that there are very few fully digitised laboratories, so students needed to be able to use the microscope and glass slides where microscopy is the primary role of the laboratory. Some literature suggested that using VM only in the context of blended learning at university where face-to-face tutorial sessions is held may be limiting. So, linking the use of VM to near-peer learning seemed to offer significant advantages to consolidate knowledge and develop students social and leadership skills and promote student engagement in an enabling environment (McLoughlin, 2000; Goldberg & Dintzis, 2007; Gatumu et al., 2014; Khaw & Raw, 2016; Saco et al., 2016).

Some of the students in the study reported that the student-student interaction was crucial in facilitating their learning. This has been reported in other studies where students appreciate that they have close interactions with the teacher as supporting student development and learning (Goldberg & Dintzis, 2007; Gatumu et al., 2014; Khaw & Raw, 2016; Bonem et at., 2019; Baber, 2020; Bardach & Klassen, 2021; Holzer et al., 2021; Capon-Sieber et al., 2022). In this study, students that had the facilitated sessions with the microscope and glass slide had very close interactions with the teacher, a ratio of one teacher to a maximum of eight students in the practical sessions. These students had one microscope each, and there were five sets of slides which students could use and exchange, this set included regular and large slides. The students in group A reported that they had greater peer interaction and more dedicated time with the teacher which supported their learning and continuous engagement in the study.

This study did not consider the role of near-peer learning, asynchronous learning, student's social interaction in the learning process and the role of feedback in student's success. Some of these were raised by students during the interviews and in the recent literature (Mason, 2001; Garrison & Cleveland-Innes, 2005; Vonderwell et al., 2007; Moore et al., 2011; Kattoua et al., 2016; Pritchard & Morrow, 2017); these areas should be considered in future work.

The use of VM for teaching and learning as a blended learning tool in Higher Education is widely accepted; however, the role of VM alone is still controversial. The most recent studies discuss the role of motivation, engagement, peer-support, and student-teacher interaction alongside the use of VM to demonstrate improved learning outcomes for students. Students experience in the study was overall positive and the use of VM as a learning and assessment tool was supported by students.

9.5. Additional themes resulting from this research but do not fall within the four research questions discussed above

The themes raised below relate to the development of a technology enhanced curriculum at UoW and the application of VM in the workplace where the researcher practices.

9.5.1. Learning futures at the UoW and VM

For many years now there are a multitude of websites, virtual collections, and MOOCs, free or with subscriptions available for students and professionals in healthcare (Onah et al., 2014; Achuthan et al., 2017; Gregori et al., 2018).

At UoW, the development of learning and teaching strategy for 2012-13 for a five-year period included the introduction of VM with Westminster Path XL in the academic year 2016-17 and a significant investment in hardware namely the acquisition of iPads loaned to students. In the reviewed learning and teaching strategy for 2018-23, there was a renewed commitment to teaching and learning with an emphasis on assessment and feedback and with great focus on the digital environment. In the academic 2018-19, a new VM suite has been purposely refurbished at UoW, in which there was a master screen that allows Westminster Path XL to be displayed and five small group Tables with a 40inch Smart Screen TVs that can be shared by up to 7 students in each to facilitate the running of practical VM sessions. Students can book this facility for group studying. This new facility has proven to be quite resourceful, and lecturers and students reported in their module feedback that this new facility is very effective for teaching and learning purposes. This study fully integrates with the strategy of learning futures at the UoW and supports the continued investment in blended learning using VM both staffing and financial commitment which translates into the learning and teaching strategy for the University.

Westminster Path XL licence was purchased, and a digital scanner was acquired. The early slides were scanned using a Hamamatsu scanner and then a VisionTek scanner

(Sakura), which were on trial. The Hamamatsu scanner had a basic software, the image quality was good and the VisionTek was good for projecting images on a wall; however, it was not able to scan in a high throughput environment. The Axio Scan.Z1 (Zeiss) was chosen as it had the best lenses resolution versus cost, the image quality is very good, the software allows more functions, and the scanner offers the option to use fluorescent scanning.

There is a library of digital images with thousands of images stored at the UoW servers, and Westminster Path XL is currently used in many modules in the Life Sciences modules as applied pathobiology and cellular and molecular pathology. The pathway of using VM is established; however, the effective use of Westminster Path XL is still not fully achieved. The use of Westminster Path XL in other modules could be considered and the use of the different features available such as office documents and videos to include gross dissection, other pathology and radiological images and videos could create a complete simulation for clinical practice for students. In addition, the development of a VM strategy with additional human resources would enable the university to develop more research and enable further training courses and support for students and lecturers in developing better resources for students.

9.5.2. Application of VM in the workplace

The skills gained when learning VM are applicable in the workplace and vice-versa, when checking the quality of staining, students need to identify the tissue using the microscope or the digital slides. In this study, students demonstrated a great flexibility in using VM and the students in ICNHST cohort demonstrated overall better learning outcomes than the other two cohort of students.

In recent years there has been an enormous drive to implement VM in laboratories, NHS innovation and improvement strategies have provided grants for laboratories wishing to implement a fully digital system (Pathology in Practice, 2020; South West London Pathology, 2020; Babawale et al., 2021). The use of VM in diagnostic laboratories has been validated in the UK at Leeds Hospital and there are other Hospitals in the process of validating VM for primary reporting (Cross et al., 2018).

The London Deanery developed a partnership with Path XL in 2012 in a pilot study to support in providing training for histopathologists and haematologist based on the training curricula of the RCPath, and early reports were favourable to the use of VM for teaching purposes (Thomas et al., 2014).

The interpretative External Quality Assurance (EQA) for pathologists and CPD traditionally includes the provision of glass slides, and more recently, VM is being used to reduce costs and improve response rate (Thomas et al., 2014; Brereton et al., 2015; RCPath, 2022).

At NWLP the use of VM for diagnostic purposed is underway. A retrospective review of cases for the period June - November 2018 was performed to validate stage 1 of WSI (Cross et al., 2018), there were thirty Consultant Histopathologists invited to participate in phase 1 in the eight specialities. The process started with training all pathologist and junior doctors using the scanner Phillips Intellisite Pathology Solution and the image viewing software Phillips Digital Pathology Solutions, following the digitisation of 20 cases/slides per speciality available in NWLP. All pathologists were asked to review the slides independently and record the diagnosis on a template sheet for each case using VM, in addition, the pathologists noted the confidence level in reporting each case using and any changes of diagnosis using VM. The consultant should also include the preferred method of diagnosis for each case. The mean diagnostic concordance was high and the mean diagnostic confidence for VM and glass slide was low. Interestingly, only a very low number of pathologists preferred VM alone.

Overall, the results of phase 1 demonstrated that the concordance between VM and glass slide was high, and the majority had no preference in the diagnostic modality, this is important to demonstrate the value of VM in the workplace at NWLP and can support the business case for digitization of the service. Stage 2 for medical renal and liver biopsies has been performed and since April 2020 these are scanned using the Aperio AT2 (Leica) at Charing Cross Hospital, which is a high throughput scanner. Phase 2 of the validation process is a prospective study over a period using live cases and soon the department will consider phase 2 for the other specialities. The findings of phase 1 were presented on the 9th of September 2019, in a poster entitled "RCPath Validation protocol for digital pathology stage 1: our experience in a large tertiary academic centre" at the 31st European Congress of Pathology by Mohamed Elsheikh, Martina Munonyara and Corrina Wright.

At the spoke's sites there are single slide scanners (Aperio CS2, Leica) which are used to scan frozen sections slides. The department has acquired teaching monitors to support teaching and learning of the junior doctors and peer review of slides.

9.6. Summary

The recent literature review in February 2022 showed studies in the field of VM and teaching of undergraduate students. The findings of this research were in agreement with some of the research studies showing that the use of VM provides an equivalent approach to LM and students' perception and preference is towards VM.

Further research should consider a bigger student cohort with a heterogenous distribution to assess processing style and working memory and a cohort with gender parity would be required to assess the role of stress and motivation tasks in teaching students using VM. The completion of the tasks post-delivery of the sessions would enable a comparison of the students' profile pre and post intervention. Also, a few additional variables should be included such as near-peer learning and student engagement, student-teacher interaction, teacher support and COVID-19 when considering the role of VM in teaching undergraduate students.

The next chapter will provide a summary of the findings in the thesis, proposes development in teaching strategies and areas for further research.

10. Conclusion and recommendations

This chapter highlights the topics explored in the thesis and answers the research hypothesis. Also, it will provide recommendations for development in teaching strategies and highlight related areas for future research.

The current study demonstrated that VM, as a blended learning tool, is as good as glass slide and microscopy approach in teaching undergraduate students in tissue recognition. Also, the use of psychometric tasks for processing speed and working memory cannot be used as predictors of students' success. Motivation and stress cannot be used as predictors of students' outcome.

Recent literature in the field of VM and pattern recognition for histology applied to teaching and learning of undergraduate Biomedical Sciences students or other fields has shown some progress has taken place. In the last few articles more studies have been published and the outcomes are not dissimilar than the ones found on this study. In discussion with peers, VM as a blended learning approach is an area of interest. However, the financial investment, the staffing restructure, and the availability to conduct studies of these nature were not considered priority. Considering the international challenges with COVID-19 since March 2020, the area of blended learning and online learning are gaining momentum and it is expected that much work may be commissioned in the forthcoming years.

In the field of diagnostic pathology, exploring the use of VM is steadily higher, there are many reports of the use of VM in histology, there is an increased demand for this approach in diagnostic settings, and there are now few fully digital pathology laboratories in the UK and others following suit including ICNHST.

The pilot study conducted in February 2016, which included thirteen students and three students' groups from two different Institutions, two separate delivery sessions, demonstrated that any intervention through the introduction of a practical component, whether microscopy sessions or blended learning using Westminster Path XL, to support students in engaging with histology content is positive and produces better student outcomes when compared to no intervention improving students' experience. Students provided feedback which was implemented in the intervention study.

The intervention study conducted by the researcher in the period January 2017 to October 2018, that included twenty-eight students and two students' groups from three different Institutions, four separate delivery sessions, twenty-seven students completed quiz one and seventeen students completed quiz three. This is in par with other studies reported and available in the literature reviewed of having an average of eighteen participants and one end-point assessment only.

The study demonstrates that there is no significant difference when using VM or teaching students with microscope and glass slide. The students in the intervention study had a wide range of ages and of familiarity with the subject and the use of technology, the latter not formally measured but available through the interviews and the informal discussion with the students, these variables were discussed in previous chapters.

The use of psychometric tasks for processing style, processing speed and memory span has not demonstrated convincing patterns to predict student success in tissue recognition in histology; however, there seems to be no advantage on having a featural processing style in tissue recognition. The use of motivation and stress levels cannot be used to predict student outcome, although higher motivation levels seem to translate in higher student engagement and stress has a weak negative correlation with quiz one result.

There are many studies on student's perception of blended learning and the use of VM for teaching. In the study, students appreciated the sessions where they used microscope and glass slides as a way of improving and consolidate learning and the teaching in small group sessions.

The use of Westminster Path XL has been found useful for students from a user perspective particularly as it allows students' independent study; however, some areas could be improved both in the viewer and quiz sections.

Blended learning VM was not more effective that glass slide/textbook approach. There are technological, student-teacher interactions and students learning preference that need to be considered. VM provides an equivalent approach as microscope and glass slide, and it can be used as an alternative or concurrently to conventional methods and as a strategy to enhance the variety of methods available to suit students individual learning preferences.

The researcher recommends that both approaches are available to students in a balanced manner. The researcher recommends that improvements are made to the software to create an enabling environment for students in the viewer software and the online assessment element.

The tissue recognition process remains poorly understood at a neurophysiologic level, and future research should include eye-tracking of visual acuity, machine learning, deep learning, and artificial intelligence. The use of cognitive processes at the beginning and the end of the intervention could be considered to understand if an intervention can modify learning outcomes and change cognitive characteristics.

It is suggested that a study involving different VM software with higher student cohort demographics and assessing learning outcomes across various regions in the UK could be considered and this would demonstrate the variability of student profiles across the learning landscape despite the challenges inherent to a national study. A multidisciplinary approach could also be considered to include other disciplines in healthcare as imaging and other disciplines in pathology.

