The Impact of Virtual Microscopes on Learning

This thesis is presented for the degree of Doctor of Philosophy of Murdoch University

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I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

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Diana Jonas-Dwyer
Abstract

Universities are using new technologies for both practical aims (to reduce costs or to cater for greater student numbers without increasing teacher numbers) and/or pedagogical aims (to improve students' learning). Frequently new technologies are introduced before the impact of these technologies on learning is fully assessed.

This thesis focuses on the introduction of virtual microscopes into histology and pathology teaching in the Health Sciences at Murdoch University.

An exploratory study was conducted in 2006 in which 47 students were randomly allocated to one of two groups. In their laboratory work one group used optical microscopes (Optical Group) and the other group used virtual microscopes (Virtual Group) during one semester. At the beginning and the end of the semester, an ASSIST survey (Tait, Entwistle, & McCune, 1998) was undertaken to determine any changes in the students' learning approach. As part of the assessments in their course, students completed an Attitude Survey about their attitudes to microscopes. Students were also required to complete a log book detailing their time spent studying. The results were analysed using appropriate statistical tests, frequencies, Chi-square, correlation, ANOVA, Two-way ANOVA, and the General Linear Model. The exploratory study tested the research design and the methods for analysing the data for the main study. Some modifications were made to the Attitude Survey prior to the commencement of the main study.

In 2007, the main study was undertaken with 293 students. In addition to the ASSIST survey, the Attitude Survey, and the log books, the students were asked to participate in focus groups and interviews to build a richer picture of microscopes and learning.

The results indicated changing trends in the students' learning approaches. The Optical Group moved from surface to strategic; the Virtual Group from deep and strategic to
surface learning during the teaching period. However, there were no statistically significant differences between the groups. The use of virtual microscopes in histology and pathology laboratories therefore does not encourage deep learning any more than the use of optical microscopes. The virtual microscopes do, however, enable students to study at times and locations that are convenient to them and they are easier to use than the optical microscopes.

The students’ responses to the items in the Attitude Survey were content analysed and 15 themes emerged from the data. These themes indicated that there are critical issues, such as authenticity and group work, which need to be addressed when introducing virtual microscopes into the classroom.

In identifying critical issues and ensuring there were no detrimental effects in using virtual microscopes, recommendations were developed for histology and pathology educators to assist the implementation of virtual microscopes into a university curriculum. This was done with a view to enhancing pedagogical practice and included the development of microscope skills, authenticity, linking theory with practice and group work.
Acknowledgements

I would like to acknowledge and thank my supervisors, Associate Professor Fay Sudweeks, Associate Professor Tanya McGill and Associate Professor Phillip Nicholls from Murdoch University who have been inspirational, steadfast and endlessly supportive to me.

I would also like to thank my family, Renee, Martin, Jade, Janet, Tim and Violet for all their support through all the years without whom I could never have achieved completion of this project.

There are also several other people who have been supportive through this time and I would like to thank Romana Martin and Carol Newton-Smith each of whom have provided friendship, support and encouraging words when required.

I would like to thank the Faculty of Medicine, Dentistry and Health Sciences at the University of Western Australia who provided me with the opportunity to pursue this research.

I would also like to thank the library staff from both Murdoch University and the University of Western Australia who also supported me through the process.
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CHAPTER 1

INTRODUCTION

Increasing student numbers and decreasing resources in universities are placing greater pressures on teaching staff to find efficient and effective ways to teach their subject specialties (Commonwealth of Australia, 2005; Ryan, Irwin, Bannon, Mulholland, & Baird, 2004). Educators are turning to technology to assist them with their teaching. In some instances, technologies are provided by universities as central teaching and learning resources. Examples of such central technologies are Learning Management Systems (e.g. Blackboard and Moodle), electronic lecture systems, (e.g. Lectopia) and electronic voting systems (e.g. TurningPoint). In other instances, educators may consider technologies that are more specifically suited to their disciplines (e.g. simulation programs in medical and dental teaching). Despite the high probability that university students will be familiar with technology, careful thought of the possible effects of technologies on learning need be considered. Technology should not be simply introduced without research and evaluation of any effect on students’ learning.

Invariably, today’s students commence university with the expectation that technologies will be used in the classroom. School leavers, in particular, have generally already acquired considerable experience using the Internet to search for information, to listen to podcasts, for social networking (e.g. Facebook, MSN, Twitter) and shopping. Many also have iPods or MP3/4 players, play or have played interactive games (e.g. Nintendo Wii, Microsoft X-Box) and regularly use other technologies (e.g. mobile phones, iPhones, GPS). Mature aged students also often commence university having used some, if not all, of these technologies.

Although educational researchers have investigated the various effects of technology use on learning, they have reported contradictory results. Some are sceptical of the impact on learners. Russell (1999, p. xiii), for example, states that “[t]here is nothing
inherent in the technology that elicits improvements in learning [... although] the process of redesigning a course to adapt the content to the technology can improve the course and improve the results”. Bates and Poole (2003) believe that technology has been driving teaching, rather than teaching driving technology. Garrison and Anderson (2003), though, are more positive and say, for example, that “[e]-Learning will inevitably transform all forms of education and learning in the twenty-first century” (p. 2).

Research into student learning (e.g. Biggs, 2003; McCune & Entwistle, 2000) has found that learning is influenced by factors such as individual student characteristics, the learning environment, and teachers’ teaching styles. Some student characteristics (e.g. cognitive styles) are considered to be “fixed”, whilst other characteristics (e.g. students’ learning approaches) are considered to be more “adaptable”. The approach that is most often encouraged at a tertiary level is that of a deep approach, where focus of the students is on understanding the subject. A surface approach is discouraged, as it is characterised by memorisation of facts and is often motivated by a fear of failure. Students’ learning approaches can be ascertained using specialised instruments, such as the Approaches and Study Skills Inventory for Students (ASSIST) (Tait, et al., 1998).

How students’ learning approaches are influenced by using technology is not clear. Weigel (2002, p. 5) states that “[f]rom a practical standpoint, deep learning and e-learning are inseparable” but Russell (1999) reported no significant difference between students learning by distance with technology and students learning by traditional methods.

In the fields of Veterinary and Health Sciences, advances in computer hardware and software since the 1990s have led to increased use of technology for teaching and learning (Holmes & Nicholls, 1996; Ryan, et al., 2004). A new technology being increasingly adopted in Veterinary Science and Medicine is virtual microscopy. However, it is not clear if students’ approaches to learning histology and pathology may be influenced by virtual microscopy.
Virtual microscopes were introduced into the teaching of histology and pathology in medical courses at the University of Iowa, USA, in 2000 (Harris, Leaven, Heidger, Kreiter, Duncan et al., 2001) and at Leeds University, UK, in 2005. A ‘virtual microscope’ is comprised of “hardware, for slide digitisation and software for a viewer, that allows users to zoom and change magnification (e.g. 20x 40x) to examine digitised slides” (Aperio Technologies Incorporated, 2006). Virtual microscopes run on personal computers through the installation of custom software for viewing digital slides. To clarify the difference between an optical microscope (with multiple-heads for viewing) with glass slides and a virtual microscope with virtual slides, see Figure 1.1 (optical microscope with multi-headed viewers) and Figure 1.2 (virtual microscope). Virtual microscopes are different from electronic simulations of a microscope, where the virtual microscopes components can be manipulated, e.g. slides, light aperture, and focus.

Figure 1.1 The optical microscope laboratory set-up
A group of students in the foreground are working together on a ten-header microscope. The demonstrator’s video-microscope relays to four wall-mounted monitors, two of which can be seen in the background.
Although virtual microscopes were first developed to accommodate physically disabled students (Pritchard, 1996), it quickly became apparent that they were also suitable for students studying remotely. Technological advances meant that virtual microscopes were continually developed and refined and that, by the early 2000s, their potential as a valuable tool was recognised by pathologists (Demichelis, Barbareschi, Dalla Palma, & Forti, 2002; Leong & McGee, 2001). At the same time, virtual microscopes were introduced to undergraduate medical teaching (Harris, et al., 2001). Virtual microscope development continued with specific application to pathology (Catalyurek, Beynon, Chang, Kurc, Sussman et al., 2003; Dee, Lehman, Consoer, Leaven, & Cohen, 2003).

1.1 Problem Definition

In the early 2000s, the use of virtual microscopes for teaching and learning at universities was limited mainly to medical schools. Harris et al. (2001) introduced virtual microscopes into three histology classes in the College of Medicine at the University of Iowa, and received
positive feedback from the students. The virtual microscopes were rated higher than the optical microscopes and the virtual microscope laboratories were rated as more efficient and accessible than the optical microscope laboratories. The researchers concluded that the transformation to using virtual microscopes for teaching was inevitable.

Heidger et al.’s (2002) research, at the same College of Medicine, asked students to rate both optical and virtual microscopes when learning histology. The students rated the resolution and image quality of the optical microscopes higher than the virtual microscopes but they rated the overall educational value of the virtual microscopes higher than the optical microscopes. Both Heidger et al.’s (2002) and Harris et al.’s (2001) studies were small scale and had low response rates. However, they do suggest that students may find virtual microscopes a useful learning tool.

Dee, Lehman, Consoer, Leaven and Cohen (2003), on the other hand, investigated the use of virtual slides to augment traditional glass (optical) slides in a cancer histopathology course. Photomicrographs were compared with virtual slides. Overall, the virtual slides image resolution was higher. The virtual slides allowed educators to point out areas of interest to the students and they enhanced the students’ abilities to be able to learn from glass slides at the optical microscope. Both students and educators preferred using the virtual microscopes to the optical microscopes when learning in groups, with the students rating the virtual microscopes more efficient and accessible than the optical microscopes. The researchers also said that they expected virtual microscopes to revolutionise the way that they teach and the ways students learn from microscopic images. The high cost of implementation was noted.

Until recently, the costs and limitations of the technology (hardware and software) prevented wider scale adoption of virtual microscopes for university teaching. There was, therefore, a limited body of research on the impact of virtual microscopes on students’ learning. However, from 2005, lower costs (data storage, hardware and software) and
improved technology (better computers and higher bandwidth) facilitated the wider introduction of virtual microscopes into health science curricula. Consequently, a proliferation of research into teaching and learning with virtual microscopes in universities has ensued (e.g. Becker, 2006; Chen, Hsue, Lin, Wang, Chen et al., 2008; Goldberg & Dintzis, 2007; Mills, Bradley, Woodall, & Wildermoth, 2007; Weinstein, Graham, Richter, Barker, Krupinski et al., 2009).

Although there is a wide range of literature about factors that influence students’ learning approaches (e.g. Biggs, 2003; Biggs & Collis, 1982; Cope & Staehr, 2005; Entwistle, 2000; Tait, et al., 1998), and considerable literature about the impact of technology on learning, there is still limited research on the impact of the specific technology of virtual microscopes on students’ approaches to learning. However, there is some research on virtual microscopes and learning outcomes. Several researchers (e.g. Blake, Lavoie, & Millette, 2003; Dee, et al., 2003; Harris, et al., 2001; Heidger, et al., 2002) have compared students’ perceptions of virtual microscopes and optical microscopes, but in all cases the students used individual optical microscopes and not multi-headed optical microscopes, such as the ones used in this study. Dee, et al., (2003) found students and staff preferred using the virtual microscopes to the optical microscopes when learning in groups and that students rated the virtual microscopes as being more efficient and accessible. They also said that they expected virtual microscopes to revolutionise the way they teach and the ways students learn from microscope images.

This thesis, therefore, will address the following broad research question:

*How does the introduction of virtual microscopes into histology and pathology laboratory classes affect students’ learning approaches and learning?*

Other questions of interest are:

1. What factors influence students’ learning with virtual microscopes?

2. Do students’ approaches to learning change with the introduction of virtual microscopes?
3. Do virtual microscopes encourage deep learning?

4. Do students’ learning approaches alter differentially with virtual and optical microscopes?

5. Are virtual microscopes more suited to a particular learning approach?

6. Are virtual microscopes easier to use than optical microscopes?

This study, therefore, looks at learning with optical and virtual microscopes, with a particular examination of virtual microscopes and focuses on identifying the factors that assist students to take a deep approach to their learning.