A study using VM as a blended approach and considering the role of peer and instant feedback for students using this method approach and near-peer learning in blended learning should be considered.

11. Author's reflexive statement

The journey of completing the Professional Doctorate in Life Sciences has been very challenging but also stimulating. The journey started in 2012 and since then many personal, professional, and academic turns created different opportunities for the researcher. Besides this, the development and implementation of the study and the write-up of the thesis had its own trials. This chapter will explore this from the researcher's perspective.

Starting of the process

One of the earliest struggles was creating a deliverable that I wanted to achieve, and that was suitable for the Professional Doctorate. My idea was to develop and implement a training tool that could be used in the workplace to facilitate the staff learning and professional development. I dwelled with some ideas, advantages, and disadvantages and how to deliver these. Once I had a firmer idea around the use of digital pathology in teaching, the supervisors were supportive and were engaged with the process of ensuring that the best question could be set up and I felt supported in the process. Dr Maitland has also been instrumental in keeping up with me as a student during the earlier years when I attended lectures.

Preparation of the tools for the study

Once the scope of the study was designed it was great to see it come to fruition, completing the ethical research documents and the proposal, selecting the tissue and the cases for the delivery, scanning, and setting up of Westminster Path XL, organising the sessions and preparing the handouts for the students went quite smoothly.

It had been long since I completed the ethical research documentation for the university, the documentation had changed, the ethical research documentation for ICNHST was more familiar. I was able to use the knowledge and skills to complete both in an appropriate manner. I consulted one of the pathologists at work and he was supportive in the process.

The preparation of the glass slides was uneventful as I am familiar with the process; however, the scanning of the slides required some learning on the process of loading/unloading the scanner, appreciating the quality of the slide, calibrating the instrument, and discriminating between the tissue section and other areas in the slide that did not require scanning. To assist in the process and to ensure that the scanner would not break, I had training to use the equipment, and this allowed me to feel at ease using it.

Psychometric tasks preparation and delivery

The subject of cognitive psychology was novel to me therefore much learning, reading, and understanding about the subject was required during the entirety of the research, I networked with individuals knowledgeable in the field and I learnt how to express my views differently.

I had to learn, understand, and deliver the psychometric tasks and this process required personal concentration and dedication to the process, I felt the responsibility of the information I had learnt and took the delivery of the sessions with the utmost respect checking in with Dr Edginton when I felt that I required additional support. In the first set of deliveries, I would say I was more nervous and conscious than the learners and as I became more familiar with the tasks, I became more relaxed without losing objectivity.

I carefully considered the physical space and the emotional space for the delivery and the delivery of the tasks themselves, and this included a multitude of smaller tasks. When providing instructions to the student, I followed the structure set to ensure reliability and consistency: the voice must be clear and without bias or chunking; in the delivery of some tasks the pacing, speed and pitch were critical to ensure reproducibility and avoid own bias hence I had to prepare and practice prior to the delivery of the tasks.

Session's delivery

The content of the sessions was familiar to me, and I felt confident during the tutorial sessions. However, the delivery of the tutorial sessions required some organisation in that, I had enough handouts printed for each session, the rooms with projection facilities were booked at three different venues and, I had to be mindful that students were either finishing a previous tutorial or finishing work to attend the sessions so they would be rushing or feeling tired to engage more actively in each session. The students were, in most cases, very agreeable and kept the engagement and students' expectations also had to be managed in terms of the content delivered and the allocated time for each session.

The delivery of the practical sessions went very well, laboratory with microscopes were booked and I had to ensure that I had enough slides for all students. Some sessions took longer than expected as students did not want to leave as they had additional questions related to the topic and students felt that the opportunity to spend time on the microscope was invaluable.

The students were overall very supportive, and it was great to see them developing in their academic and professional skills throughout the study. It gave me great satisfaction when some of the students contacted me to let me know they had got a job after graduation and kept in contact with me.

Qualitative and quantitative methods

To analyse the data produced in the study I required a refresher in IBM SPSS version 25 and dedicated some time downloading the newer version and exploring the software, this was relatively straight forward. I further refreshed on the different statistical branches and had to understand how to use them for my research and inferential statistics took longer to acquaint. I was grateful for the support of a colleague who dedicated time to support me in this task. In the later reviews of the write-up, I felt that the time invested and the support from colleagues had made a difference and I was confident with the use of the software.

Qualitative research was new to my array of skills and to effectively understand it and be able to reflect on it, I struggled somehow, I learnt a new approach to evaluate information, write and reflect on my practice and explore these which does not come naturally to me in academic writing.

Reviewing the content produced by the interviews, required that I learn about how to conduct them in an effective manner including how to set the scene, manage discussion and promote a trusting environment, how to extract the information from the interviews in a meaningful way and how to analyse it. this was a laborious process and I felt supported by the supervisors. Further reading, many discussions and multiple iterations were required to understand the way interview analysis made my research richer.

Thesis write-up

The write-up of the thesis was a continuous process that started when the draft was submitted and continued after the pilot study. This process was less organised, and I struggled with writing the thesis on a continuous and systematic way. At each turn of the academic year when I submitted my updated report, this was one of those opportunities to take stock and I was able to dedicate more time with reviewing my achievements, redoing the literature review, and checking for new updates on the literature and to plan the following year. The year 2017 was challenging, one of the reasons was due to work related commitments, I was promoted to Laboratory Manager in 2017 and was involved in the centralisation of histology services in North West London Pathology since then. In my personal life, I also had major events taking place at the time which meant I had to balance all these other activities with my personal academic development and continuing the practical work with the study whilst working full-time.

During 2017-2018, pursing the Professional Doctorate became overwhelming and I felt disengaged with the academic process. I could see that I was on track in terms of delivering the study and gaining the students engagement and feedback. However, I struggled to keep sight of the writing and at times failed to see the bigger picture. For me, the bigger picture is manifold: my personal development which includes the pursuit of knowledge in my faith and my professional development, the notion of bringing new learning tools to students and the building of new body of knowledge to enable technology and learning opportunities to progress and thrive. During these trialling times, some close friends and my sister nudged me softly to complete the thesis and reminded me of my goal.

New opportunities

In the Summer of 2018, I was invited to complete the Postgraduate Certificate in Teaching and Learning in Higher Education at LMetU as I am a visiting lecturer at the university and in September 2018, I started this certificate. Though it was challenging to manage all the demands that I had, I soon found out the benefits of being exposed to the learning theories and pedagogies explored in the modules which have been invaluable to understand the theoretical underpinnings that I had to explain in the write-up and found it valuable to engage with like-minded colleagues.

It was in 2019 that I was exposed to the writing retreat concepts which I attended and found it extremely useful to assist me in systematic writing (Murray and Newton, 2009). The retreat provided by an approach but also the impetus and the drive to complete the writing journey, the event was well structured, and the session lead explained the day clearly, I was not so sure about the process and the importance of the talk/debrief initially but going through the process provided new insights and a better way of working and putting your work in action. Since using this model, I have been using this approach to assist me with tasks that require a high degree of focus and discipline, whether is writing or studying. One of the challenges in doing a

Professional Doctorate is that you are not in a university context all the time and the information and facilities that are available if you are off site at times goes unnoticed, this was one of those that had I been exposed earlier may have served me better.

My confidence in delivering presentations, chairing meetings and networking outside my comfort zone grew, I presented an interactive session with Dr Tony Warford in 2015 and another session with Dr Tony Madgwick in 2016. I delivered a presentation at the IBMS congress in 2017 and presented at the Postgraduate session in 2018 in the psychology session. I presented several posters in "Digital training in Histopathology" with the relevant updates at the time in different fora: 2016, 2017 and 2018. I chaired the afternoon sessions of Issues with Tissues in 2016, 2017 and 2019.

I was planning to present a poster at Digital Pathology in December 2019 and another ant the European Conference of Pathologists in 2020; however, with the international challenges with COVID this did not take place. I plan to write several articles on my finding's relevant fields of psychology, education, and pathology as opportune and I have explored the appropriate journals to publish.

The study has affected my practice as it increased my knowledge in the areas of education and psychology, I can appreciate how students learn, how to support them better and how to engage them and keep their motivation by using newer functionalities in the technologies used, the importance of instant and personalised feedback and near peer-learning in the process. Also, I have a better appreciation of different learning styles and am now better equipped to engage with qualitative research and reflection.

Completing the thesis and presenting it to a wider audience, experts in the different fields of practice, particularly when it will be exposed to critique is provocative. However, this is the product of my work, and I completed this work with all my passion, and I am proud of the final draft. Part of the process of completing the Professional Doctorate allowed me to learn new skills, know myself better and push myself into the unknown. Completing the thesis is also a testament to my personal resilience and persistence in completing this project which started in 2012 whilst balancing all other areas of my life.

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Appendix 1 – Participant Information Sheet and Consent Form

PARTICIPATION INFORMATION SHEET

<u>Seeing and Naming Patterns (SNAP)</u>

Researcher: Nymeth Ali

Supervisor: Dr Anthony Madgwick & Dr Trudi Edginton

You are being invited to take part in a research study to understand the impact of blended learning with virtual microscopy in the training of undergraduate students compared with glass-slide/textbook approaches.

This research is being undertaken as part of the researcher's studies for the Professional Doctorate in Life Sciences at the University of Westminster.

The study will involve you:

1) To complete some initial tasks to allocate each student to a different group, this should take 30min. per individual.
2) Attend 6 tutorial sessions during the 2016-2017 academic year, for a maximum of 30 min each session.
3) An assessment after 2 sessions and after session 6. Also, there will be a one month and three month post formative assessment. Each of the assessments should take a maximum of 15min.

4) At the end of the study, a questionnaire will be given to each participant to complete.
5) A cohort of students will be invited to participate in in-depth interviews at the end of the study.

This study is an additional training to the core modules you need to undertake to complete your undergraduate degree and will have no impact on your final grades.

For this study, you will be provided additional resources in the form of slides and virtual microscopy for the duration of the program which you can use at any time. All the material that is being provided will aid your practical skills in the laboratory and you will gain skills that you can apply during your undergraduate degree and in the workplace; all slides and images provided are real cases that will expose you to histology content which will enrich your knowledge in histopathology.

Please note:

- Your participation in this research is entirely voluntary.
- You have the right to withdraw at any time without giving a reason.
- Withdrawal from the research project will have no direct effect upon your academic assessment and marks.
- You have the right to ask for your data to be withdrawn as long as this is practical, and for personal information to be destroyed.

- Your responses will normally be made anonymous, unless indicated above to the contrary, and will be kept confidential unless you provide explicit consent to do otherwise, for example, the use of your image from photographs and/or video recordings.
- No individuals should be identifiable from any collated data, written report of the research, or any publications arising from it.
- All computer data files will be encrypted and password protected. The researcher will keep files in a secure place and will comply with the requirements of the Data Protection Act.
- All hard copy documents, e.g. consent forms, completed questionnaires, etc. will be kept securely and in a locked cupboard, wherever possible on University premises. Documents may be scanned and stored electronically. This may be done to enable secure transmission of data to the university's secure computer systems.
- If you wish you, can receive information on the results of the research. Please indicate on the consent form if you would like to receive this information.
- The researcher can be contacted during and after participation by email (Nymeth.ali@my.westminster.ac.uk).
- If you have a complaint about this research project you can contact the project supervisor, Dr. Anthony Madgwick by e-mail (T.Madgwick@westminster.ac.uk) or by telephone (0207 911 5000 ext 64157).

CONSENT FORM

Title of Study: **Seeing and Naming Patterns (SNAP)**

Lead researcher: Nymeth Ali

I have been given the Participation Information Sheet and/or had its contents explained to me.	Yes ❒	No ❒
I have had an opportunity to ask any questions and I am satisfied with the answers given.	Yes ❒	No ❒
I understand I have a right to withdraw from the research at any time and I do not have to provide a reason.	Yes ❒	No ❒
I understand that if I withdraw from the research any data included in the results will be removed if that is practicable (I understand that once anonymised data has been collated into other datasets it may not be possible to remove that data).	Yes ❒	No ❒
I give permission that my entry grades and the results of my university modules are accessible to the investigator.	Yes ❒	No ❒
I would like to receive information relating to the results from this study.	Yes ❒	No ❒
I wish to receive a copy of this Consent form.	Yes ❒	No ❒
I confirm I am willing to be a participant in the above research study.	Yes ❒	No ❒
I note the data collected may be retained in an archive and I am happy for my data to be reused as part of future research activities. I note my data will be fully anonymised (if applicable).	Yes ❒	No ❒

Participant's Name: ______________________________

Signature: ______________________________ **Date:** ________________

This consent form will be stored separately from any data you provide so that your responses remain anonymous.

____

I confirm I have provided a copy of the Participant Information Sheet approved by the Research Ethics Committee to the participant and fully explained its contents. I have given the participant an opportunity to ask questions, which have been answered.

Researcher's Name: ______________________________

Signature: ______________________________ **Date:** ________________

Appendix 2 – Perceived Stress Scale Questionnaire

Perceived stress scale (PSS) by Sheldon Cohen (1994)

www.mindgarden.com

Name: ____ Date: _______

Age: ____________________Gender (circle) F M

0 = Never 1 = Almost never 2 = Sometimes 3 = Fairly Often 4 = Very often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and "stressed"?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last month, how often have you found that things were going your way?	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4

7. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last month, how often have you been angered because of the things that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Scoring: PSS scores are obtained by reversing responses (0=4, 1=3, 2=2, 3=1, 4=0) to the four positive stated items (items 4, 5, 7 and 8) and then summing across all scale items.

Scale out of 40, score around 13 being considered average:

- Scores ranging from 0-13 are considered low stress.
- Scores ranging from 14-26 are considered moderate stress.
- Scores ranging from 27-40 are considered high perceived stress

Appendix 3 – Motivation Questionnaire

Motivation questionnaire

Tuan, H-L.; Chin, C-C.; Shieh, S. (2005). The development of a questionnaire to measure students' motivation towards science learning. International Journal of Science Education, vol 27, 6: 639–654.

1 = if the statement you strongly disagree

2 = if the statement you disagree

3 = if the statement you have no opinion

4 = if the statement you agree

5 = if the statement you strongly agree

1. Whether the science content is difficult or easy, I am sure that I can understand it.	1	2	3	4	5
2. I am not confident about understanding difficult science concepts.	1	2	3	4	5
3. I am sure that I can do well on science tests.	1	2	3	4	5
4. No matter how much effort I put in, I cannot learn science.	1	2	3	4	5
5. When science activities are too difficult, I give up or only do the easy parts.	1	2	3	4	5

6. During science activities, I prefer to ask other people for the answer rather than think for myself.	1	2	3	4	5
7. When I find the science content difficult, I do not try to learn it.	1	2	3	4	5
8. When learning new concepts, I attempt to understand them.	1	2	3	4	5
9. When learning new science concepts, I connect them to my previous experiences.	1	2	3	4	5
10. When I do not understand a science concept, I find relevant resources that will help me.	1	2	3	4	5
11. When I do not understand a science concept, I would discuss with the teacher or other students to clarify my understanding.	1	2	3	4	5
12. During the learning processes, I attempt to make connections between the concepts that I learn.	1	2	3	4	5
13. When I make a mistake, I try to find out why.	1	2	3	4	5
14. When I meet science concepts that I do not understand, I still try to learn them.	1	2	3	4	5
15. When new science concepts that I have learned conflict with my previous understanding, I try to understand why.	1	2	3	4	5
16. I think that learning science is important because I can use it in my daily life.	1	2	3	4	5
17. I think that learning science is important because it stimulates my thinking.	1	2	3	4	5
18. In science, I think it is important to learn to solve problems.	1	2	3	4	5

19. In science, I think it is important to participate in inquiry activities.	1	2	3	4	5
20. It is important to have the opportunity to satisfy my own curiosity when learning science.	1	2	3	4	5
21. I participate in science courses to get a good grade.	1	2	3	4	5
22. I participate in science courses to perform better than other students.	1	2	3	4	5
23. I participate in science courses so that other students think that I am smart.	1	2	3	4	5
24. I participate in science courses so that the teacher pays attention to me.	1	2	3	4	5
25. During s science course, I feel most fulfilled when I attain a good score in a test.	1	2	3	4	5
26. I feel mist fulfilled when I feel confidents about the content in a science course.	1	2	3	4	5
27. During a science course, I feel most fulfilled when I am able to solve a difficult problem.	1	2	3	4	5
28. During a science course, I feel most fulfilled when the teacher accepts my ideas.	1	2	3	4	5
29. During a science course, I feel most fulfilled when other students accept my ideas.	1	2	3	4	5
30. I am willing to participate in this science course the content is exciting and changeable.	1	2	3	4	5
31. I am willing to participate in this science course because the teacher uses a variety of teaching methods.	1	2	3	4	5

32. I am willing to participate in this science course because the teacher does not put a lot of pressure on me.	1	2	3	4	5
33. I am willing to participate in this science course because the teacher pays attention to me.	1	2	3	4	5
34. I am willing to participate in this science course because it is challenging.	1	2	3	4	5
35. I am willing to participate in this science course because the students are involved in discussions.	1	2	3	4	5

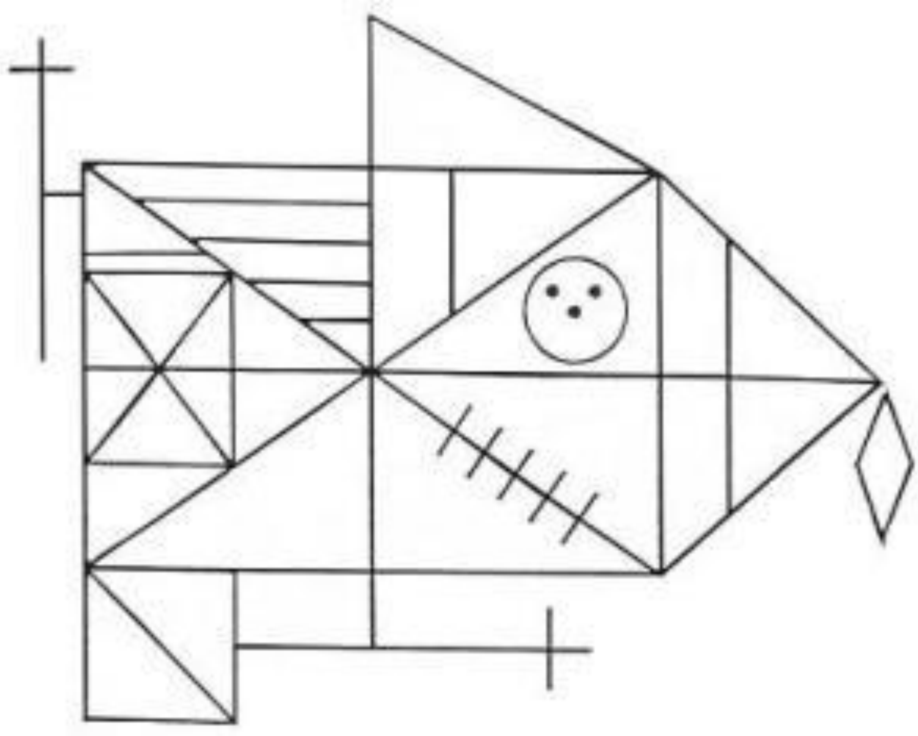
Reverse scoring questions for questions: 2, 4, 5, 6, 7 21, 22, 23 and 24.

Scale out of 175, score of 120 is the mean:

- Scores of 132 and above are considered high motivation.
- Scores around 123 are considered moderate motivation.
- Scores of 114 and below are considered low motivation.

Appendix 4 – Rey-Osterrieth Task

Rey-Osterrieth image (as provided by Dr Edginton)



Appendix 5 – WAIS Version III Task

Digit span task (as provided by Dr Edginton)

Digit forward		**Trail score**	**Item score (0,1,2)**
1	1-7		
	6-3		
2	5-8-2		
	6-9-4		
3	6-4-3-9		
	7-2-8-6		
4	4-2-7-3-1		
	7-5-8-3-6		
5	6-1-9-4-7-3		
	3-9-2-4-8-7		
6	5-9-1-7-4-2-8		
	4-1-7-9-3-8-6		
7	5-8-1-9-2-6-4-7		
	3-8-2-9-5-1-7-4		
8	2-7-5-8-6-2-5-8-4		
	7-1-3-9-4-2-5-6-8		
	Total score (maximum = 16)		

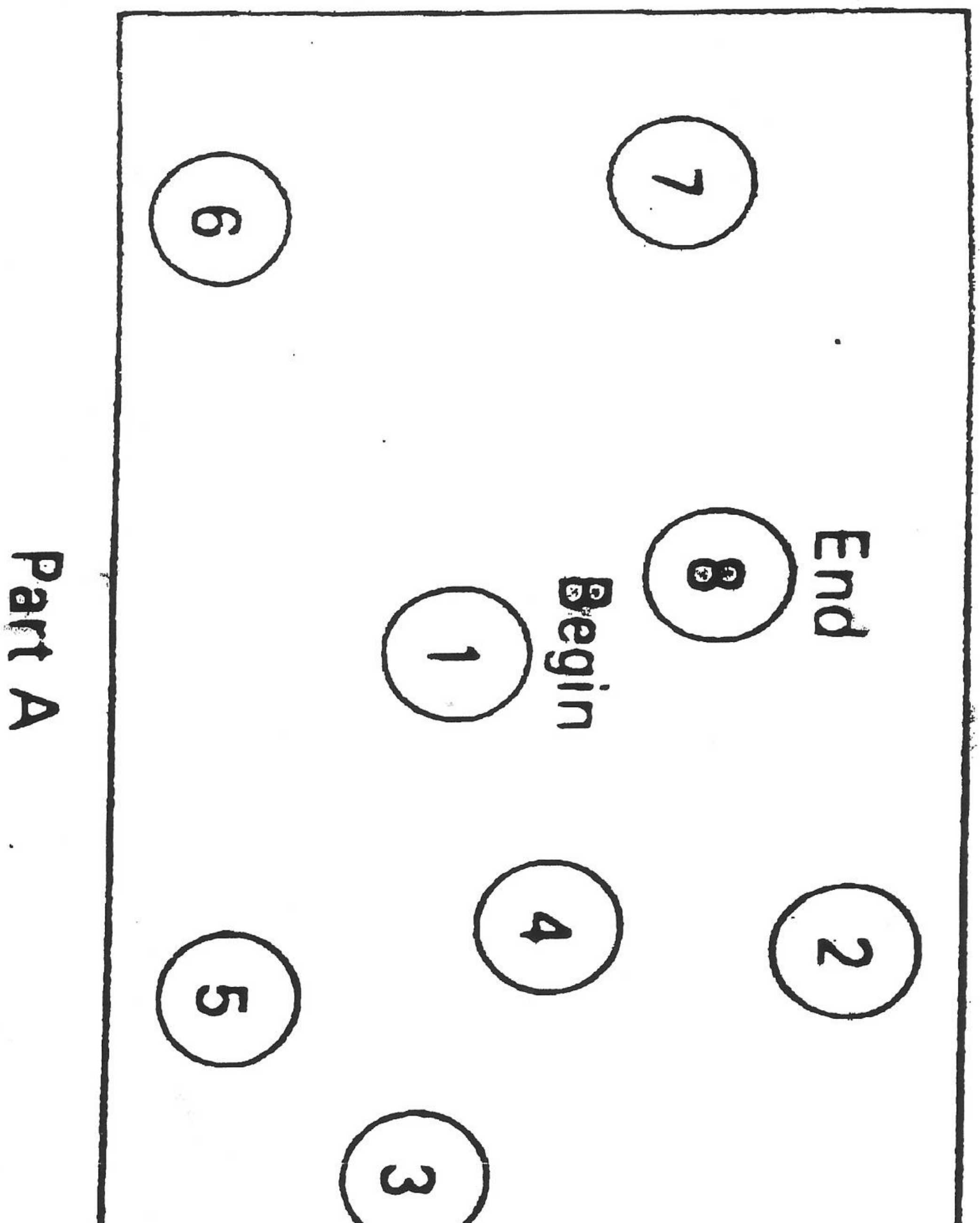
Digit backward		Trail score	Item score (0,1,2)
1	2-4		
	5-7		
2	6-2-9		
	4-1-5		
3	3-2-7-9		
	4-9-6-8		
4	1-5-2-8-6		
	6-1-8-4-3		
5	5-3-9-4-1-8		
	7-2-4-8-5-6		
6	8-1-2-9-3-6-5		
	4-7-3-9-1-2-8		
7	9-4-3-7-6-2-5-8		
	7-2-8-1-9-6-5-3		
	Total score (maximum = 14)		