1.2 Aims and Objectives

The main aim of this thesis is to explore any connection between the use of virtual microscopes in the fields of veterinary and health sciences and students’ learning approaches. This study therefore aims to identify, in particular, if this new technology will influence students to take a deep approach to their learning. Another aim of this study is to gain insight into students’ learning outcomes in histology and pathology laboratories equipped with virtual microscopes.

The main objective of the study is to compare the learning experiences of different groups of students using either optical or virtual microscopes and to determine any differences between them. These insights may be used to inform future learning designs in histology and pathology using microscopes. Other objectives include adding to the general body of knowledge about good practice in the implementation of technological innovations in higher education and about the factors influencing deep learning in education.
1.3 Significance and Outcomes of the Research

Previous research (e.g. Ryan, et al., 2004) into veterinary medicine students’ learning approaches found that grades were associated positively with both deep and strategic approaches, but negatively with surface approaches, and that students’ perception of a high workload was also associated with a surface approach. Tertiary institutions should strive to encourage students to adopt deep approaches to learning (Biggs, 2003). This thesis adds to this body of knowledge in providing a greater understanding of the impact of technology on facilitating deep learning; in particular, the effect of virtual microscopy technology. The methodology for this research was rigorously tested with an extensive exploratory study to determine whether there would be any detrimental impact on students’ learning approaches prior to undertaking the main study in the three disciplines.

This thesis makes four major contributions to scholarly knowledge.

This study combined research on virtual microscopes and learning approaches in three disciplines (Veterinary Science, Chiropractic Science and Biomedical Science).

Students’ perceptions of learning histology and pathology with both optical and virtual microscopes are clarified.

The results from this thesis facilitated the development of a model, the Virtual Microscope Implementation Model (VMIM), to assist educators integrating virtual microscopes into their curricula.

This study identified key issues associated with the introduction of virtual microscopes and recommends ways to use them to encourage students to adopt a deep approach to their learning in histology and pathology. If findings from this research determine best practice with virtual microscopes that encourage deep learning these should be implemented over practices that lead to surface learning.
The outcomes will:

1. provide a greater understanding of the role virtual microscopes can play in encouraging deep learning in histology and pathology;
2. provide critical success factors for implementing virtual microscopes for histology and pathology;
3. provide ways to encourage deep approaches to learning;
4. outline students preferences for either virtual or optical microscopes when learning histology and/or pathology; and
5. determine whether virtual microscopes contribute to and enhance students’ learning

The results of this study provide a better understanding of the current issues associated with students’ learning with virtual microscopes and what can be done to encourage students to adopt a deep approach to their learning.

1.4 Research approach

To provide insight into the research questions, a mixed methods approach was used. Mixed methods research includes both qualitative and quantitative components. A review of existing quantitative instruments that could be used to measure students learning approaches was undertaken. The Approaches and Study Skills Inventory for Students (ASSIST) survey (Tait, et al., 1998) was chosen as it was applicable to the research, has been used in a number of disciplines, and had previously been widely tested and validated. The instrument could not, however, be used to determine students’ perceptions of learning histology and pathology or their views on learning with microscopes; therefore, qualitative components were added (e.g. students reflections on their learning). On completion of a comprehensive exploratory study, minor modifications were made to the main study with the introduction of focus groups and interviews to further explore students’ perceptions of learning with microscopes. The main study included students from three separate
disciplines: Chiropractic Science, Biomedical Science and Veterinary Science. The researcher worked with three lecturers to develop appropriate assessments, and to give feedback based on the findings of this research.

1.5 Organization of the thesis

This thesis is organised into seven chapters. Chapter 1 provides a background to the research, presents the aims and objectives of the research and identifies the significance of the research.

Chapter 2 reviews the literature on learning, approaches to learning, measuring learning approaches, teaching approaches, learning environments, visual learning in histology and pathology, virtual microscopes. It also presents the theoretical framework of the study.

Chapter 3 reports on the methodology used in the study, including the research design, study population, the procedures followed and the instruments, materials and analysis used for both the exploratory and the main studies. Chapter 4 describes the physical and virtual learning environments of the exploratory and main case studies.

Chapters 5 and 6 present the results of the research. Chapter 5 describes the results of the exploratory study, including students’ study approaches, time spent studying and reflections. The chapter also shows how the results of the exploratory study informed the methodology of the main study. Chapter 6 reports the results of the data collection and analyses of the main study including the ASSIST results, time spent studying, reflections, focus groups and interviews.

Chapter 7 discusses the study results and presents a model and guidelines for integrating virtual microscopes into curricula and recommendations for further research.
1.6 Summary

This chapter provided an introduction and background to the research including, learning and learning styles and approaches, a definition of the problem and the research questions. It then outlined the aims and objectives of the study, significance and outcomes of the research, the research approach and expected outcomes. Chapter 2 reviews the literature on learning, learning theories, approaches to learning, measurement of learning approaches, teaching approaches, the learning environment, visual learning in histology and pathology, virtual microscopes, and the theoretical framework of the research.
CHAPTER 2

LITERATURE REVIEW

The following sections review the literature relevant to this thesis; specifically that concerning learning and microscopes. A general definition of learning adopted for this research is provided by Schunk (2008, p. 2):

> an enduring change in behaviour, or in the capacity to behaviour, or in the capacity to behave in a given fashion, which results from practice or other forms of experience.

Learning is a complex process, influenced by many factors, such as individuals’ backgrounds, previous knowledge, conceptions of learning, the learning environment and teaching methods. Psychologists and educators have developed theories to explain how students learn and to determine how to maximize and encourage learning through teaching. Thus, many different learning theories have evolved over time.

The first section in this chapter provides an overview of the most common learning theories while the second section describes different approaches to viewing how learning occurs and is measured. The chapter then focuses on the learning environment and its impact on learning, along with factors that encourage students to adopt a deep learning approach. Active learning and visual learning, critical aspects of working with microscopes are also discussed. The key issues associated with virtual microscopes are described in detail. From the literature presented in this chapter, a theoretical framework is developed to provide a foundation for the research.

2.1 Learning Theories

Learning theories developed mainly as a result of the application of psychological theories being applied to learning. The main aim of learning theories is to help educators understand
the ways students learn and be able to use that knowledge to help students to learn more effectively. Theories evolve over time and are thus often tied to specific timeframes.

According to Schunk (2008, p. 22), most learning theories share some common assumptions, in that:

- learners progress through stages/phases; material should be organised and presented in small steps; learners require practice, feedback and review; social models facilitate learning and motivation; and motivational and contextual factors affect learning.

However, various theories have developed to explain learning from a particular perspective. In an attempt to understand the contexts of learning theories and their impact on teaching and learning, the major theorists who have influenced the development of three main learning theories (behaviourism, cognitivism and constructivism) are discussed in the following sections.

### 2.1.1 Behaviourism

Behaviourist learning theory dates from the mid-1920s, and grew from psychologists of the time (e.g. Pavlov, 1927; Skinner, 1935; Watson, 1913).

Behaviourism suggests that learning occurs through stimuli and response, and certain behaviours are reinforced while others are not, which means that reinforcement is a necessary condition for learning. The founder of behaviourism was John B. Watson (1913) who explicated the psychologists’ view of behaviourism. Watson theorised that individuals possess instinctive behaviours and motives but that the more important determinants of behaviours are learned (Mowrer & Klein, 2001). This process is known as classical conditioning which is an involuntary type of learning. The theory focuses on measurable, behavioural outcomes and not on knowledge, attitudes, beliefs or actions.
Pavlov (1927), a Russian psychologist, studied reflex reactions in humans and animals and found that a number of responses could be associated with other elements (e.g. a bell is rung just prior to feeding, the dog salivates, and is conditioned to associate the bell ringing with food). Pavlov added to classical conditioning theory and applied it to abnormal behaviours. He believed that any perceived stimulus could be conditioned to any response.

Schunk (2008) claims that Pavlov’s model was extended by Watson to account for more diverse forms of learning and personality characteristics. In the USA, Thorndike (1911) was engaging in similar work to Pavlov. He thought learning involved the formation of associations (connections) with successful responses being established and unsuccessful ones abandoned. Skinner (1935) added to these theories by developing his own theory called operant or instrumental conditioning, which included positive and negative reinforcements, punishment, and extinction. In operant conditioning, behaviours are emitted voluntarily and the organism experiences some consequences of the behaviour.

Today, Behaviourism is sometimes known as behavioural analysis and is still widely used for behaviour modification in fields such as health, psychology and education, e.g. for developmental disabilities and to modify unwanted behaviours in health or education settings. While Behaviourists view learners as passive and as responding to stimuli and responses in the environment, other theorists posited that learning may not merely be a result of the environment but could be due to brain processes (cognitivism).

### 2.1.2 Cognitivism

Cognitive learning theories arose as a result of psychologists (e.g. Wertheimer, Koffka, Kohler, Piaget, Vygotsky and Bruner) questioning behaviourist theories. Cognitive theories are thought to be innate. These gained popularity from the 1960s and were influenced by information processing theory, which was explored further by Mayer (1996). Cognitivists are concerned with what learners know and how they acquire knowledge. In this theory, learning
is seen as something that occurs in the mind: information comes in, is processed, and leads to outcomes (one of which may be learning). In other words, cognitive theorists study the cognitive processes of memory, thinking, problem solving and decision making. Individuals create their own schema or frameworks to help them understand their world.

Cognitive theories were later applied to education. Some of the main proponents of these educationally oriented theories were Chomsky (1959), Ausubel (1968), Piaget (1972), Vygotsky (1978), Anderson (1997) and Bandura (1986).

Chomsky, a linguist who studied language acquisition, vehemently opposed Skinner’s behaviourist explanations of language acquisition. Chomsky (1959) wrote a critique of Skinner’s theories in which he disputed the adequacy of behaviourist concepts and vocabulary (e.g. stimulus, response) in explaining language acquisition and he thought that behaviourism was not objective. Chomsky maintains that children have an innate knowledge of basic grammar, or linguistic nativism, which is common in all human language (universal grammar). His work on education was significant and had a profound effect on linguistics.

Ausubel (1968) undertook educational research in school settings and believed that students learnt by relating new material to relevant existing ideas. He believed that the ideas were assimilated into cognitive structures on a substantive, non-verbal basis. He called his theory "subsumption". Ausubel (1970) also suggested that students could be encouraged to learn by using advance organisers which act as bridges between new knowledge and existing related ideas. Advance organisers introduce broad statements at the beginning of the lesson that help to connect new learning with prior learning. They appear to work best with older learners (Luiten, Ames, & Ackerson, 1980).
Piaget (1972), a philosopher, scientist, and educational researcher, strongly influenced education by proposing that children learned according to their cognitive developmental stage. He defined four stages of cognitive development in children:

- **Stage 1 (0 to 2 years)** *Sensorimotor Stage*: when children use their senses to explore the world.
- **Stage 2 (2 to 7 years)** *Preoperational Stage*: when children acquire motor skills and are egocentric.
- **Stage 3 (7 to 11 years)** *Concrete Operational Stage*: when children begin to think logically.
- **Stage 4 (11 + years)** *Formal Operational Stage*: when children develop abstract reasoning (1972).

Vygotsky (1978) was another influential theorist in this area. Vygotsky was a Russian psychologist whose research focused on whether children’s developmental levels were fixed or their learning assisted (scaffolded) by providing adult guidance and/or by working collaboratively with more capable peers. Vygotsky also conceptualised the “zone of proximal development” which could be used to identify a child’s points of developmental readiness which could then be used to provide an activity that the child could complete with assistance. The zone is described by Vygotsky (1978, p. 86) as:

> The distance between the actual development level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers… The zone of proximal development defined those functions that will mature tomorrow but are currently in an embryonic state. These functions could be termed the “buds” or “flowers”… rather than the fruits of development.