Letter-number sequencing		Trail score	Item score (0,1,2,3)
1	L-2 (2-L)		
	6-P (6-P)		
	B-5 (5-B)		
2	F-7-L (7-F-L)		
	R-4-D (4-D-R-)		
	H-1-8 (1-8-H)		
3	T-9-A-3 (3-9-A-T)		
	V-1-J-5 (1-5-J-V)		
	7-N-4-L (4-7-L-N)		
4	8-D-6-G-1 (1-6-8-D-G)		
	K-2-C-7-S (2-7-C-K-S)		
	5-P-3-Y-9 (3-5-9-P-Y)		
5	M-4-E-7-Q-2 (2-4-7-M-Q)		
	W-8-H-5-F-3 (3-5-8-F-H-W)		
	6-G-9-A-2-S (2-6-9-A-G-S)		
6	R-3-B-4-Z-1-C (1-3-4-A-C-R-Z)		
	5-T-9-J-2-X-7 (2-5-7-9-J-T-Z)		
	E-1-H-8-R-4-D (1-4-8-D-E-H-R)		
7	5-H-9-S-2-N-6-A (2-5-6-9-A-H-N-S)		
	D-1-R-9-B-4-K-3 (1-3-4-9-B-D-K-R)		
	7-M-2-T-6-F-1-Z (1-2-6-7-F-M-T-Z)		
	Total raw score (maximum = 21)		

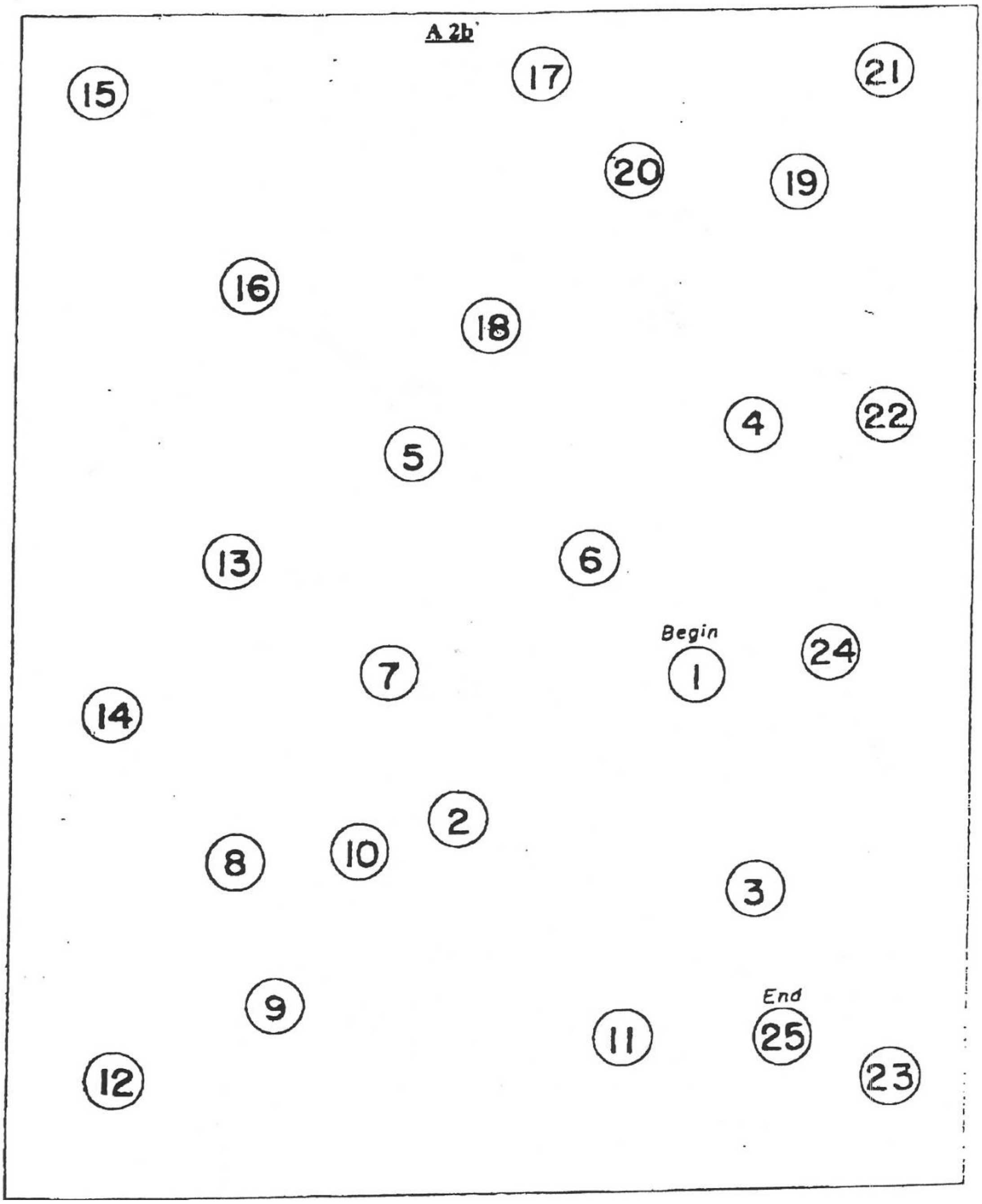
Appendix 6 – Trail Making Task

Trail making task (as provided by Dr Edgington)

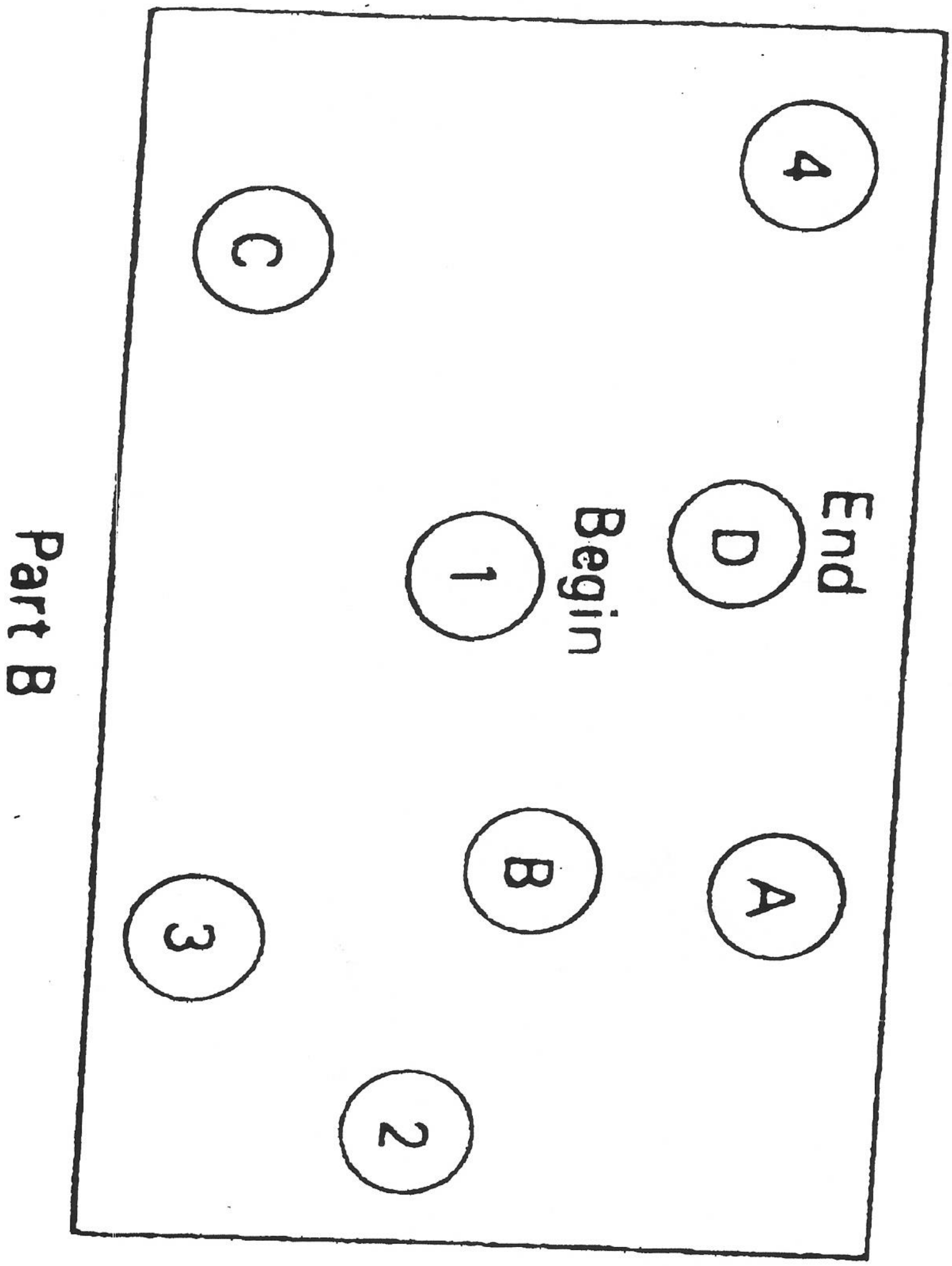
Experiment – connect the numbers without lifting the pen



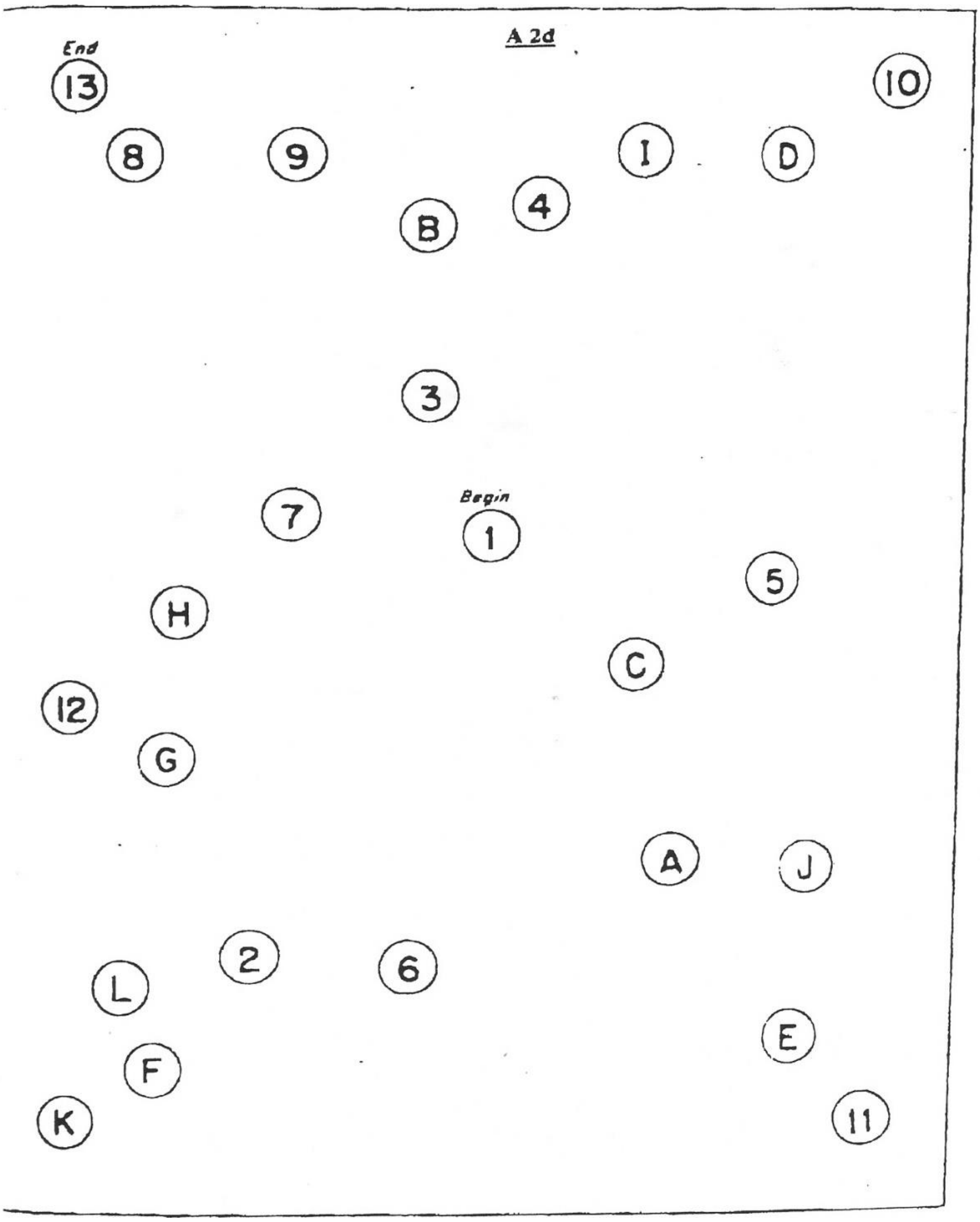
Trail A


A 2b
15
17
21
20
19
16
18
4
22
5
13
6
Begin
1
24
7
14
2
10
8
3
End
9
11
25
12
23

Experiment – link the letter and the numbers, numerically and alphabetically without lifting the pen