Anderson (1997) also put forward a new theory, that of, the schema theory of learning. He said that organised knowledge is made up of a complex network of abstract mental structures that represent individuals’ understandings of the world. The main principles put forward for teaching are to teach general knowledge and broad concepts, then build on that knowledge (schemata) and help students to make connections between ideas. Prior
knowledge is necessary to build new knowledge so teachers need to either teach the prerequisite knowledge or to remind students of what they already know before introducing new material. Schemata will change in response to new knowledge and are organised in meaningful ways to individuals.

A variation of cognitive theory that was based on observational learning studies, conducted by Bandura (1986), is Social Cognitive Theory; so named by Bandura to distinguish his theory from other cognitive theories. Bandura’s theory suggested that anything that could be learned from direct experience could also be learned from observation. Bandura (1986, p. xii) explained that:

… the theoretical approach of this book is designated as social cognitive theory. The social portion of the terminology acknowledges the social origins of much human thought and action; the cognitive portion recognizes the influential causal contribution of thought processes to human motivation, affect and action.

Learning was seen as occurring in a social environment, through the observation of others and through modelled behaviours. Bandura expanded his theory to include the self-regulation of thoughts, emotions and actions through such activities as setting goals, judging anticipated outcomes of actions, and evaluating progress toward goals. He was a prolific researcher and writer and is well known for his work on self-efficacy (belief in whether you can do something or not) and how that impacts on learning (Bandura, 1977, 1986, 1993).

Vykotsky and Piaget both believed that social factors influence learning, which is one of the reasons they are also cited as being influential in constructivist learning theories.

Cognitive learning models isolate mental operations in order to discover the most efficient mapping of external reality onto learners (Jonassen, 1996, p. 55).

In a similar vein, Flavell (1981) believes that students need to learn how to learn, and to be able to monitor and adapt their own learning; that is, metacognition.
In cognitive learning theory, therefore, the focus was on what happens in the mind and not on observed behaviour; however, to some theorists, neither cognitive nor behavioural theories totally explain learning.

2.1.3 Constructivism

Many researchers and practitioners (e.g. Von Glaserfeld, 1995a) questioned cognitivist assumptions about learning as they did not feel that they completely explained students’ learning and understanding. Constructivism is an epistemology or way of knowing that sees learners as active agents in the learning process. In fact, learners are said to create their own learning (Schunk, 2008). According to Howe and Berv (2000), there are two basic premises in constructivist learning theories:

- learning takes as its starting point the knowledge, attitudes, and interests students bring to the learning situation, and
- learning results from the interaction between these characteristics and experience in such a way that learners construct their own understanding (pp. 30-31).

Learners perceive the world in many different ways, and there is no one perception that is more correct than another (Howe & Berv, 2000; Richardson, 1997). Von Glaserfeld (1995a) claimed that:

from the constructivist perspective learning is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction. Problems are not solved by retrieval or rote-learned “right” answers. To solve a problem intelligently, one must first see it as one’s own problem… and “having found a viable way to solve a problem does not necessarily eliminate all motivation to search further. Learners construct meaning for themselves based on their prior knowledge and integration of new knowledge (p. 14).

Tobin and Tippens (1993) emphasize that an important point of constructivism that is sometimes overlooked is not that knowledge is personally constructed but that it is also ‘socially mediated’.
The elements of constructivism and their relationships are clearly illustrated in a model developed by Jonassen (1994) (Figure 2.1). The ‘web’ model has three main components — context, collaboration and construction — and shows how knowledge is acquired by students. Knowledge involves all three components. **Context** is determined by authentic tasks, apprenticeship (which is part of modelling processes), situated learning, and case based learning that requires domain/context specific reasoning. **Collaboration** is facilitated by knowledge and involves coaching and social negotiation, which in turn involves construction. The knowledge process of **construction** involves internal negotiation, articulation, and reflection. Jonassen describes his model as a tentative one but has not developed it further (D. Jonassen, personal communication, 27 November, 2009). However, it is particularly relevant to the research in this thesis.

One of the key elements in Jonassen’s model is *authentic tasks*. Duffy and Jonassen (1992) also refer to this element in suggesting that “the context need not be the real world of work in order for it to be authentic. Rather, the authenticity arises from engaging in the kinds of tasks using the kinds of tools authentic to that domain” (p.9).

A wider perspective on authenticity in learning is expressed by Herrington and Oliver (2000) who outline nine characteristics of authentic learning:

- **authentic contexts** – reflects the way knowledge is used in real life
- **authentic activities** – that are complex and ill defined
- **access to expert performances** – enabling modelling of processes
- **multiple roles and perspectives** – providing alternative solution pathways
- **collaboration** – allowing for the social construction of knowledge
- opportunities for reflection – involving metacognition
- **opportunities for articulation** – to enable tacit knowledge to be made explicit
- **coaching and scaffolding** – by teacher at critical times
- **authentic assessment** – reflecting the way knowledge is assessed in real life
These nine characteristics represent the spectrum of authenticity that can be found in learning designs; however, an authentic task may not necessarily include all nine aspects.

As previously stated, in constructivist learning theory, students take an active role. *Active Learning* is described by Bonwell and Elison (1991) as:
activities involving students in doing things and thinking about what they are
doing...[and means] that students must do more than just listen: They must read,
write, discuss, or be engaged in solving problems. Most important, to be actively
involved, students must engage in such higher-order thinking tasks such as analysis,
synthesis, and evaluation (section 2, para. 2.).

There are two important elements in this approach: (i) people are given control of
their own learning; and (ii) individuals explore and experiment with a task to determine the
rules, principles and strategies of effective performance (Bell & Kozlowski, 2008). Active
learning has parallels with social constructivist learning theory as students are actively
constructing their own meanings.

To encourage students to become active learners, educators (e.g. Seeler, Turnwald,
& Bull, 1994; Wilson & Fowler, 2005) have manipulated the learning environment by
introducing project work and learning groups, and by encouraging faculty to adopt more
supportive/facilitative roles. Students can, however, be provided with scaffolding (guidance)
by teachers or more experienced peers to assist them to learn (e.g. Richardson, 1997).
Scaffolds were first suggested by Bruner (1967) and are frequently referred to in the
literature as creating constructivist learning environments (Richardson, 1997; Vygotsky,
1978).

There are variations in constructivist learning theory, the major ones being radical
constructivism, cognitive constructivism and social constructivism. Radical constructivism
sees knowledge as being in the minds of people, who must construct knowledge on the
basis of what they know as being true and that what they know can be considered to be a
more or less accurate representation of a world that exists in itself, prior to and independent
of the knower’s experience of it (Von Glaserfeld, 1995b).

Psychological (Piagetian psychological or cognitive constructivism) proponents of
constructivism see the meaning making process as individualistic and the purpose of
constructivist teaching is to lead students towards higher levels of understanding and
analytic capabilities (Richardson, 1997). This is achieved by facilitating an environment
where students experience some cognitive dissonance (Festinger, 1957) which is discomfort caused by two conflicting thoughts (e.g. existing beliefs and new ideas), and by setting tasks that should lead to the reorganisation of their existing cognitive maps.

*Social constructivist* learning theorists view learning as being socially constructed through conversation, discussion and negotiation (Confrey, 1995). They view the social as essential and, in fact, critical in both the construction of knowledge and the appropriation of knowledge. There are two approaches with their own scholarly traditions: situated cognition, and sociocultural. In situated cognition:

knowledge is constructed by a person in transaction with the environment... both the individual and the environment change are a result of this learning process (Richardson, 1997, p. 7).

The sociocultural approach is based on Vygotsky’s approach which:

sees the development of an individual as being reliant on social interactions. It is within this social interaction that cultural meanings are shared within the group, and then internalized by the individual (p. 8).

The learning theories discussed in this section influenced educational researchers to investigate how students approach learning.

### 2.2 Learning Styles and Approaches

Students do not all approach learning uniformly; in fact, there are probably as many ways to learn as there are to teach. Students have different motivations to learn; one may be driven by a desire to gain a qualification, while another wants to understand all he/she can about a subject. Over the past decade, there has been a trend to encourage academic staff to move away from teacher-centred approaches towards more student-centred learning as evidenced by several Australian University web sites informing and supporting staff to take a more student centred approach (Ingelton, Kiley, Cannon, & Rogers, 2000; Moore, 1999). This is partly in response to the acceptance of social constructivist learning theory as well as an
effort to improve teachers’ pedagogical performance by moving more towards being “a guide from the side” and a facilitator of students’ learning.

In an effort to determine how students learn, researchers began studying students’ learning styles and approaches to learning; there is now abundant literature in this area. Learning styles and learning approaches are different, although they are sometimes used interchangeably in the literature. Learning styles refers to students’ preferred mode of learning, e.g. visual, verbal, textual (Pashler, McDaniel, Rohrer, & Bjork, 2009). Learning styles proponents believe that students learn best when instruction is tailored to their individual learning style (Pashler, et al., 2009). The learning styles school of thought also believes that “individual differences are based upon psychological attributes that determine the strategy that each learner adopts for processing information and his/her preferences for learning situations” and that they are a stable aspect of individuals’ personalities (Cuthbert, 2005, p. 238).

Several researchers have developed classification schema for learning styles, including Coffield, Moseley, Hall and Ecclestone (2004) who classified learning styles into five families, some of which were based on fixed traits and others on more flexible traits:

- constitutionally-based learning styles – born with the traits, e.g. genetic influences, dominant sensory or perceptual channels;
- cognitive structure;
- stable personality type;
- ‘flexibly stable’ learning preferences; and
- learning approaches and strategies.

In contrast, Zinkiewicz, Hammond and Trapp (2003) classified learning styles into four main models:

- personality models (focusing on how differences in personality shape orientations towards the world); information-processing models (how information-processing preferences affect learning); social interaction models (considering ways in which
students in specific contexts will behave in the classroom); and instructional and environmental references (pp.19, 20).

A main criticism of learning styles is that they encourage stereotyping and labelling due to their positivistic and individualistic perspective on learning, thereby encouraging a division into those who fit the models and those who do not, with the latter being in need of remedial action (Cuthbert, 2005). Other researchers, such as Sadler-Smith (2001), suggest that there are reliability and validity problems with some of the instruments used to measure learning styles (e.g. Kolb’s Learning Styles Instrument (LSI)) while others (e.g. Heffler, 2001) found the LSI had good test-retest reliability, with the latest LSI instrument being more reliable.

Whereas, learning styles refers to students’ preferred mode of learning, learning approaches refers to students’ learning intentions: deep, strategic or surface.

The original research into students’ approaches to learning was undertaken by two Swedish researchers, Marton and Säljö (1976). These researchers set a reading task for a group of students and then interviewed them to determine how the students approached the task. From this, they identified two main approaches to learning used by the students: deep and surface approaches. A deep learning approach was characterised by students who attempted to understand the passage in a holistic way, while surface learning was characterised by students attempting to memorise facts (1976). A further approach was suggested by McCune and Entwistle (2000), a strategic approach, characterised by students’ awareness of learning in its context (e.g. alertness to assessment requirements and criteria, monitoring the effectiveness of ways of studying) and self-regulation of study (e.g. organising study thoughtfully, managing time and effort effectively).

Student approaches to studying appear to be generated from their intentions. According to Entwistle and Peterson (2004), when students use a deep approach, the students’ intentions are to understand ideas for themselves. In a surface approach the
intention is to cope with course requirements. In a strategic approach the intention is to do well in the course and/or to achieve personal goals.

Students also adopt varying approaches to studying based on personal factors (e.g. preferred study approach) and teaching context (e.g. the learning environment provided). At about the same time Biggs (1987) and Tait, Entwistle and McCune (1998), developed instruments identifying three approaches to studying. Biggs’ three approaches were: (i) **deep** - characterised by a focus on understanding; (ii) **surface** – characterised by rote learning; and (iii) **achieving** - characterised by students’ focus on maximising grades. Tait, Entwistle and McCune’s three approaches were defined as: (i) **deep approaches** - characterised by a preference to work conceptually and driven by intrinsic curiosity; (ii) **strategic approaches** - characterised by a focus on obtaining high marks and organised studying; and (iii) **surface approaches** - characterised by an intending to achieve a pass, avoiding too high a workload, misunderstanding requirements, and/or thinking that factual recall is all that is required.