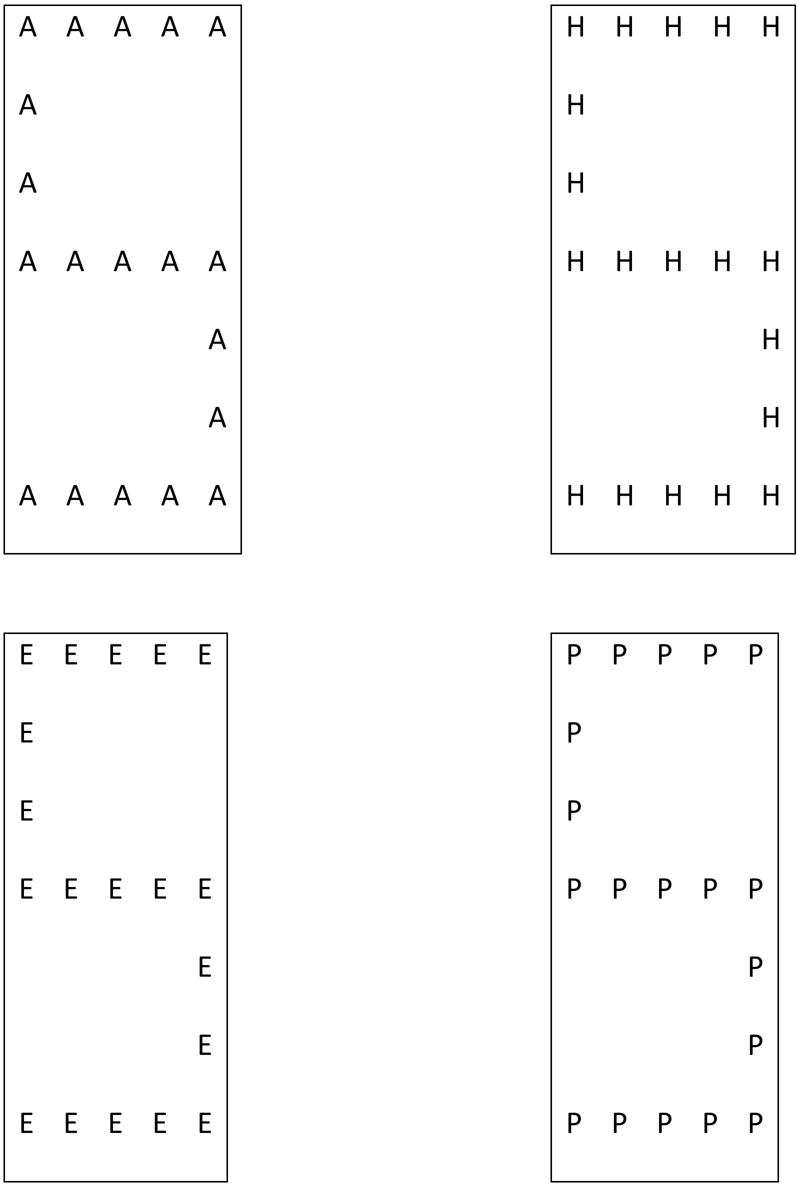


Trail B



Appendix 7 – Navon Task

Navon Task (developed by Nymeth Ali)



S	S	S	S	S
S				S
S				S
S	S	S	S	S
S				S
S				S
S				S

S	S	S	S	S
S				S
S				S
S	S	S	S	
S				
S				
S				

S	S	S	S	S
S				
S	S	S	S	
S	S	S	S	
S				
S				
S	S	S	S	S

E				E
E				E
E	E	E	E	E
E	E	E	E	E
E				E
E				E
E				E

S				S
S				S
S	S	S	S	S
S	S	S	S	S
S				S
S				S
S				S

A				A
A				A
A	A	A	A	A
A	A	A	A	A
A				A
A				A
A				A

P				P
P				P
P	P	P	P	P
P	P	P	P	P
P				P
P				P
P				P

H	H	H	H	H
H				H
H				H
H	H	H	H	H
H				H
H				H
H				H

E	E	E	E	E
E				E
E				E
E	E	E	E	E
E				E
E				E
E				E

H	H	H	H	H
H				H
H				H
H	H	H	H	
H				
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H	H	H	H	H
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A	A	A	A	A
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P	P	P	P	P
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P	P	P	P	P
P				P
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A	A	A	A	A
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P	P	P	P	
P	P	P	P	
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P	P	P	P	P

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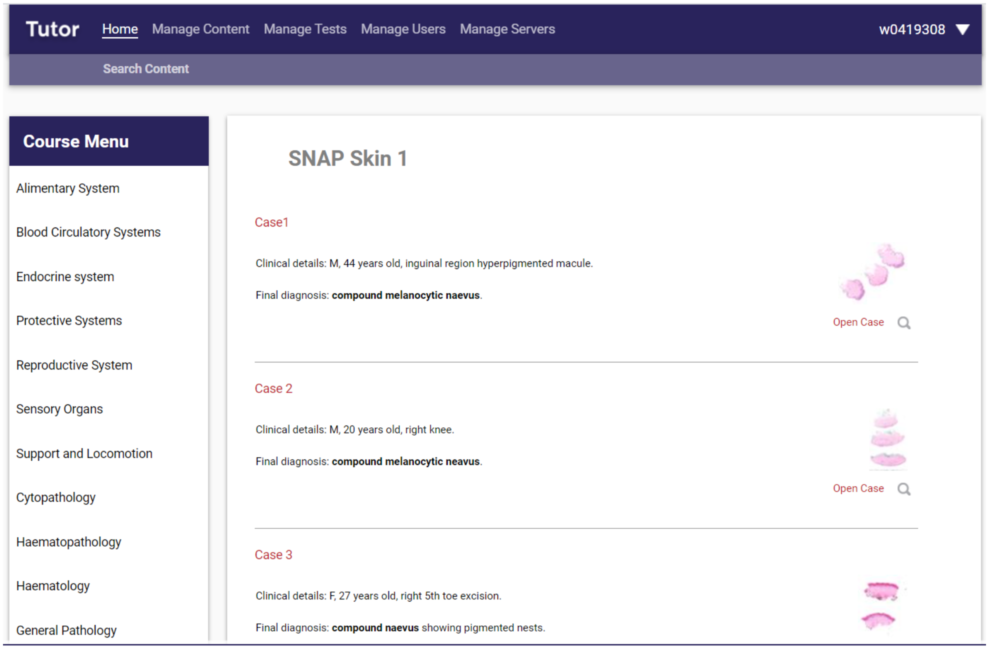
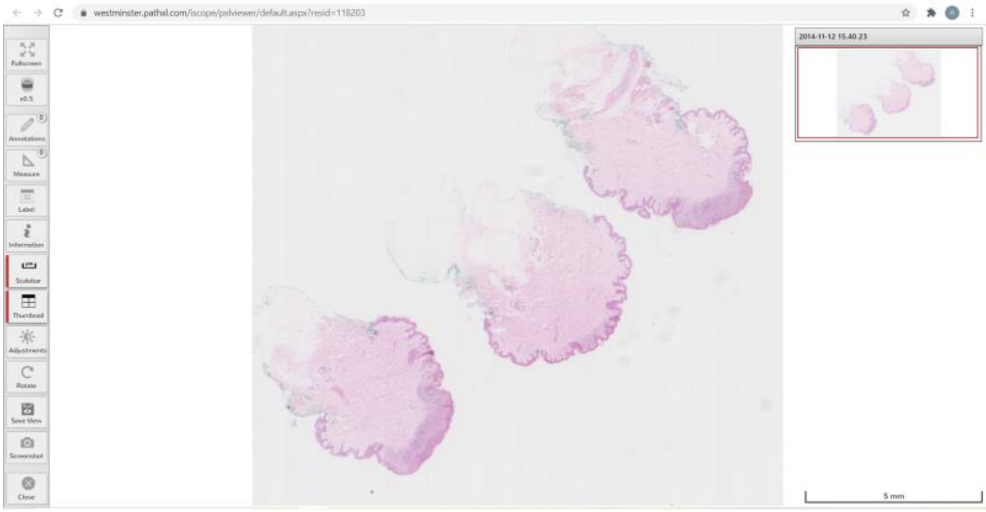
Appendix 8 – Westminster Path XL screenshots

Screenshots of Westminster Path XL – Student viewer mode

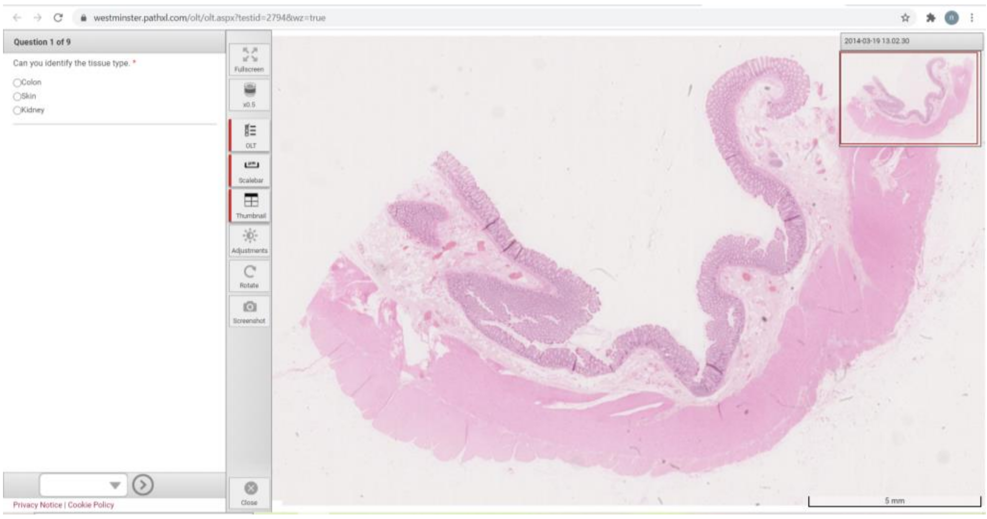


Student viewer when logging into Westminster Path XL. The course menu would include only the relevant modules the students were participating – SNAP prefix (Seeing and naming patterns).



Student viewer when opening the image. On the left hand-side there is the menu bar and on the right side, the overview of the slide. At the bottom right side, the scale bar has been added. Hovering over the image or using the magnification bar, the image can be zoomed.

Screenshots of Westminster Path XL – assessment mode



In the assessment mode, the student can view the question to the left side of the screen, the menu bar next to it and then the image to view.

Appendix 9 – Training Evaluation Form

Training Evaluation Form

Name: ___________________________________

<u>Instructions:</u> Please indicate your level of agreement with the statements listed below.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1. The objectives of the training were clearly defined.					
2. Participation and interaction were encoura ged.					
3. The topics covered were relevant.					
4. The content was organised and easy to follow.					
5. The materials distributed were helpful.					
6. The training experience will be useful.					
7. The trainer was knowledgeable about the training topics.					
8. The trainer was well prepared.					
9. The trainer was available for consultation outside the training time.					
10. The training objectives were met.					
11. The time allocated for the training was sufficient.					
12. The duration of the course was right.					

13. The meeting room and facilities were adequate and comfortable.					
14. Have your skills/knowledge increased as a result of the training.					
Microscopy session					
15. The microscope slides were useful.					
16. There was enough time to look at the slides.					
Westminster Path XL					
17. The case studies were useful.					
18. I could navigate the module very easily.					
19. I like the look and feel of the module.					

	Excellent	Satisfactory	Unsatisfactory	Poor
20. Would you recommend this training to your colleagues?				
21. How would you rate the training overall				
22. What did you like most about the training?				
23. What aspect of the training could be improved?				
24. Please share other comments or expand on previous responses.				

Appendix 10 – Pilot study psychometric task results

Pilot study – Students' psychometric tasks

Learner ID	Group	Gender	Age	PSS	MS
SAPA	B	1	23	5	151
RASM	A	2	24	11	151
JOAN	A	2	32	13	145
SABO	B	2	24	11	153
AYKE	A	2	21	8	153
RESA	B	1	20	11	129
IQBI	C	2	24	13	158
BECH	C	2	43	19	150
VIUJ	A	2	29	13	154
JAVA	C	1	29	14	116
JETA	C	1	28	9	139
MOKA	B	1	23	17	134

Groups: A – Microscope, B – Westminster Path XL, C- control group

Gender: 1 – male, 2 – female

Processing style: 1 – global, 2 – featural and 3 – mixed (psychometric tasks)

Pilot study – Students' psychometric tasks

Learner ID	RO (1)	RO 1 PD	RO (2)	DSF	DSB	DST	scale	LNS	scale	TMTA	scale	TMTB	scale	Navon global	Navon Featural	Navon diff	N Pdom	RO (3)	RO3 PD
SAPA	34	2	27	13	7	20	12	6	5	28	40	64	31	20	0	20	1	26	2
RASM	35	2	20	8	6	14	8	5	4	22	70	52	69	20	0	20	1	18	2
JOAN	36	2	23	10	6	16	9	7	6	30	45	54	60	0	20	-20	2	25	1
SABO	36	1	22	11	6	17	10	6	5	31	31	38	90	8	12	-4	2	24	1
AYKE	36	2	20	11	6	17	10	9	8	23	60	53	60	12	8	4	1	21	3
RESA	35	1	9	10	4	14	8	5	4	23	60	52	65	20	0	20	1	15	3
IQBI	36	1	23	10	5	15	15	6	5	30	55	73	5	13	7	6	1	18	1
BECH	36	2	21	13	8	21	10	6	5	51	5	82	20	20	0	20	1	27	2
VIUJ	36	1	15	4	6	10	15	2	2	28	40	95	5	20	0	20	1	16	1
JAVA	36	2	19	11	8	19	11	10	9	25	50	39	90	20	0	20	1	22	1

Learner ID	RO (1)	RO 1 PD	RO (2)	DSF	DSB	DST	scale	LNS	scale	TMTA	scale	TMTB	scale	Navon global	Navon Featural	Navon diff	N Pdom	RO (3)	RO3 PD
JETA	36	2	13	9	10	19	11	7	6	30	30	52	65	19	1	18	1	14	2
MOKA	34	1	19	9	5	14	8	5	6	45	5	116	5	14	6	8	1	18	1

Appendix 11 – Pilot study assessment results

Pilot study – Assessment results

	1			2			3			4			5			6			7			8			9			10			T
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	50
SAPA	1	0	1	1	1	1	1	0	1	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	1	1	2	1	1	1	20
RASM	1	1	1	1	1	2	1	0	0	1	2	1	1	1	1	0	0	0	1	1	2	1	0	0	1	1	2	1	0	2	27
JOAN	1	0	2	1	1	2	1	2	0	1	1	0	1	1	1	1	2	2	1	0	1	1	0	1	1	1	1	1	1	2	31
SABO	1	0	2	1	0	2	1	0	1	1	0.5	1	1	0	0	1	0.5	2	1	2	2	1	0	1	1	1	1	1	0	2	28
AYKE	1	0	1	0	0	0	0	0	0	1	0	1	1	0	1	1	0	2	1	1	1	0	0	0	0	0	0	1	1	1	15
RESA	1	2	2	1	2	2	1	0	1	1	0	0	1	1	2	1	0	2	1	1	1	1	0	1	1	2	2	1	0	2	33
IQBI	1	1	2	1	0	1	1	0	0	1	1	1	1	0	1	1	1	2	1	2	2	1	2	2	0	0	0	1	2	2	31
BECH	1	1	2	1	1	2	1	2	2	1	2	2	1	0	0	1	1	1	1	1	2	0	0	0	1	0	0	1	1	1	30

	1			2			3			4			5			6			7			8			9			10			T
	a	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**50**
VIUJ	1	1	2	1	1	2	1	0	0	1	2	2	1	1	2	1	1	1	1	2	2	1	1	2	1	1	2	1	0	1	36
JAVA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1	17
JETA	1	0	0	1	0	0	1	0	0	1	2	2	1	0	0	1	1	1	1	1	1	1	0	1	1	0	0	1	0	1	20
MOKA	1	1	2	1	1	2	1	2	1	1	1	1	1	0	0	1	0	0	1	0	1	1	0	1	1	1	1	1	1	1	27

Each question – 5 points: A – 1 point, B – 1 point, C – 3 points (max.)

Appendix 12 – Pilot study questionnaire feedback

Pilot study – Students' feedback results

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Q1	3	4	0	0	0
Q2	3	3	1	0	0
Q3	5	2	0	0	0
Q4	2	3	2	0	0
Q5	2	4	1	0	0
Q6	3	4	0	0	0
Q7	5	2	0	0	0
Q8	4	3	0	0	0
Q9	3	2	2	0	0
Q10	0	7	0	0	0
Q11	0	5	1	0	1
Q12	1	3	2	0	1
Q13	2	5	0	0	0
Q14	2	3	2	0	0
Group A	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
Q15	2	3	1	0	0
Q16	1	2	2	1	0

Group B	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Q17	2	2	2	0	0
Q18	1	3	2	0	0
Q19	2	2	1	1	0
Overall	**Excellent**	**Satisfactory**	**Unsatisfactory**	**Poor**	
Q20	3	4	0	0	
Q21	3	4	0	0	

Themes	No of comments
Westminster Path XL less strain to the eye	1
Increase knowledge	4
More Westminster Path XL slides	1
Labelled Westminster Path XL slides	1
Longer lectures	2
Freedom to look at Westminster Path XL anytime	2
Split sessions	3
Trainer was prepared	1
Variety of microscopic slides	1
Exam time/end of term	2
Prior knowledge not all had	1
Microscopy rather than Westminster Path XL	1

Appendix 13 – Intervention study psychometric task results

Students' psychometric tasks

Learner ID	Group	Gender	Age	PSS	MS
KOMA	B	2	19	14	148
GAWI	B	2	19	16	130
MOMU	B	2	22	23	137
SATA	A	2	19	23	149
SAAK	A	2	19	15	136
SAAR	A	2	25	16	167
MOAM	B	1	29	17	153
PHWH	B	2	34	18	124
HAKH	A	2	34	23	129
JANI	A	1	21	17	130
AYDA	B	2	24	19	131
UOAH	A	1	21	34	138
AMIB	B	2	47	18	139
QASA	B	1	27	20	145
LUJO	A	2	46	21	138
KASC	B	2	28	21	141
JOFE	A	2	26	21	145

Learner ID	Group	Gender	Age	PSS	MS
RUMI	B	2	26	22	132
FEYA	A	1	47	21	127
SIKU	B	2	26	22	141
OSPE	B	1	27	22	149
KIPA	A	2	31	17	153
PASA	B	2	26	25	145
FAMO	A	2	23	19	130
SHLI	B	2	30	18	128
NAJA	B	2	26	15	115
LIBA	A	2	26	24	139
SAKA	A	2	26	15	145

Groups: A – Microscope, B – Westminster Path XL

Gender: 1 – male, 2 – female

Students 1-6 from the University of Westminster

Students 7-12 from London Metropolitan University

Students 13 – 28 from Imperial College NHS Trust, students 14 and 19 are work placement students

Processing style: 1 – global, 2 – featural and 3 – mixed (psychometric tasks

Excluded students - from ICNHST

Learner ID	Group	Gender	Age	PSS	MS
NIPA	A	2	40	28	167

Students' psychometric tasks (cont.)

Learner ID	RO (1)	RO 1 PD	RO (2)	DSF	DSB	DST	scale	scaled scores	LNS	scale	scaled scores	TMTA	Scale	TMT B	scale	Navon G	Navon F	Navon diff	N P dom	RO (3)	RO 3 PD
KOMA	36	1	1	6	12	18	10	3	10	9	3	48.91	2	1.14.87	2	20	0	-20	1	30	1
GAWI	36	2	2	8	6	14	8	3	8	7	4	34.86	20	1.13.47	2	9	11	2	3	36	1
MOMU	36	2	2	6	3	9	4	5	6	5	5	36.03	20	2.28.85	2	1	19	18	2	33	2
SATA	36	2	1	7	5	12	6	4	9	8	3	1.10.00	2	3.09.50	1	20	0	-20	1	30	1
SAAK	36	2	2	8	5	13	7	4	7	6	4	34.41	22	47.4	80	0	20	20	2	24	2
SAAR	36	2	2	9	6	15	8	3	9	8	3	30.69	30	41.5	88	12	8	-4	3	30	2
MOAM	36	2	2	10	5	15	8	3	9	8	3	21.32	75	58.57	55	18	2	-16	1	18	2
PHWH	35	1	1	10	5	15	9	3	12	12	2	34.38	26	52.75	60	20	0	-20	1	29	2
HAKH	36	1	1	10	6	16	9	3	10	9	3	38.1	28	59.59	50	0	20	20	2	33	1

Learner ID	RO (1)	RO 1 PD	RO (2)	DSF	DSB	DST	scale	scaled scores	LNS	scale	scaled scores	TMTA	Scale	TMTB	scale	Navon G	Navon F	Navon diff	N P dom	RO (3)	RO 3 PD
JANI	35	2	2	11	9	20	12	2	8	7	4	39.94	10	1.45.94	2	19	1	-18	1	25	2
AYDA	34	2	2	8	4	12	6	4	8	7	4	22.1	70	1.01.84	2	20	0	-20	1	12	2
UOAH	36	1	1	8	7	15	8	3	10	9	3	20.78	75	59.53	40	20	0	-20	1	30	1
AMIB	36	1	1	6	5	11	6	4	5	5	5	35.91	30	1.11.13	30	20	0	-20	1	26	1
QASA	36	1	1	11	5	16	9	3	4	3	6	37.98	20	1.12.14	20	20	0	-20	1	31	1
LUJO	36	1	1	9	7	16	9	3	11	11	3	30	50	1.14.82	30	19	0	-19	1	30	1
KASC	35	2	2	9	6	15	8	3	3	2	6	56.26	2	1.47.45	2	19	1	-18	1	22	2
JOFE	35.5	2	2	12	7	19	11	3	9	8	3	30.12	30	44.67	80	18	2	-16	1	11.5	2
RUMI	36	2	2	11	6	17	10	3	10	9	3	28.22	40	49.54	70	18	2	-16	1	33	2
FEYA	36	2	1	11	4	15	9	3	10	10	3	40.85	10	1.13.13	30	0	20	20	2	23	1
SIKU	36	2	2	8	6	14	8	3	7	6	4	23.51	60	1.08.38	20	19	1	-18	1	35.5	2
OSPE	36	2	2	11	5	16	9	3	10	10	4	17.09	90	54.87	60	12	8	-4	3	20	1