Cuthbert (2005) points out that some research (Richardson, 1990) has been critical of the strategic approach being included in the ASSIST but there is general support of the deep and surface approaches.

Research into student learning at a tertiary level suggests that students should be encouraged to adopt approaches to studying that lead to deep learning (Biggs, 1987; Cope & Staehr, 2005) which is characterised by a genuine interest in ideas, seeking meaning, using evidence and relating ideas (Biggs, 1987; Entwistle, Tait, & McCune, 2000; Marton & Säljö, 2005).

Studies have also investigated ways to develop deep learning approaches in students. For example, Cleveland-Innes and Emes (2005) investigated the role of social interaction, socialisation and academic interaction, and their effects on student approaches to learning. They found that both peer interaction and faculty interaction effected a change in
approaches to learning over time and concluded that a critical factor in the determination of the approach to learning was the socialization process.

Educational researchers continued to develop ways to classify students learning approaches and styles. Biggs (2003; Biggs & Collis, 1982) developed a taxonomy, the Structure of Observed Learning Outcomes (SOLO), that classifies learning into five approaches:

- Prestructural, the student misses the point;
- Unistructural, the student can identify or do a simple procedure;
- Multistructural, a disorganised list of items or knowledge-telling (masses of detail);
- Relational, shows understanding through integration of data or understands how to apply a concept to a familiar data set; and
- Extended Abstract, unseen problems can be handled by relating to an existing principle and questioning and going beyond existing principles.

The SOLO taxonomy assists educators to assess learners’ achievement of learning outcomes and in some ways equate to surface (prestructural) and deep learning (extended abstract).

Reid, Duvall and Evans (2005) redesigned a second year medical course to promote deep learning, as suggested by Biggs (2003). This involved constructing learning objectives based on the SOLO taxonomy, constructively aligning their written assignments and examinations with the objectives and included problem-based learning in their redesign. They found that the students showed almost no change in their learning approaches during the course and suggested that the reasons for such little change could have been that the students already had high scores on the deep approach at the beginning of the study or that the changes to the learning environment were not strong enough to change students’ approaches.
The approaches to learning perspective believe that different learning outcomes can be attributed to students’ different learning intentions. Cuthbert (2005) says that the approaches to learning school of thought believe that there are differences in the quality of engagement of learners that can be classified into three main groups: learning for understanding, learning for reproduction and learning for achievement. He also says that individual’s approaches to learning are contextually determined; “the learner’s approach to the learning task depends upon his/her conscious choices for learning, study practices are situationally specific” and that “students have different intentions for different learning tasks depending on the nature of the task and the context” (p.239). Researchers have also criticised learning approaches and the instruments used to determine them (Coffield, et al. 2004). Tickle (2001) for example said that identifying a students’ orientation does not tell us anything about how competent the student is in using it. Cuthbert (2005, p.244) says that “a student with a high orientation towards a deep approach, but who is not particularly competent, may perform less well than a student with a highly polished surface approach”. Coffield et al. (2004) say that more than 100 studies have addressed the theoretical and empirical tasks of evaluating the effectiveness of the inventories and their implications for pedagogy in universities (2004). They say that most of the studies fall into either the theoretical and conceptual development of rationales for focussing on approaches and strategies for learning, or focused on refinements to the reliability and validity of particular inventories to measure approaches and strategies to learning. They found that there were no empirical evaluations of changes to pedagogy arising from use of the inventories. However, they did identify Entwistle’s ASSIST and Vermunt’s Inventory of Learning Styles (ILS) as models of learning developed within the specific context of higher education that unlike many of the other instruments they reviewed (Coffield, et al., 2004).

Educators have reported varying levels of success when trying to shift students to a deep approach. As previously discussed, Reid, Duvall and Evans (2005) reported no significant change in students’ approaches after they redesigned a second year medical course according to SOLO as suggested by Biggs (2003). However, Cope, Staehr, and
Horan (2002) reported more success in shifting students towards a deep approach by their redesign of an Information Technology unit over a five year period. The researchers acknowledged that deep approaches require a large time investment by students. They found that through manipulating the learning environment by gradually reducing the workload in the subject (to educationally critical content); using assessment tasks to encourage a consistent workload over the duration of the subject (tutorial marking sessions requiring students to think about the content on a regular basis and the provision of constant feedback on their progress); as well as monitoring the students’ perceptions of the workload, deep learning was encouraged.

In contrast, Kjellgren, Hendry, Hultberg, Plos, Rydmark, Tobin and Saljo (2008) found that students’ higher age and gender was related to their using deep approaches to their learning. Older students had a deeper motivation for their learning and female students as a group adopted a deep approach to their learning more often than males.

These learning theories led educationalists to ask how students’ learning could be measured and the answer is coloured by their learning theories and teaching epistemologies.

Measuring learning is complex, as learning can be influenced by so many factors. How does one know whether a student has learned as a result of a particular activity or experience, or whether the learning occurred due to other factors such as maturation, prior knowledge or experience? Behaviourists measure learning by observing and recording behaviours (e.g. task analysis), while cognitivists measure learning by asking their subjects to complete some task or instrument while providing a score for performance. Constructivists measure learning by assessing the process of knowledge acquisition (Jonassen, 1996).

There are many instruments available to measure students’ approaches to studying and their learning styles. These instruments have been developed based on various theories
and within different disciplines, e.g. psychology, sociology, management and education. A report on learning styles and pedagogy (Coffield, et al., 2004) examined 13 of the most influential models and concludes that “it matters fundamentally which instrument is chosen” by researchers. Coffield et al. (2004) recommended Allinson and Hayes Cognitive Style Index instrument (1996) as they felt it had the best evidence for reliability and validity of all the 13 models examined, even though the pedagogical implications of the model had not been fully explored.

Three of the most commonly used instruments for student learning approaches are the Study Process Questionnaire (SPQ) (Biggs, 1987), the Inventory of Learning Styles (ILS) (Vermunt, 1988) and the Approaches and Study Skills Inventory for Students (ASSIST) (Tait, et al., 1998). The SPQ classifies students into deep or surface learners, as well as identifying their motivation for learning. The ILS classifies students as being meaning-directed, reproduction-directed, application-directed or undirected. The ASSIST was previously known as the Approaches to Study Inventory (ASI) (Entwistle & Ramsden, 1983) but developed over time to be the Revised Approaches to Study Inventory (RASI) and then the ASSIST. The instrument is being continually refined and improved (Entwistle, personal communication, 15 February, 2006). Coffield et al. (2004) suggest the ASSIST model be used in one of three main ways:

as a diagnostic tool for lecturers and students to discuss approaches to learning and how they might be developed;

a diagnostic tool for course teams to use in talking about the design and implementation of the curriculum and assessment, including forms of support such as study skills courses;

a theoretical rationale, based on extensive empirical research, for discussion among lecturers (e.g. on teacher training and staff development courses) about students learning and ways of improving their approaches (p.99).

Other popular instruments are the Inventory of Learning Processes (ILP) (Schmeck, Ribich, & Ramanaiah, 1977), the Learning and Study Strategies Inventory (LASSI) (Weinstein, Zimmerman, & Palmer, 1988) and the Inventory of Learning Styles (ILS) (Vermunt, 1988).
In general, the ASSIST inventory appears to lack constructs on aspects of social learning. It does not ask students about their interactivity with other students, about the subject, or whether their original ideas have changed in response to discussing their ideas with other students. As social learning is an important part of social constructivist learning contributing to a deep approach, this is a deficiency in the measure. The ASSIST however, was developed for use in higher education (Coffield, et al., 2004) and has been shown to be a valid and reliable instrument.

### 2.3 Teaching Approaches

Inevitably, learning theories also have implications for teachers and the ways they may teach. Teaching is a complex process influenced by many factors, such as teacher beliefs about teaching, culture, society, individual motivation and students’ behaviours and motivations (Biggs, 2003). There can however be differences between teachers’ espoused theories of teaching and the actual theories used (Phillips, 2005). Teachers may, for example, say they believe in constructivist (student centred) approaches to teaching but in practice they use teacher-centred practices. Teachers adopting a constructivist approach view learners as actively engaged, constructing meaning, bringing their prior knowledge to bear on new situations and adapting their knowledge structures. They view teaching both a learning process for themselves and their students, and the curriculum as a set of learning activities and interactions that assist students to learn, the focus is on the learning (Driver, 1995).

Several instruments have been developed to assist teachers to identify their predominant teaching style. For example, two instruments have been developed to determine whether teachers hold student-centred or teacher-centred approaches to teaching: the Teaching Behaviours Preferences Survey (Behar-Horenstein, Mitchell, Notzer, Penfield, & Eli, 2006) and the Principles of Adult Learning (PALS) (Barrett, Bower, & Donovan, 2007).
Teaching styles can also influence the learning environment and students' learning approaches (Ramsden & Entwistle, 1981).

2.4 The Learning Environment

A major factor influencing students' learning and teachers' teaching is the learning environments created for students. Students adopt varying approaches to learning in response to the learning environment (Biggs, 2003; Cope & Staehr, 2005). Factors that influence learning include physical and non-physical spaces, teaching approaches and methods (Ramsden & Entwistle, 1981), workload (Lizzio, Wilson, & Simons, 2002), content, assessment, teaching styles, the communication of expectations to students, the students themselves and technological tools, such as virtual learning environments (VLE).

A virtual learning environment can be viewed as a useful collection of e-learning tools in a package that allows a common interface and sharing of data between the tools (Weller, 2007, p. 16).

Examples of VLE systems are Blackboard™ (formerly known as WebCT™), Moodle™, Desire to Learn™ and Angel™. VLEs afford interactive activities and digital resources to students.

Research into different approaches to studying identifies more than just students' intrinsic characteristics; differences also exist as functions of the learning environment. Student learning researchers also suggest that learning environments be designed to reduce surface learning approaches characterised by unrelated memorising, syllabus boundness, lack of purpose and a fear of failure (Entwistle, 2000) and instead be organised to encourage deep approaches. Several researchers have provided guidelines to assist teachers with this (e.g. Cope, et al., 2002; Entwistle & Peterson, 2004).

Biggs (2003, p. 29) suggests that "constructive alignment" be used to encourage deep learning in undergraduate teaching environments. Constructive alignment is characterised when curriculum objectives, teaching/learning activities and assessment tasks
are aligned. McCune and Hounsell (2005) elaborate further and suggest that “any such environment is a complex composite of many interacting influences that need to be aligned towards supporting deep active learning, if there is to be any overall effect” (p. 7).

Entwistle and Peterson (2004) caution that even when learning environments are created specifically to encourage deep learning there is no guarantee that they will have equal beneficial effects on all students. They also suggest that learning environments should make students ‘somewhat uncomfortable’ (constructive friction) to encourage learning but that only on the proviso that support be provided to allow new strategies to be developed without anxiety.

Some of the characteristics that encourage students to adopt deep learning approaches are also characteristics of social constructivist learning environments and are shown in Table 2.1.

Table 2.1 Learning environment characteristics that encourage deep approaches to learning

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Example</th>
<th>Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject well organised</td>
<td>Generative topics, Clear aims, Clear goals</td>
<td>Cope, Staehr &amp; Horan (2002)</td>
</tr>
<tr>
<td>Teach to prior knowledge</td>
<td>Identify what students know, Adopt teaching approach to support course aims and objectives</td>
<td>Cope, Staehr &amp; Horan (2002)</td>
</tr>
<tr>
<td>Manageable workload</td>
<td>Negotiate at unit, department and university level, Focus on depth of learning rather than breadth</td>
<td>Cope, Staehr &amp; Horan (2002)</td>
</tr>
<tr>
<td>Opportunity for group discussion</td>
<td>Schedule time for discussion of both content and learning processes</td>
<td>Entwistle &amp; Peterson (2004)</td>
</tr>
<tr>
<td>Provide illustrative examples</td>
<td>Give selected examples to assist with the</td>
<td>Entwistle &amp; Peterson (2004)</td>
</tr>
</tbody>
</table>
Student perceptions of the learning environment in one study (Kirkwood & Price, 2005) showed that students’ attitudes towards information and communication technologies (ICT) influence their study approaches. Kirkwood and Price (2005) suggest that it is important that ICT use is integrated as part of the assessed course outcomes rather than being an add-on after the course is designed.

Leung, Mok and Wong (2008) examined the influence of assessment (high level multiple choice questions aimed towards assessing students understanding rather than rote learning) on nursing students’ learning approaches and found there was a shift towards surface learning. They posited that excessive workload may have been the cause rather than the assessment. Focus group data from students suggested that setting scenario based questions, simulated role plays and case studies might direct learning towards their understanding of knowledge, critical thinking and application of knowledge.

In a longitudinal study of an Information Systems Development (ISD) unit that aimed to improve the proportion of students using deep learning approaches, a key factor of the learning environment that influenced the students’ approaches was the students’ perception of the workload in the unit (Cope & Staehr, 2005). A high workload was initially identified,
which led to surface approaches being used. Other researchers have also found that excessive workloads lead to students adopting surface approaches to learning (Ramsden & Entwistle, 1981; Ryan, et al., 2004). Over a five year period, Cope and Staehr (2005) gradually reduced the students’ workload in the ISD unit while ensuring there was enough educationally critical content. In the fifth year of the study, a statistically significant increase in the use of deep approaches to learning was achieved and they attributed it to the students identifying that they had been given enough time within the unit to allow them to use deep approaches.

The possible consequences of a learning environment on students’ approaches to learning are shown in Table 2.2. In each possible scenario, students’ approaches could stay the same (see Scenario 6) or could shift to a different approach (see Scenarios 1-5).

### Table 2.2 The possible impact of a learning environment’s on students’ approaches to learning

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Deep Learning Increased</th>
<th>Strategic Learning Increased</th>
<th>Surface Learning Increased</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>✓</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>x</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>3</td>
<td>x</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>6</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

#### 2.5 Visual Learning in Histology and Pathology

Learning histology and/or pathology is very visual (Gibson, 1979). Visual images have the potential to assist learners to learn rapidly but only when they are used appropriately and when not confounded by competing textual information. Researchers (e.g. Mayer, 1996) believe that there are dual channels of communication – auditory and visual – and that when text is inappropriately combined with visuals, learners cannot process the information effectively. On the other hand, when auditory and visual are appropriately combined (e.g.
visual content does not include an overload of text but includes audio narration, comprehension can increase due to the decrease in cognitive load (Clark, Nguyen, & Sweller, 2005). This is especially relevant to learning materials, such as Microsoft Powerpoint™ presentations.

Pathologists require knowledge and judgement in order to be able to make a diagnosis. Knowledge of histology and pathology can be taught, while judgement is linked with experience in recognising and categorising lesions (Underwood, 1987). One of three methods — pay off, heuristic, or pattern recognition — is used for diagnosis (Underwood, 1987, p. 10). The first, the pay off method, is a therapeutic solution to a diagnostic problem and is not directly applicable to histopathology. The second and third methods are the main diagnostic processes used in biopsy interpretation (Underwood, 1987, p. 75). The heuristic diagnosis is used by both novice and experienced histopathologists and describes goal-seeking behaviour, e.g. a problem that needs solving, such as “Is this liver diseased (e.g. cirrhotic)?” This form of diagnosis is not without its problems as sometimes the question may be misleading, but it is the easiest to teach and to learn (Underwood, 1987, p. 77). Information is accumulated about a biopsy and may reference a set of external criteria, books, atlases, monographs or slides (using a flow sheet either mentally or on paper) until a diagnosis can be made. The third method, pattern recognition, is founded on Gestalt psychology and is the most frequently used diagnostic process in histology/pathology:

the perception of form, as opposed to the identification of an object from the sum of its separate components... this means recognising a lesion from its overall pattern rather from the sequential assessment of individual features (Underwood, 1987, p. 77).

The disadvantages may be that pattern recognition is more subjective and probably more error prone.

The experienced histopathologist responds by a subconscious reflex action, recognising a pattern in a biopsy by comparing the lesion in question with a set of memorised patterns accumulated from previous experience... and allows a diagnosis to be inferred (p.77).
Underwood recommends combining heuristics with pattern recognition to increase the reliability of a diagnosis. Clearly visual learning is an important part of learning histology and pathology.

### 2.6 Virtual Microscopes

One of the traditional tools used to teach health science students about histology and pathology is the optical microscope. Students find optical microscopes hard to use. Farah and Maybury (2009) say that students find them difficult, frustrating, and tiresome. Students complain about the quality and consistency of its use, which has a detrimental effect on their engagement with the course content. With the advent of newer technologies, virtual microscopes are now being introduced into these subjects and there are signs that, in the near future, diagnostic pathology will move towards virtual microscopy. Recently, *The Wall Street Journal* quoted Dr Michael Feldman, the Director of Pathology Informatics at the University of Pennsylvania Health System, as saying that the technology will “transform diagnostic pathology” (Scott, 2008).

In educational institutions, there are increasing pressures on academics to incorporate economically efficient, as well as effective means to teach their subject specialties. The increased use of technologies, *prima facie*, appears to be the solution. Jonassen, Peck and Wilson (1999, p. 218) say that “Technologies … should be used as tools that students learn with … When students learn by using technologies as tools for growing and sharing… they are learning meaningfully”.

The use of virtual microscopes for teaching histology to veterinary science students is a relatively new development and there is limited research on the resulting impact on students’ learning outcomes or students’ approaches to learning. The research, to date, has been mainly concentrated in histology and pathology within the field of Medicine (Dee, 2006; Dee, 2009; Dee, et al., 2003; Harris, et al., 2001). This was probably due to the earlier
limitations of the technology, along with the expense. More recently technologies have improved and costs decreased (Dee, 2009), enabling research to move into the Veterinary Science (Mills, et al., 2007; Sims, Mendis-Handagama, & Moore, 2007). The literature identifies both positive and negative issues when using virtual microscopes for learning. The ten main issues — ease of use, freedom and access, improved time management, clarity and quality, health issues, convenience, group work, engagement, economics and assessment — are now discussed.

1. Ease of Use

Two recent studies (Heidger, et al., 2002; Mills, et al., 2007) reported that students found both optical microscopes and virtual microscopes easy to use. Another study (Husmann, O’Loughlin, & Braun, 2009), on the other hand, reported that students found virtual microscopes easy to use. These studies will be discussed.

Heidger, et al., (2002) state that the time allocated to histology in the undergraduate medical course at Iowa College of Medicine is continually being reduced. One of the methods used to cope with this reduction has been to introduce virtual microscopy alongside traditional optical microscope use in the first year medical students’ lab work for learning histology. Students’ perceptions of the overall educational value of both optical and virtual microscopes were reported. The students rated the virtual microscopes higher than the optical microscopes for their ease of use, availability, quality of imaging and the overall educational value. However, they also rated the optical microscopes favourably for their resolution, ease of use and the overall educational experience. The students clearly rated both the virtual and the optical microscopes as being appropriate tools for learning histology. The researchers did not ask whether the students preferred one over the other.

Mills, Bradley, Woodall, and Wildermoth (2007) surveyed veterinary science students who had used both optical and virtual microscopes to learn veterinary histology.
They asked them to respond to 17 items, by choosing an answer from a five point scale (5 strongly agree, 4 agree, 3 neutral, 2 disagree, 1 strongly disagree). The students found both the optical and the virtual microscopes equally easy to use.

In another survey Husmann, O’Loughlin and Braun (2009) compared traditional (optical) and virtual microscopes. They found that 36% of the undergraduate anatomy students surveyed commented that virtual microscopes were easy to use, e.g. “it takes less time to focus in on the object you are trying to look at which in turn gives you more time studying what you need to be.” (p. 224).

2. Freedom and Access

Although several recent studies have found that virtual microscopes afforded more freedom and access to students and to be able to study at times and places convenient to them, there were some flaws in the studies.

Harris et al. (2001) compared virtual and optical (regular) microscope laboratory classes for teaching histology to medical students, and found virtual microscopic labs were a viable addition to, if not a replacement for, optical microscopes and glass slides. Students provided higher ratings to the accessibility and efficiency of the virtual microscopes and quality of the images and navigation in comparison to the optical microscopes. They also found that the use of the virtual microscopes provided more opportunities for teachers to use strategies that promoted self-directed and independent student group learning, as well as providing more flexible access to the microscopes outside of regular labs. The study did, however, have a low response rate of only 25%. Their findings related to more flexible access is also supported by other studies (e.g. Goldberg & Dintzis, 2007; Harris, et al., 2001; Mills, et al., 2007).

In their study Blake, Lavoie and Millette (2003) described the move from traditional microscopy to virtual microscopy to teach histology to first year medical students. They
concluded that both students and staff strongly supported the move and that they had totally phased out optical microscopy, as the virtual microscopes afforded the students greater freedom to access histology slides any time and place of their choosing.

Sims, Mendis-Handagama and Moore (2007) introduced virtual microscopes into the teaching of microscopic anatomy and histopathology to veterinary students. Their motives were to employ new methods that could reduce lab costs, increase students’ access to slides, improve the students’ use of time, and improve teaching and learning effectiveness. Their evaluation was by way of self-report and did not include evaluating improvements in learning related to learning outcomes or assessment. Therefore further research is required to determine whether virtual microscopes affect students learning outcomes or assessment results.

3. Time management

Three studies (Husmann, et al., 2009; Kumar, Velan, Korell, Kandara, Dee et al., 2004; Mills, et al., 2007) have recently found students using virtual microscopes were able to management their time more effectively, with one study also reporting that students spent more time on task as a consequence.

Kumar et al. (2004), reported that using virtual microscopy meant that there was more time to review and discuss slides than there was with the optical microscopes. They also reported that many medical students had difficulties in using optical microscopes. In Mills, Bradley, Woodall and Wildermoths’ (2007) study, veterinary science students were surveyed to compare the use of optical microscopes with virtual microscopes. Students responded to 17 items by choosing an option from a 5 point scale (5 strongly agree, 4 agree, 3 neutral, 2 disagree, 1 strongly disagree). They found that students rated effective time management much higher for virtual microscopes (4.47 mean, 91.1% agreement) than optical microscopes (2.83 mean, 25.61% agreement). Husmann, O’Loughlin and Bruan
(2009) surveyed students about their use of virtual microscopes and reported that 20% of all student comments were about students liking the out of class access to the virtual microscopes and that this could lead to better use of class time. Other comments suggested that students spent more time on task with minimal time being spent on learning how to use the equipment.

4. Slide quality and clarity

Several recent studies show that medical students feel that virtual slides are an adequate replacement for traditional optical slides in terms of quality and clarity. At an annual Pathobiology of Cancer Workshop for non-physician pre-doctoral students and post-doctoral fellows working in cancer research, virtual slides were included with traditional slides at the workshop and were evaluated by the participants and evaluated for facilitating student learning (Dee, et al., 2003). The results indicated that the virtual slides enhanced students’ ability to grasp morphological features better than the traditional photomicrographs.

Chen, Hsue, Lin, Wang, Chen, Lin, & Lin (2008) found that virtual microscopy has many advantages over optical microscopy in oral and maxillofacial pathology education. This study used rating scales to evaluate the students’ perceptions of using virtual microscopes for their learning. The students rated all aspects of their Web-based study highly (glass slides available in digital format) and they were impressed with the virtual microscopy. Chen et al.(2008), also reported that the virtual microscopes provided additional advantages for students in that they did not have to rent out optical microscopes. The students could now view, manipulate and position the high quality image on a monitor as if they were viewing the original glass slide. They concluded by saying that virtual microscopy enables learning. A weakness in this study is that there was no evaluation of improvements to actual learning outcomes or student grades. Another recent study by Glatz-Krieger, Spornitz, Spatz, Hihatsch and Glatz (2006) found that dental students using virtual microscopes also rated the virtual slide quality as being superior or equal to optical (glass) slides.
5. Health Issues

Health issues with optical microscopes have been documented extensively. Professional daily users of microscopes report a number of health problems. For example up to 80% of users reporting headache, backache and other problems such as motion sickness (e.g. Golding, 2006; Kofler, Kreezy, & Gschwendtner, 2002; Thompson, Mason, & Dukes, 2003). It is not known at this time, whether virtual microscope users experience similar health issues. Recent research has reported improvements to health problems, such as nausea, eye strain and motion sickness (Kumar, Velan, de Permentier, Adam, Bonser et al., 2009) for users of virtual microscopes.