Learner ID	RO (1)	RO 1 PD	RO (2)	DSF	DSB	DST	scale	scaled scores	LNS	scale	scaled scores	TMTA	Scale	TMTB	scale	Navon G	Navon F	Navon diff	N P dom	RO (3)	RO 3 PD
KIPA	36	1	1	11	9	20	12	2	10	9	3	43.02	20	1.02.30	50	20	0	-20	1	33	1
PASA	36	2	2	8	9	17	10	3	11	10	3	40.76	10	1.24.03	2	20	0	-20	1	30	2
FAMO	36	2	2	9	5	14	7	4	8	7	4	37.56	20	1.59.07	2	17	3	-14	1	31	2
SHLI	35	1	1	8	8	16	9	3	11	10	3	27.29	50	59.2	50	11	9	-2	1	26	1
NAJA	35	1	1	10	7	17	10	3	11	10	3	38.64	20	1.19.55	2	0	20	20	2	29	1
LIBA	31	2	2	8	3	11	6	4	8	7	4	34.79	20	1.01.94	40	20	0	-20	1	20.5	2
SAKA	36	1	1	9	8	17	10	3	12	11	3	30.14	30	1.03.77	20	9	11	2	2	20	1

Excluded students - from ICNHST

Learner ID	RO (1)	RO 1 PD	RO (2)	DSF	DSB	DST	scale	scaled scores	LNS	scale	scaled scores	TMTA	Scale	TMTB	scale	Navon G	Navon F	Navon diff	N P dom	RO (3)	RO 3 PD
NIPA	35	2	2	11	8	19	11	4	8	7	4	40.42	10	54.52	70	17	1	-16	2	**26**	**1**

Appendix 14 – Intervention study assessments results

Quiz results

	Quiz one										Quiz two										Quiz three									
	1			2			3			T	1			2			3			T	1			2			3			T
	C	N		C	A		S	MM		21	S	N		C	A		S	BCC		21	C	A		S	MM		S	SCC		21
KOMA	2	1	1	1	1	1	2	1	1	11	2	2	3	2	1	1	2	2	3	18	2	2	2	2	1	1	1	1	1	13
GAWI	2	2	3	1	1	1	2	1	1	14	2	2	3	2	2	3	2	2	3	21	2	2	3	2	2	2	1	1	1	16
MOMU	2	1	1	1	1	1	2	1	1	11	2	2	3	2	2	3	1	1	1	17	1	1	1	2	2	3	1	1	1	13
SATA	1	1	1	2	2	3	2	2	2	16	2	2	3	2	1	1	2	2	3	18	2	2	3	2	2	3	1	1	1	17
SAAK	2	2	3	1	1	1	1	1	1	13	1	1	1	2	1	1	1	1	1	10	1	1	1	1	1	1	1	1	1	9
SAAR	2	2	3	2	2	3	2	2	2	20	2	2	3	2	2	3	2	2	3	21	2	2	3	2	1	1	2	2	3	18
MOAM	2	2	3	2	2	3	2	1	1	18	2	1	1	2	2	3	2	2	3	18	2	2	3	2	2	3	1	1	1	17

	Quiz one										Quiz two										Quiz three									
	1			2			3			T	1			2			3			T	1			2			3			T
	C	N		C	A		S	MM		21	S	N		C	A		S	BCC		21	C	A		S	MM		S	SCC		21
PHWH	2	1	1	2	2	2	2	1	1	14	2	2	2	2	1	1	1	1	1	13	2	1	1	2	1	1	1	1	1	11
HAKH	2	2	3	1	1	1	1	1	1	13	2	2	2	2	2	3	1	1	1	16	2	2	3	2	1	1	2	2	3	18
JANI	2	2	2	2	2	3	2	2	1	18	2	2	1	1	1	1	1	1	1	11										
AYDA	2	2	3	2	2	3	2	2	3	21	2	2	3	2	1	1	2	2	3	18	2	1	1	2	1	1	2	2	2	14
AMIB	2	1	1	1	1	1	2	1	1	11	2	1	1	2	2	2	2	2	3	17	1	1	1	2	1	1	2	2	2	13
QASA	2	1	1	2	2	1	2	1	1	13	2	2	2	1	1	1	1	1	1	12	1	1	1	2	1	1	2	2	1	12
LUJO	2	2	3	2	2	2	2	2	3	20	2	2	3	2	2	3	2	2	3	21	2	2	3	2	2	3	1	1	1	17
KASC	2	2	3	2	2	3	2	1	1	18																				
JOFE	2	1	1	2	2	3	1	1	1	14	2	2	2	2	1	1	1	1	1	13										
RUMI	2	2	3	1	1	1	2	2	3	17																				

	Quiz one										Quiz two										Quiz three									
	1			2			3			T	1			2			3			T	1			2			3			T
	C	N		C	A		S	MM		21	S	N		C	A		S	BCC		21	C	A		S	MM		S	SCC		21
FEYA	2	1	1	2	2	3	2	2	3	18	2	2	3	2	2	3	2	2	3	21	2	2	3	2	2	3	2	2	3	21
SIKU	1	1	1	2	2	3	2	1	1	14	1	1	1	1	1	1	2	1	1	10										
OSPE	2	2	3	2	2	3	2	1	1	18	2	2	3	2	2	3	2	2	2	20										
KIPA	2	1	1	2	2	3	2	2	3	18																				
PASA	2	2	3	1	1	1	2	1	1	14	2	2	3	2	1	1	2	2	3	18	2	2	3	2	2	3	2	2	3	21
FAMO	2	2	3	2	2	3	2	1	1	18	2	2	3	2	1	1	1	1	1	14	2	2	3	2	2	3	1	1	1	17
SHLI	2	1	1	2	2	3	2	1	1	15																				
NAJA	2	2	3	1	1	1	2	2	2	16	2	2	3	2	1	1	2	2	2	17	2	2	3	2	2	2	2	2	1	18
LIBA	2	2	3	1	1	3	2	1	1	16	2	2	3	2	1	2	2	2	3	19										
SAKA	2	2	3	2	2	1	1	1	1	15																				

Each image – 3 questions: first question – 2 points, second question – 2 points, third question – 3 points (7 points maximum)

Each quiz had three questions

Appendix 15 – Intervention study feedback questionnaire

Students' feedback results – review

	Strongly Agree	Agree	Neutral	Disagree	Strongly Agree	No answer
Q1	10	5	0	0	0	0
Q2	8	7	0	0	0	0
Q3	10	2	2	0	0	1
Q4	9	3	2	0	0	1
Q5	9	5	1	0	0	0
Q6	9	6	0	0	0	0
Q7	12	2	1	0	0	0
Q8	13	2	0	0	0	0
Q9	8	1	5	1	0	0
Q10	7	7	1	0	0	0
Q11	4	7	2	1	1	0
Q12	5	7	1	2	0	0
Q13	6	6	2	0	1	0
Q14	8	5	2	0	0	0
Group A	Strongly Agree	Agree	Neutral	Disagree	Strongly Agree	No answer
Q15	5	2	1	0	0	0
Q16	1	1	3	3	0	0

Group B	Strongly Agree	Agree	Neutral	Disagree	Strongly Agree	No answer
Q17	5	1	1	0	0	0
Q18	4	2	1	0	0	0
Q19	4	2	1	0	0	0

Overall	Excellent	Satisfactory	Unsatisfactory	Poor	No answer
Q20	9	6	0	0	0
Q21	8	5	0	0	2

Themes	No of comments
Increase knowledge/contribute to core module understanding	12
Westminster Path XL good but sometimes images would not appear	2
Lecturer was prepared, good delivery and availability of lecturer	4
Use of microscopes	5
Multiple room locations	1
Encouraging environment	2
More content on handouts	1
Longer session	6
Beneficial for all undergraduate student's relevant topic	1
Opportunity to ask questions	3
More microscopy sessions	2
Software was excellent	1
Good handouts – colours	3
More slides/images	1

Appendix 16 – Students' interview questions

Guiding questions

1. How did you find the training?
2. How did you find the lectures?
3. How did you find the practical sessions? – Microscope or Westminster Path XL. Advantages and disadvantages of the tool/ what worked well when you were using the …/ the range of experience
4. How did this method suit you? Which allowed better processing of information and how did you feel, motivation and stress. Any method easier or reduced cognitive load
5. How was your experience using Westminster Path XL for the assessment? Positive and challenges in using this approach.
6. Would you recommend the use of technology in teaching and education? Could you please elaborate?
7. Have you been able to implement it at work/University/applying for a job?
8. Would you like to add anything that we have not discussed yet?

Appendix 17 – Students' interview transcripts

AMIB

1. The tissue recognition sessions, I found it useful. I wish it had more sessions, the tutorials were very short, we were given the material, but I did not have enough time to do my own work on it.

   There were many issues with the website and the passwords. When I found the information, I was able to identify the content shown in the slide, the tissue, the organ, the disease, what we were supposed to see and identify it. The one thing I would have liked to see if there was an arrow to mark the areas in the slide that we were supposed to be looking at, they were just talking about it generally, so if you don't have the experience you would not be able to see what part of the cell they were referring to, like say, they were showing a certain condition, now showing what is what so I was not sure which was which, since I was learning this was an issue.

2. The lectures were good, but they were very brief, they showed us the different parts of the cells and which is which and showed us the terminology. I would have liked longer sessions or more sessions, 30min per session. In the 20min sessions, there were a lot of details, and they were going quickly, we could ask questions, but the time was short, there was so much to ask.

3. I did Westminster Path XL, and I looked at the website in my own time, the slides were not identified, the learning material was good, but when we had the test it was difficult

to identify, to be honest, I should have spent more time with the learning material but the issue with the log in made it difficult. Everywhere you are, for teaching, spend as much time as you want and you can use the internet to go in more detail, find other slides.

4. I prefer Westminster Path XL definitely. With the microscope, the focus is more challenging. It was easier with Westminster Path XL; I could enlarge the slides. I have not used the focus on the microscope for a long time, last week, I had to use at work, and it was very challenging, try to focus and move the slide. I need to practice the microscope because I have got used the digital.

5. Westminster Path XL assessment was more efficient than a paper copy. Everything is in assessment there for you, you can move to another image without having to focus again. It is easier to compare, all is in front of you. I cannot think of any disadvantages at the moment.

6. I would recommend the use of technology definitely because, with the slide they can break, you have to have so many slides to cover all the students, you cannot just have one. Also, the website is low cost, and it is not time-consuming for the laboratory to cut so many slides. If we do digital it is easier, you can have different stains and compare. You can do it in your own time or a microscope, you only need a computer anywhere anytime.

   There are different methods, a camera, IPad, Westminster Path XL, a photograph is good, but you need more images with a camera, with Westminster Path XL one image works for all. With many photos, you can miss something, so one image (in Westminster Path XL) is better.

7. So far, I have not applied to my role, I have recently become a Band 4, and I don't look at slides all the time.

   I attended a course last week, and I was able to recognise some of the sections but not all of them.

   One thinks that the training has helped me with, is that I am more curious when I am embedding if I don't recognise the tissue I go and look at the form to check what the tissue type it is.

8. I had quite a few password issues, I would have liked longer sessions or more sessions. I think that the slide should have been labelled, this would help a lot to identify specific areas that we should look at.

FEYA

1. The training was ok, it was detailed and relevant to me.
2. The lectures were interesting, they were straight to the point and easy to follow. The terminology was ok and easy to follow, and the length of the sessions was ok.
3. I had the microscopy practical sessions, the microscope was not readily available, and I cannot always go back to the slides, it was a one-off practical session. With the University Path XL, I can always go back.
4. The microscope sessions were good for me. If I am looking at the other point of view, if you are not in the lab Westminster Path XL is better, what you see on the slide is the same as you see on the Westminster Path XL. The use of a microscope is good; however, using Westminster Path XL, the skill of using a microscope is lost.
5. The assessment initially was challenging, especially the password, also, I could not go back with Westminster Path XL, and if it is a paper I can go back later.
6. I would recommend the use of technology, but I don’t want to lose the skills of using the microscope so I don’t think we should go fully technical digital.
7. I have started implementing what I learnt when I am staining, I can look at the stains and see the difference in the cell components.
8. All have been covered.

GAWI

1. The training was interesting because I used Westminster Path XL, I could zoom in and see the details, I didn't have to focus on the microscope, making sure the slide or the lightning was ok, I could see everything on the screen.

2. The lectures were interesting, I remember the slides on the iPad, and we had everything printed as well. Maybe we could have had more time to go more in-depth, not more sessions but longer sessions, we could go deeper on the subject.

3. I had Westminster Path XL, for studying, this was better for me. I cannot bring the slides home, to study histology I can log in and compare the slides with the book. With the microscope, I am restricted to the laboratory practical. The disadvantage is that you can only see what is uploaded there.