6. Convenience

A recent study found that convenience was a major factor in students’ preference for virtual microscopes over optical microscopes to learn histology.

The Podiatric Medical School at Rosalind Franklin University of Medicine and Science replaced optical microscopes with virtual microscopes for teaching histology. At the end of the teaching period, they surveyed students about their learning experiences and preferences for both types of microscopes, and concluded that virtual microscopy and the virtual slide box were preferred by both students and faculty staff. They identified convenience as a factor (Becker, 2006).

7. Group Work

In two recent studies (Goldberg & Dintzis, 2007; Kumar, et al., 2004) virtual microscopes were found to have facilitated group work in students. However, both studies were comparing students using optical microscopes singularly, prior to the introduction of the virtual microscopes.
Goldberg and Dintzis (2007) used virtual microscopes and group activities to transform their teaching in first year histology and pathology classes to medical students, by moving away from content focused to more facilitator focused discussions. The five-year study found that students’ final test mean score improved by 8-14% over this period. According to Goldberg and Dintzis (2007), the virtual microscopes were instrumental in enabling improvements, such as group-based teaching strategies that encouraged the students to adopt a more active role in their learning, and made the classes more enjoyable for staff to teach. Whilst the study had a number of flaws (e.g. the whole style of teaching changed in this unit and other unknown factors may also have influenced students’ exam results) overall the study reports a positive learning experience by the students and concludes with the students’ suggestion that this approach be adopted by all courses taught in the Medical School. Kumar et al. (2004) also found that students working in diads with virtual microscopes helped students to collaborate and be interested in pathology.

8. Engagement

A recent study found that virtual microscopes encouraged students to engage with their learning. However, the researchers also made significant changes to the curriculum, which was a confounding factor. Farah and Maybury (2009) introduced virtual microscopes into their third year systemic pathology unit as part of the dental curriculum at the University of Queensland. Students in this unit were asked to participate in a voluntary survey consisting of 31 statements about their experiences, to which students responded on a 5-point scale. A 95% response rate was reported. The researchers admit that they did more than just introduce virtual microscopes; they also made other significant changes to the curriculum, e.g. they introduced a Learning Management System (Blackboard) that was used for communication outside of class (announcements, email and grade book tools), and made changes to group work and formative and summative assessments. They concluded that students were more engaged in their learning through the changes they made:
This data shows that the virtual microscope positively altered how the students learnt and interacted with the course material both in the short and long term ... the enhancement of the learning process by using virtual microscopes speaks highly of its effectiveness in helping students engage and interact with the course material (Farah & Maybury, 2009, p. 177).

Given that their teaching methods had also changed the virtual microscope may not be solely responsible for the reported changes.

9. Economic Impact

Researchers (e.g. Krippendorf & Lough, 2005; Sims, et al., 2007) have identified economic factors as one of the motivators for trialling virtual microscopes. Krippendorf and Lough’s (2005) motivation in moving away from optical microscopy to virtual microscopy-based histology laboratories was to streamline learning for their large classes, as well as to alleviate the maintenance and replacement costs of the college’s microscopes and microscope slides. Other researchers (e.g. Mills, et al., 2007) also concluded that virtual microscopes would replace or supplement their current optical microscopes for teaching histology and/or pathology.

10. Assessment

A number of recent studies comparing students using virtual microscopes for assessment with students using optical microscopes for assessment found that virtual microscopes could be used with no detrimental effects. In fact, some studies reported improvements in assessment results.

Kumar et al.’s (2004) study found that virtual microscopy slides eliminated the skill barrier for students trying to learn optical microscopy, image quality was improved, and the ability to maintain orientation, speed and efficiency increased. According to Kumar et al., high quality learning resources (e.g. virtual slides) can ensure that microscopic examination of tissues is meaningful and interesting for students learning histology and histopathology.
Virtual microscopy was used without any issues in summative assessments. A comparison of summative assessment results for students using glass slides and virtual microscopes showed no difference.

Krippendorf and Lough (2005) also made a comparison of students using virtual microscopes with students using optical microscopes in their histology laboratories. The laboratory examination scores for these classes were compared with the four previous classes (years) that had used optical microscopes exclusively. In two of the three exam scores compared through the Wilcoxon Signed Rank Test, the mean scores showed no difference, but in the final exam scores the mean was significantly higher for students who used the virtual microscopes, thus suggesting that virtual microscopes may significantly improve student performance. They also found that the students were overwhelmingly positive about using the virtual microscopes and that faculty preferred teaching with them too.

Becker (2006) compared the laboratory grades and exam results of podiatric medical students using virtual microscopes with the grades from the previous years' class when they were using optical microscopes and found that their grades and exams were significantly higher than in previous years. The teachers thought this could be attributed to less stress during exams, as they did not have to move stations, refocus microscopes and identify specimens in a fixed period of time. However, they also felt that it could also have been partly attributed to the students knowing that they were part of a study and this affected their behaviour (known as the Hawthorne effect). The authors do reinforce the need to use optical microscopes for specialists who will need to use it in their career.

In another study by Golberg and Dintzis (2007), over a five year period that incorporated virtual microscopes along with a change in focus to more facilitator-focused discussions, it was found that students’ final test mean score improved by 8-14% over the study period. In contrast, Scoville and Buskirk (2007) randomly assigned students to one of
four groups (low, moderate, high moderate, or high achieving) for a histology unit; they also randomly assigned them to use either optical or virtual microscopes. A comparison of their test results found no significant interaction effects for either.

In a more recent study by Husmann, O'Loughlin and Braun (2009), the results of undergraduate anatomy students using virtual microscopes were compared with the results of previous students who used optical microscopes. The researchers state that student performance improved after the introduction of virtual microscopes but they also claim they cannot directly attribute these improvements to the virtual microscopes alone. However, they postulate that students did not have to spent time learning how to use optical microscopes and could therefore devote time to learning about histology, this could have contributed to the improvements in their results.

### 2.7 Theoretical framework

Learning is culturally and contextually situated (Brown, Collins, & Duguid, 1989), therefore the learning environment will vary depending on the context. However, from a social constructivist learning theory perspective there are a number of factors that can influence students’ learning including: context, construction and collaboration which are the main factors in Jonassen’s (1994, p. 36) model of constructivism. This study adopts a social constructivist approach to learning, where learners are seen as constructing knowledge for themselves, by engaging in authentic activities (based on real tasks), through social interaction and articulation (e.g. conversation, discussion and negotiation) (Confrey, 1995) and through appropriate scaffolding by experts.

From the literature on learning theories (Section 2.1) there are several vital components that need to be incorporated into the teaching and learning environment to encourage deep learning approaches when introducing new technologies. These are shown in Figure 2.2, which is an adaptation of Jonassen’s 1994 model.
The model forms the theoretical framework for the study. Ideally, when each component of the model is present, students can adopt deep approaches to their learning. The components are:

1. **Social interaction**
   
   To facilitate social interaction students were expected to engage in social interaction in their laboratory classes through group work. Students worked in groups in their laboratories to complete activities with microscopes.

2. **Scaffolding**
   
   A comprehensive advance organiser was supplied to students in the form of a laboratory manual by the unit coordinator. Templates for log books and reflections were designed and made available to students by the researcher.

3. **Articulation**
   
   The laboratory group work provided students with an environment conducive to articulating their emerging thoughts. Their experiences were captured through focus groups and interviews.

4. **Knowledge**
   
   To determine whether students' learned in their unit/s, students grades were accessed and matched with their learning approach.

5. **Authentic activities**
   
   Virtual microscopes are currently used by histologists and pathologist in the "real world". The activities undertaken by the students were designed to mirror the way these activities are done in the workplace.

6. **Teacher**
   
   The teacher's role is to design the learning experience to achieve the desired learning outcomes and to provide students with suitable scaffolding depending on their needs.
In summary, students take part in social interaction in the learning environment. This includes articulating their ideas about the topics with other students and rejecting or incorporating other students’ views into their own knowledge base.

2.8 Conclusion

This chapter outlined the main learning theories and discussed their influence on learning approaches and measurement of their effectiveness. It outlined the impact of the learning environment on students’ learning approaches and also discussed the role of visual learning in histology and pathology. It is important to note that findings from previous studies involving optical and virtual microscopes also presented here and several issues with their use were discussed. The chapter concludes with the researcher’s theoretical framework for the study.
CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this study. The methodology is an embedded case study using mixed (qualitative and quantitative) methods. These methods were used to investigate the degree to which the introduction of virtual microscopes affected students’ learning. The philosophical assumptions and the theoretical perspectives underlying the methodology adopted in this study justify the choice of the case study and analyses used in this study.

The chapter outlines the research questions and presents the ethical considerations addressed in this study. The methodology is described for both the exploratory case study (2006) and the main case study (2007). First, the exploratory study is described, including the selection of participants, materials used, data collection, data cleansing and data analysis. Second, the modifications made to the main study as a result of the exploratory study are discussed and include the addition of focus groups and interviews. Finally, the methodological design and procedures adopted to enable the research questions to be addressed are summarised.

3.2 Methodological Considerations

In the social and behavioural sciences there are two major approaches - qualitative and quantitative - that guide researchers in their research. Table 3.1 shows the main differences between the two approaches. The research design selected is influenced by the researcher’s own philosophy and beliefs. Historically, researchers have adopted either one or the other approach. In the last decade, though, researchers have increasingly adopted a more
pragmatic paradigm, one of mixed methods, where the research questions determine the 
research methods used to answer them. Tashakkori and Teddlie (1998) define mixed 
approach studies as:

... studies that are products of the pragmatist paradigm and that combine the 
qualitative and quantitative approaches within different phases of the research 
process (p. 19).

Table 3.1 shows some of the fundamental differences between the two main 
paradigms. In this study, the researcher follows the pragmatist paradigm in that she feels the 
research questions should dictate the research methods used to answer the research 
questions.

Table 3.1 Differences between the qualitative and quantitative paradigms

<table>
<thead>
<tr>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holistic, inductive paradigm</td>
<td>Hypothetical-deductive paradigm</td>
</tr>
<tr>
<td>Naturalistic/constructivist</td>
<td>Positivist/experimental</td>
</tr>
<tr>
<td>Ontology - multiple realities</td>
<td>Ontology - a single reality</td>
</tr>
<tr>
<td>No a priori theories</td>
<td>A priori theories</td>
</tr>
<tr>
<td>Knower and known are inseparable</td>
<td>Objective knower and known are separate</td>
</tr>
<tr>
<td>Value-bound</td>
<td>Value-free</td>
</tr>
</tbody>
</table>

Source: Adapted from Tashakkori and Teddlie (1998).

3.3 Researchers’ Paradigm

The researcher’s own philosophical view leans towards the non-positivist paradigm, and 
adopts a social constructivist approach to learning, but this does not preclude the use of a 
pragmatic approach to the research questions, or the inclusion of quantitative measures 
such as instruments and statistical analyses. The research questions should dictate the 
research methods used in a study (Creswell & Plano Clark, 2007). The questions in this 
study could not be addressed by using a purely quantitative or purely qualitative approach; 
rather, they demanded a mixture of both. Mixed methods allow researchers “to measure 
trends, prevalences, and outcomes and at the same time examine meaning, context and
process” (Creswell & Plano Clark, 2007, p. 175). Through the use of quantitative (questionnaires) and qualitative (reflective questioning, focus groups and interviews) instruments a richer picture of the research problems emerges. The limitations with each type of approach are counteracted by the inclusion of both types of methods. Some of the epistemological differences between the approaches are outlined in Table 3.2.