4. Westminster Path XL suited me better especially for the purpose of the study, I only had to remember and recognise the features of the slide, Westminster Path XL was better for me, if I had used the microscope, I would have improved the microscopy skills.

5. No issues with Westminster Path XL in the assessment.

6. The training was an extra session to learn more, it was out of the histology lecture if I did something with you when I went to class, it was easier as I already knew about it.

   I think microscopy needs to be there, the basics, I remember you saying that to understand what is abnormal we first need to know what is normal, so I first learnt what is normal on Westminster Path XL, then I could carry on using microscopy and my eye would be sharper.

7. The training was useful, especially for the university portfolio that I had to get together. We did coursework where we had to work on slides and find our own diagnosis on a case study, we had slides and online. The practice that I had the year before Westminster Path XL study was useful, this was on infection and immunity and applied pathobiology.

8. All have been covered.

HAKH

1. I was really happy to be a part of the training, you didn't come to my lectures, you went to the tissue sciences lecture for the recruitment and my friend told me about it, and when I contacted you and asked if I could be part of it.

2. The lectures were very clear and interesting, the right length of time, if they were longer, we would stop listening, and they would be boring. The terminology was really good and easy to understand, we could ask questions, and you would explain them to us.

3. I had the microscope sessions, they were really good, we should do a bit more training on, you are expected to know how to use a microscope when you start university. With pipetting, gel electrophoreses they explain it, with the microscope they expect you to know how to use and many people struggle to focus and so on, so your sessions were really good, I got much more practice than other colleagues on my degree. For me, it made it easier for other lessons to identify the different tissues, the use of the microscope made it much easier, I can focus and set up the microscope correctly.

4. I preferred the microscope, hands-on, I learn better with paper that way. Not stressful as I found the areas that I was expecting.

5. The assessment via Westminster Path XL was more difficult for me, when I am looking at different things, it starts getting confusing, paper and microscope is easier for me to concentrate and to recognise.

6. We should use technology. However, we cannot solely do it, when you know it so well, you can recognise it on the paper, microscope or the computer. To recognise individual cells, I would need more time, I learnt at college the basics, but it was a long time ago, we should have a refresher, and they should not expect us to remember, we forget for example the different types of cells, red blood cell, white blood cells. If you are not doing every day, then technology should be introduced to help you, it doesn't matter the method.

7. To be honest, I did not to those subjects if I did, I would feel that I have a bit more advantage. Now looking for jobs, I can use that experience of being on that environment, when I read the documents, I do understand what they say, otherwise, I wouldn't have a clue.

8. I wish I had done better, because we were in the 2nd year there was a lot of work and if I have had more time to dedicate more time to it then, I would give my 100%.

KIPA

1. The training was good, we went through all the stages, lectures, slides, it was useful, and we could put the puzzle together, you were always there to answer any questions.

2. The lectures were useful, we didn't know the terminology before, it was in-depth and was all presented and introduced in the lecture, we could use the tissue recognition skills. The sessions were quite frequent, and the material was very useful.

3. I had the microscope practical, we had to do self-study, we were provided with the slides, and I used to look at the slides at the workplace under the microscope. Because we were learning, the microscope was very useful, the disadvantages were a limit with the magnification, with the digital, you could go high power, for example, look at the nuclei, sometimes we had to convince that it is there.

4. If I had a choice, I would do both to see the difference, routinely I would use the microscope, but digital would be useful also. Westminster Path XL was more convenient, anywhere, microscope I could only use at work, not at home, so I am restricted at work and only at certain times. With digital pathology, I look at images at home, and on the weekend, I would have preferred.

5. The assessment was good, the only thing is that I found a little bit hard using the technical terms, I was not competent in identifying the features, as technology goes it was good, we looked at the different slides, zoom in and see the features.

6. Technology is easier, it makes the picture clearer. For example, any nuclear changes, you just assume, with the microscope you need more experience, looking at it digitally

you can see in a bigger screen and zoom in/out, with a microscope, it needs experienced eyes.

7. Implementation, definitely, it helped me when I started the project, I did not have much knowledge of tissue recognition. For example, with the skin, I understand different layers, different epithelium, with the colon, different features and different epithelium and different areas. All this I learnt from the lectures and the process; I can identify them now routinely.

8. None, I am happy with what we have done.

MOAM

1. The training was very enjoyable, and it was very engaging and certainly lots of positive outcomes for me.

2. The lectures were very organised and put things into perspective quite well and gave a much good emphasis on how the pathology works and how it links to the microscopic images.

3. I used Westminster Path XL, certainly, giving a clear image and more freedom to move around, less fidgety, to the point, amazing resolution. I felt that I had more benefit as I looked across the whole image on Westminster Path xl than microscope, being able to zoom in/out of the zoom features made it more simplistic than using the microscope. The disadvantages, in a sense, it is still a digital image rather than the real image, if something was distorted, you could not do anything to sort it.

4. As a learner Westminster Path XL suited me better because you have the freedom to study at your own leisure, you can study at home and if you fancy if you have got a liking to the subject you can form a memory basis by simply reviewing the slides on Westminster Path XL.

5. I am very technological, I actually enjoyed getting the hands on the technology I did not play with before, it was more challenging that difficult.

6. The assessment was interesting, I had not experienced it before, the questions were very relevant, the only issue was that you don’t have any idea if you are right or wrong, I would like feedback at the time of the assessment if I could review straight after.

7. Technology should definitely be used but not replacing the current method, technology can sometimes push teaching away, some teachers may be so dependent on technology that they lose the ability to engage and teach students, you have to have a balance and offer the best of both worlds, whilst you are in a facility of learning it should certainly be less depending of technology than when they are studying away from a facility and technology gives that ability. The use of photographs, if you are on a microscope and can take pictures, if you are staining a slide, if you take an image it will hit your memory far better than using a pre-stained slide whether as a microscope or Westminster Path XL, it helps kick start the memory.

8. Implementation of what I have learnt, again, when you see the slides presented on Westminster Path XL, it looks professional, the best you are going to get, as opposed at the university slides, we have at university, where students have stained the technique may not be so good. With the Westminster Path XL, it is expected the level of material to be very good, gives you an idea of what not to give and sets good standards.

   I have used the app, and I gained a lot, images looked a piece of art, when using the app I started having a science mentality, to recognise this and that, starting to know where things are coming from, rather this is a nice cluster of this, I can now recognise the intestinal tract or piece of kidney or prostate, you can start recognising specific unique features of each type of tissue which I may not have done just by looking in books, in books we take a glimpse at the images and focus on the text.

The training gave me better analytical skills, it was new, and I spent a lot of time playing with it, and when I was in the 3rd year, I could recognise tissue features on a very quick basis, and it was specific due to this, I had not done this before.

The terminology in the lectures you gave beforehand helped with the nuclear structure, the rest was neither a loss nor gain.

The length of the sessions was just the right level, good level tutorial, I am always up for a pop quiz, maybe a few questions for our own reflections at the end of the session would be useful for me, questions may be useful to make sure I got the points across and for your own feedback.

The training was a brilliant experience, I am really glad I got to use Westminster Path XL, as during university I never got to use anything like this, and seeing the big range of slides, to zoom in/out gives the true definition of something. It was a lot of fun, and I got to do something new, it was a + + for me.

PHWH

1. To begin with, I wasn't quite used to the training sessions, it was a bit difficult to kind of tell what is what but after some time it got easier, particularly the skin.

2. The lectures were informative, and they were quite short, not drawn out and boring. The language was ok, and the frequency of the sessions was good and just before the first assessments, the length was fine and the terminology when I did not understand I could ask you.

3. I had Westminster Path XL, it was a little bit difficult to navigate, but it was just when I first start using it. When I got used to logging in and stuff, it was ok, not sure if it was very user-friendly. The advantages were that the images are just there, you don't have to focus, it is all there, you don't have to look for any areas, and it was a lot easier. I would suggest that the navigation boxes could be a bit easier, the design of it, we are used to looking at easy things, and that wasn't.

4. I would have chosen Westminster Path XL, the images are there, I don't have to go to the laboratory, and I can refer to the images, I just had to explore the site a bit more.

5. The first assessment I did I was not very familiar with the layout, some of them I had to guess, but after a while, I knew the questions, and it was much easier to find what I had to look for and points I needed to see, it helped me focus a bit better.

6. I think technology has a place, but I would like to use the microscope sometimes, so I know how to use it.

7. The training was very applicable, the one thing it would be nicer to have this through my studies, we were in the 2nd year, and there was a lot that I didn't know, some of the terminology I didn't know, and I would have liked to have it throughout my studies. As a professional coming from the laboratory, it was a different way of the lectures that have a big curriculum, when you came, it was much focused and a few issues only.

SAAR

1. I found the sessions very informative, there were pictures, and I am a picture learning person.

2. Lectures were very neatly done, they (handout) were all in boxes, they were all in one sheet (print style) which gives me a mind map, the kind of information which makes me satisfied after I read it. About the people in the room, it was quite good. We were all females and more comfortable actually and made me speak out more and ask more questions with things that I am stuck with. The length of the session was 30min was very good, not tiring, and the terminology was good.

3. I had microscope sessions, people who are not very used to use microscope could not see what other people see and they get more tired. I enjoyed it; I am not strange about using a microscope. I think it was the best method for me than Westminster Path XL, I like to see the whole structure, with Westminster Path XL it was on the computer, and I cannot get to the other side.

4. After looking at the microscope, the Westminster Path XL was easy, but at the beginning maybe I was not sure, but after having the sections and the slides in my hand it was easy. I didn’t have any issues with Westminster Path XL for the assessment.

5. Technology is an advantage, the microscope is big and expensive, if you are not an expert, you cannot purchase a microscope, and it is easier to go digital.

6. I was able to implement what I learnt here, at the same time we were having the same topics at university and in the last homework I was asked which was a melanoma and I was able to answer it very quickly because we had just seen them with you.

7. I think if a microscope is not available, Westminster Path XL is the 2nd best option, I actually bought myself a Nurugo to look at my skin, but it is not exactly a microscope.

8. Nothing to add.

PASA

1. The sessions were very interesting, I learnt a lot I would say, even though the sessions were short, there was a lot of information and the fact that we could take the information home.

2. I think you explained very thoroughly, normally there is only a power-point presentation, and they will only read some bullet points, and you expanded and made detours.

3. I had Westminster Path XL, I quite liked it. I got not only to see the tissue as through a microscope and I got to zoom in a lot more than you can actually do on a microscope and I could go back and go to areas that I thought it wasn't looking right, you had the device there, with the microscope you had limited amount of zoom in/out, if you do in the computer is a lot easier; however, sometimes the pictures would not load and I had to wait until they got clear and not pixelated.

4. I preferred Westminster Path XL, it was interesting and different, I have not experienced it before, I normally look at slides during QC, and this was different, seeing as a whole and then parts, on the microscope you lose sometimes where you are looking at.

5. Westminster Path XL could be more user-friendly, it took a while to get there for the assessment, but I got there eventually, and I did it.

6. Technology yes, because it is easier, if you got a microscope and you are showing your students a certain area, you need to find it first unless you mark it, with the computer

you can screenshot it and if you find another area, a normal and an abnormal area you can screenshot it, both of them and compare and show to the students, there is a limit amount of things you can do with the microscope than with a computer.

7. When I do specials stains and look at the microscope, I can compare the test slide with the control, I can see the features that I have learnt during the session, and I remember.
8. I would have like to have more special stains and different ones rather than just HE.

Appendix 18 – Study completion, timeline, and costs

Timeline

Academic year	Event
2012/13	Start of the MPhil/DProf
2015/16	Conversion to DProf
May 2016	Submission of APR 1, completed September 2016
May 2017	Submission of APR2, completed September 2017
2018/19	Write-up year
May 2019	Submission of APR3
September 2019	Submission of Thesis
June 2020	Viva voce
June 2021	Interim submission
January 2022	Final submission

Costs

University fees – University fees covered in partnership by ICNHST and the researcher

Handouts – colored printouts for all students, costs covered by ICNHST

Glass slides - microtomy and staining by the researcher, costs covered by ICNHST

Travelling – for the researcher, costs covered by the researcher

Conferences – for the researcher, costs covered by the researcher

Students were not paid, offered any gifts, or favors during or after the intervention.