### Table 3.2 Epistemological differences between qualitative and quantitative methods

<table>
<thead>
<tr>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purposeful sampling</td>
<td>Random sampling</td>
</tr>
<tr>
<td>Small samples of people</td>
<td>Large samples of people</td>
</tr>
<tr>
<td>Theory generation</td>
<td>Theory verification</td>
</tr>
<tr>
<td>Multiple perspectives</td>
<td>Reductionist</td>
</tr>
<tr>
<td>Open-ended emerging data</td>
<td>Empirical observation and measurement</td>
</tr>
<tr>
<td>Constructivist or emancipatory assumptions</td>
<td>Postpositivist assumptions</td>
</tr>
</tbody>
</table>

Mixed methods strengthen research by offsetting the weaknesses of both quantitative and qualitative research “… and provide more comprehensive evidence for studying a research problem using all of the tools of data collection available [rather than being restricted to one particular methodology]” (Creswell & Plano Clark, 2007, p. 9). Mixed methods, therefore, were used for the collection, evaluation and analysis of the data in this study.

### 3.4 Research Design

The mixed methods approach was applied to an embedded case study design to evaluate the intervention of virtual microscopes (independent variable) into histology and pathology teaching as part of a Bachelors Degree in the Faculty of Health Sciences at Murdoch University and to determine any change to students’ learning approaches (dependent variable). Mixed methods allow for more diverse perspectives to be examined (Creswell & Plano Clark, 2007).
Case studies are grounded in reality, bound to the subject in question and provide reinterpretations of information (Alderman, Jenkins, & Kemmis, 1976). A case is defined by Stake (1995, p. 2) as “a specific, complex functioning thing ... a bounded system”. Stake (1995, p. 3) defines case studies as either “intrinsic” (the case is given to us), “instrumental” (instrumental to accomplishing something) or “collective” (several cases are studied) and recommends that cases should be primarily selected on their ability to maximize what can be learned, but ease of access and hospitality to the enquiry should also be considered. Case studies can be used “to describe an intervention and the real life context in which it occurred” (Yin, 2003, p. 15). Donmoyer (2000, p.63) says that “the purpose of research is ... to expand the range of interpretation available to the research consumer”. When various sources of data are used and converge to corroborate the same fact or phenomenon this is referred to as data triangulation (Patton, 2002). The credibility of case studies is enhanced by thoroughly triangulating the descriptions and interpretations continuously throughout the study (Stake, 2000). Yin (2009) says that data collection should follow three principles: use of multiple sources of evidence; creating a case study database; and maintaining a chain of evidence.

Scholz and Tietje (2002) also say that case studies should draw from multiple sources of information and that they can have sub-cases embedded within them (Yin, 2003). Embedded cases involve more than one unit of analysis, contain sub-units that focus on different aspects of the case, and are not restricted to using only qualitative methods (Scholz & Tietje, 2002).

Positivistic researchers’ main criticism of case studies is that the results (treatment and measurement variables) are not generalizable to other populations and settings (Donmoyer, 2000). Qualitative researchers have either argued that generalizability is not important in case studies or that generalizability can be replaced by trustworthiness, credibility, confirmability and data dependability (Yin, 2009). Donmoyer (2000) supports Yin and adds that researchers’ paradigms (a priori assumptions) have an influence on their
research, determines what the data is which in turn influences their findings. For a synopsis of the strengths and weaknesses of various case designs see Table 3.3.

Table 3.3 Various case designs, their strengths and weaknesses (adapted from Yin (2009)).

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Case Design</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holistic (single-unit of analysis)</td>
<td>Single case designs</td>
<td>Can confirm, challenge or extend a theory (theory building)</td>
<td>Danger of analyses being conducted at an abstract level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extreme or unique cases can be studied</td>
<td>Case may not be the case it was thought to be at the outset</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Typical case captures circumstances and conditions of everyday situation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Revalatory case allow researchers to observe and analyze phenomena previously inaccessible</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Longitudinal case allows the researcher to study a single case at two different points in time to show how conditions change over time</td>
<td></td>
</tr>
<tr>
<td>Embedded (multiple units of analysis)</td>
<td>Single case designs</td>
<td>Can focus a case study inquiry</td>
<td>Danger of focusing only on a sub-unit level and failing to return to the larger unit of analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Add opportunities for more extensive analysis</td>
<td></td>
</tr>
<tr>
<td>Holistic (single unit of analysis)</td>
<td>Multiple case designs</td>
<td>Replication design (literal replication) or contrasting conditions (theoretical replications) allows for corroboration (robust design</td>
<td>Extensive resources and time beyond the means of a single student or research investigator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May be more generalizable</td>
<td></td>
</tr>
<tr>
<td>Embedded (multiple units of analysis)</td>
<td>Multiple case designs</td>
<td>Each case may include quantitative data, including the use of surveys within each case</td>
<td>Extensive resources and time beyond the means of a single student or research investigator</td>
</tr>
</tbody>
</table>
Although, according to Yin (2009), multiple case design is more robust, in this study the researcher was not seeking to replicate, rather to explore, therefore the embedded case study approach was chosen as it allowed for the case as a whole (health science students) to be investigated, and the views from three different groups of students (Veterinary Science, Biomedical Science and Chiropractic Science) to be explored and contrasted using multiple units of analysis (the group as a whole, the sub-groups and individual students) through several methods (survey, focus groups and interviews) thereby increasing data triangulation. In addition, the case was selected due to its convenience. It also provided an opportunity to include the views of several different groups of students in the research who were studying histology and pathology and using microscopes as part of their undergraduate degree in Chiropractic, Veterinary Science or Biomedical Sciences.

Both case study and mixed method methodologies should follow systematic processes, such as those outlined by Yin (2003, 2009) and Creswell and Plano Clark (2007). They should: define the research questions; select the cases and determine data gathering and analysis techniques; prepare to collect the data; collect the data; analyse and evaluate the data; and write up the results.

As this would be the first time that virtual microscopes were used at Murdoch University in histology and pathology laboratories, it was important to identify any impact on the students’ learning approaches and/or their learning before undertaking the main case study. To test the research methodology, the researcher conducted an exploratory case study to investigate the introduction of virtual microscopes.

Students participating in the exploratory study were required to:

- complete a consent form;
- provide demographic information (e.g. age, gender and level of comfort with technology);
• complete in full the ASSIST survey twice, once at the beginning of semester (ASSIST1) and again at the end of the semester (ASSIST2);
• keep a log book of time spent studying histology and pathology (both virtual and face-to-face);
• complete reflections about their learning experiences in the unit; and
• consent to the researcher collecting and cross-referencing (by code) assignment and exam results with other data.

For the main case study the procedures were identical to those for the exploratory case study with the following exceptions:

• tick boxes were included on the first consent form for students to indicate whether they were prepared to be contacted later during the teaching period to be part of a focus group or to be interviewed;
• a separate consent form for students taking part in the focus groups and interviews was introduced, with tick boxes included for students to indicate their agreement to recording; and
• focus groups and/or individual interviews were conducted with students.

3.5 Research Questions

The research questions to be addressed in this study emerged from reading the literature on learning and the evaluation of technological interventions. They focus on suggestions for improving student learning with virtual microscopes. The overarching research question is:

*How does the introduction of virtual microscopes into histology and pathology laboratory classes affect students’ learning and approaches to studying?*

The research also addressed the following specific questions:

1. What factors influence students’ learning with virtual microscopes?
2. Do students’ learning approaches change with the introduction of virtual microscopes?
3. Do students’ learning approaches alter differentially with virtual and optical microscopes?
4. Do virtual microscopes encourage deep learning?
5. Are virtual microscopes easier to use than optical microscopes?

Table 3.4 shows the research questions and the methods that were used to address these questions.

Table 3.4 Research questions and methods used

<table>
<thead>
<tr>
<th>No</th>
<th>Question</th>
<th>Data</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What factors influence students’ learning with virtual microscopes?</td>
<td>ASSIST1 ASSIST2 Reflections Interviews Focus Groups Assessment grades</td>
<td>Content analysis Chi-square t-test GLM Correlation</td>
</tr>
<tr>
<td>2</td>
<td>Do students’ approaches change with the introduction of virtual microscopes?</td>
<td>ASSIST1 ASSIST2 Interviews Focus groups</td>
<td>Descriptive statistics Chi-square Content analysis</td>
</tr>
<tr>
<td>3</td>
<td>Do students learning approaches alter differentially with virtual and optical microscopes?</td>
<td>ASSIST1 ASSIST2 Reflections</td>
<td>Correlation Chi-square t-test GLM Content analysis</td>
</tr>
<tr>
<td>4</td>
<td>Do virtual microscopes encourage deep learning?</td>
<td>ASSIST1 ASSIST2 Reflections Interviews Focus Groups</td>
<td>Content analysis Chi-square Correlation</td>
</tr>
<tr>
<td>5</td>
<td>Are virtual microscopes easier to use than optical microscopes?</td>
<td>Reflections</td>
<td>Content analysis</td>
</tr>
</tbody>
</table>

3.6 Ethical Considerations

An ethics application for the proposed research was submitted to the Human Research Ethics Committee at Murdoch University and was approved in February 2006. An important factor that was considered was whether any of the participants in the study would be disadvantaged by taking part in the study. The first year students were excluded as possible
participants as they could have been disadvantaged by not learning how to use optical microscopes. The second and third year students would not be disadvantaged as they had already learned how to use optical microscopes.

Three consent forms were prepared: one for the exploratory study and two for the main study (see Appendices A.1-A.3). Each form described the study, informed the students about their rights, and sought their permission to access collected data as part of the study. Students were assured anonymity in any publications, as each student would be assigned a unique code. The students were informed that they would be able to withdraw from the study at any time without prejudice and that, to protect students from any possible bias, lecturers in the unit would not be able to access any of the study data or coded results until after the submission of results at end of semester.

The consent forms for the exploratory and main study differed as students in the main study were able to indicate via a tick box whether they were prepared to be contacted later in the teaching period to be part of a focus group or to be interviewed. Students who indicated their willingness to participate in an interview or a focus group also signed a second consent form specifically for this purpose. Students were also asked to consent to the interview and/or focus group being recorded to assist with transcriptions. All data collected was stored in a locked cabinet in the researcher’s office.

### 3.7 Data Collection

The data collection for the study is shown in a timeline in Figure 3.1. The timeline segments show details of each data collection point during the relevant teaching periods. Details of the data collection for the exploratory study are described in Section 3.8, while the data collection for the main study is described in Section 3.9.
The following sections outline in detail the methodology used in the exploratory and main studies, and includes individual sections about the participants, materials, procedures, data cleansing and data analysis.

3.8 The Exploratory Case Study

3.8.1 Participants

For the exploratory case study, the participants were students enrolled (on-campus) in CHI301 Processes in Human Disease, an undergraduate Chiropractic unit of study. The students were studying histology and pathology as part of their degree. In their five-year program, the students learn to use optical microscopes to develop an understanding of the structure and function of both normal and pathological tissue and disease processes. As chiropractors, they would not need to use microscopes but they would need to have developed a good understanding of various diseases and their underlying causes in order to diagnose their patients’ problem. They would also need to be able to rule out possible causes of pain in their patients and, when necessary, refer them to medical doctors. Since optical microscopes were not mandatory for these students’ future careers, they were selected as a suitable case and were introduced to virtual microscopes in 2006.

The total student enrolment in CHI301 was 56 with 47 students consenting to participate. Of the 47 students, two withdrew from the unit resulting in data from 45 students for the demographic section, log books and reflections. These 45 students were in one of two laboratory groups, those using the optical microscopes (Optical Group - OG) \((n=25)\) and those using the virtual microscopes (Virtual Group - VG) \((n=20)\).
One of the aims of the study was to identify changes in students’ study approaches by comparing ASSIST1 data with ASSIST 2 data for each student; therefore, incomplete ASSIST data from 12 of the 47 students (including the 2 who withdrew after the first ASSIST) meant that these students’ ASSIST results were discarded, leaving a total of 35 students who were included in this section of the analysis. Of the 35 students, there were 19 students in the Optical Group and 16 students in the Virtual Group.

Although the students were randomly allocated to either the optical or the virtual microscopes for their classes, none was excluded from using either type of microscope for self-study purposes.

Figure 3.2 shows the number of participants, the methods used and the products in the exploratory study.
Chapter 3

Figure 3.2 Mixed methods and procedures used in the exploratory study

Key
O = Optical Group
V = Virtual Group

Chapter 3
59
3.8.2 Materials

This section describes the materials that were used to collect data in the study. They include the demographics, the ASSIST, student log books and reflection forms (see Appendices, B-F for individual items).

1. The Approaches and Study Skills Inventory for Students (ASSIST)

The ASSIST has been shown to be a reliable measure of learning approaches in a number of studies (e.g. Entwistle, et al., 2000; Speth, Namuth, & Lee, 2007; Tait, et al., 1998) as well as being an instrument that is contextually relevant to higher education (Coffield, et al., 2004). Permission was sought and granted by Entwistle (2006) to use his well-established instrument to measure students’ learning approaches. The ASSIST instrument contains three distinct sections.

Section A determines students’ current conceptions of learning and comprises six items that students respond to by choosing an answer based on how close the statement is to their own thinking (Table 3.5). The response uses a 5-point Likert-like scale (5 very close, 4 quite close, 3 not so close, 2 somewhat different, 1 very different). The responses for items (a), (c) and (e) are added to obtain a score for the conception of learning as reproducing knowledge, while (b), (d) and (f) provide a score for the conception of learning as involving personal understanding and development.

Table 3.5 Section A - Conceptions of Learning

<table>
<thead>
<tr>
<th>What is learning?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproducing knowledge</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td>c</td>
</tr>
<tr>
<td>e</td>
</tr>
<tr>
<td>Personal understanding and development</td>
</tr>
<tr>
<td>b</td>
</tr>
<tr>
<td>d</td>
</tr>
<tr>
<td>f</td>
</tr>
</tbody>
</table>


Section B determines students’ current *approaches to studying*. There are 52 items that identify three different approaches — deep, strategic and surface — with each item’s response being on a 5 point Likert-like scale (5 agree, 4 agree somewhat, 3 unsure, 2 disagree somewhat, 1 disagree). The ASSIST instructions direct students to try not to use ‘unsure’.

The *deep approach* is made up of four sub-scales: seeking meaning (SM), relating ideas (RI), use of evidence (UE), and interest in ideas (II). Each sub-scale comprises of four items outlined in Table 3.6. The students’ responses to each sub-scale of four questions is totalled to provide a single score for each, which is then added together to provide a single score for the approach (SM + RI + UE + II = Deep Approach Score).

Table 3.6 Section B - The Deep Approach sub-scales and items

<table>
<thead>
<tr>
<th>Item No</th>
<th>Deep Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seeking meaning (SM)</strong></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>I usually set out to understand for myself the meaning of what we have to learn.</td>
</tr>
<tr>
<td>17</td>
<td>When I’m reading an article or book, I try to find out for myself exactly what the author means.</td>
</tr>
<tr>
<td>30</td>
<td>When I am reading I stop from time to time to reflect on what I am trying to learn from it.</td>
</tr>
<tr>
<td>43</td>
<td>Before tackling a problem or assignment, I first try to work out what lies behind it.</td>
</tr>
<tr>
<td><strong>Relating ideas (RI)</strong></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>I try to relate ideas I come across to those in other topics or other courses whenever possible.</td>
</tr>
<tr>
<td>21</td>
<td>When I’m working on a new topic, I try to see in my own mind how all the ideas fit together.</td>
</tr>
<tr>
<td>33</td>
<td>Ideas in course books or articles often set me off on long chains of thought of my own.</td>
</tr>
<tr>
<td>46</td>
<td>I like to play around with ideas of my own even if they don’t get me very far.</td>
</tr>
<tr>
<td><strong>Use of evidence (UE)</strong></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>I look at the evidence carefully and try to reach my own conclusion about what I’m studying.</td>
</tr>
<tr>
<td>23</td>
<td>Often I find myself questioning things I hear in lectures or read in books.</td>
</tr>
<tr>
<td>36</td>
<td>When I read, I examine the details carefully to see how they fit in with what’s being said.</td>
</tr>
<tr>
<td>49</td>
<td>It’s important for me to be able to follow the argument, or to see the reason behind things.</td>
</tr>
</tbody>
</table>
Interest in ideas (II)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Regularly I find myself thinking about ideas from lectures when I’m doing other things.</td>
</tr>
<tr>
<td>26</td>
<td>I find that studying academic topics can be quite exciting at times.</td>
</tr>
<tr>
<td>39</td>
<td>Some of the ideas I come across on the course I find really gripping.</td>
</tr>
<tr>
<td>52</td>
<td>I sometimes get ‘hooked’ on academic topics and feel I would like to keep on studying them.</td>
</tr>
</tbody>
</table>

The *strategic approach* is made up of five sub-scales each with four questions: *organised studying* (OS), *time management* (TM), *alertness to assessment demands* (AAD), *achieving* (A) and *monitoring effectiveness* (ME) (Table 3.7). As in the deep approach, the sub-scales are totalled providing a single score for each and are then added together to provide a single score for the approach (OS + TM + AAD + A + ME = Strategic Approach Score).

Table 3.7 Section B - The Strategic Approach sub-scales and items

<table>
<thead>
<tr>
<th>Item No</th>
<th>Strategic approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organised studying (OS)</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>I manage to find conditions for studying which allow me to get on with my work easily.</td>
</tr>
<tr>
<td>14</td>
<td>I think I’m quite systematic and organised when it comes to revising for exams.</td>
</tr>
<tr>
<td>27</td>
<td>I’m good at following up some of the reading suggested by lecturers or tutors.</td>
</tr>
<tr>
<td>40</td>
<td>I usually plan out my week’s work in advance, either on paper or in my head.</td>
</tr>
<tr>
<td>5</td>
<td>I organise my study time carefully to make the best use of it.</td>
</tr>
<tr>
<td>18</td>
<td>I’m pretty good at getting down to work whenever I need to.</td>
</tr>
<tr>
<td>31</td>
<td>I work steadily through the term or semester, rather than leave it all until the last minute.</td>
</tr>
<tr>
<td>44</td>
<td>I generally make good use of my time during the day.</td>
</tr>
<tr>
<td><strong>Alertness to assessment demands (AAD)</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>When working on an assignment, I’m keeping in mind how best to impress the marker.</td>
</tr>
<tr>
<td>15</td>
<td>I look carefully at tutors’ comments on course work to see how to get higher marks next time.</td>
</tr>
<tr>
<td>28</td>
<td>I keep in mind who is going to mark an assignment and what they’re likely to be looking for.</td>
</tr>
<tr>
<td>41</td>
<td>I keep an eye open for what lecturers seem to think is important and concentrate on that.</td>
</tr>
</tbody>
</table>
Achieving (A)
10 It’s important to me to feel that I’m doing as well as I really can on the courses here.
24 I feel that I’m getting on well, and this helps me put more effort into the work.
37 I put a lot of effort into studying because I’m determined to do well.
50 I don’t find it at all difficult to motivate myself.

Monitoring effectiveness (ME)
7 I go over the work I’ve done carefully to check the reasoning and that it makes sense.
20 I think about what I want to get out of this course to keep my studying well focused.
34 Before starting work on an assignment or exam question, I think first how best to tackle it.
47 When I have finished a piece of work, I check it through to see if it really meets the requirements.

The surface approach is made up of four sub-scales, each with four questions: lack of purpose (LP), unrelated memorising (UM), syllabus-boundness (SB) and fear of failure (FF) (Table 3.8). The four sub-scales are totalled to provide a single score, and then each score is totalled to gain a single score for the approach (LP + UM + SB + FF = Surface Approach Score).

Table 3.8 Section B - The Surface Approach sub-scales and items

<table>
<thead>
<tr>
<th>Item No</th>
<th>Surface Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lack of purpose (LP)</strong></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Often I find myself wondering whether the work I am doing here is really worthwhile.</td>
</tr>
<tr>
<td>16</td>
<td>There’s not much of the work here that I find interesting or relevant.</td>
</tr>
<tr>
<td>29</td>
<td>When I look back, I sometimes wonder why I ever decided to come here.</td>
</tr>
<tr>
<td>42</td>
<td>I’m not really interested in this course, but I have to take it for other reasons.</td>
</tr>
<tr>
<td><strong>Unrelated memorising (UM)</strong></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>I find I have to concentrate on just memorising a good deal of what I have to learn.</td>
</tr>
<tr>
<td>19</td>
<td>Much of what I’m studying makes little sense: it’s like unrelated bits and pieces.</td>
</tr>
<tr>
<td>32</td>
<td>I’m not really sure what’s important in lectures, so I try to get down all I can.</td>
</tr>
<tr>
<td>45</td>
<td>I often have trouble in making sense of the things I have to remember.</td>
</tr>
<tr>
<td><strong>Syllabus-boundness (SB)</strong></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>I tend to read very little beyond what is actually required to pass.</td>
</tr>
<tr>
<td>25</td>
<td>I concentrate on learning just those bits of information I have to know to pass.</td>
</tr>
<tr>
<td>38</td>
<td>I gear my studying closely to just what seems to be required for assignments and exams.</td>
</tr>
<tr>
<td>51</td>
<td>I like to be told precisely what to do in essays or other assignments.</td>
</tr>
</tbody>
</table>
**Fear of failure (FF)**

<table>
<thead>
<tr>
<th>Score</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Often I feel I’m drowning in the sheer amount of material we’re having to cope with.</td>
</tr>
<tr>
<td>22</td>
<td>I often worry about whether I’ll ever be able to cope with the work properly.</td>
</tr>
<tr>
<td>35</td>
<td>I often seem to panic if I get behind with my work.</td>
</tr>
<tr>
<td>38</td>
<td>Often I lie awake worrying about work I think I won’t be able to do.</td>
</tr>
</tbody>
</table>

Section C identifies students’ preference for different types of course and teaching, and is composed of eight items (Table 3.9) that students respond to by choosing an answer on a 5 point Likert-like scale (5 definitely like, 4 somewhat like, 3 unsure, 2 somewhat dislike and 1 definitely dislike). Again, students were asked to try not to choose the ‘unsure’ option. The responses to items (b), (c), (f) and (g) are added together to obtain a score for the preference for different types of course and teaching as supporting understanding, while (a), (d), (e) and (h) provide a score for the preference for different types of course and teaching as not supporting understanding. The highest score indicates students’ dominant preference.

Table 3.9 Section C - Preferences for different type of teaching and learning environment

<table>
<thead>
<tr>
<th>Preference for different types of course and teaching</th>
<th>Supporting understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>b Lecturers who encourage us to think for ourselves and show us how they themselves think.</td>
<td></td>
</tr>
<tr>
<td>c Exams which allow me to show that I’ve thought about the course material for myself.</td>
<td></td>
</tr>
<tr>
<td>f Courses where we’re encouraged to read around the subject a lot for ourselves.</td>
<td></td>
</tr>
<tr>
<td>g Books which challenge you and provide explanations which go beyond the lectures.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preference for different types of course and teaching</th>
<th>Not supporting understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Lecturers who tell us exactly what to put down in our notes.</td>
<td></td>
</tr>
<tr>
<td>d Exams or tests which need only the material provided in our lecture notes.</td>
<td></td>
</tr>
<tr>
<td>e Courses in which it’s made very clear just which books we have to read.</td>
<td></td>
</tr>
<tr>
<td>h Books which give you definite facts and information which can easily be learned.</td>
<td></td>
</tr>
</tbody>
</table>

The instrument concludes with a final question asking students to rate themselves on a 9-point scale (9 very well, 7 quite well, 5 about average, 3 not so well, 1 rather badly) to indicate how well they think they have been doing based on their assessed work so far.
As mentioned in the literature review, researchers report their validation of the ASSIST instrument using Cronbach’s (1951) alpha which is a measure of reliability (Bland & Altman, 1997). Generally a score above 0.70 is well regarded. In this study, the instrument was validated by calculating Cronbach’s alpha for all three sections of the instrument (see Appendix D) and the sub-items in Section B. The Cronbach alpha scores for the three study approaches in Section B are compared with other studies in Table 3.10. As can be seen, the results are comparable.

Table 3.10 Cronbach's Alpha scores for Section B of the ASSIST

<table>
<thead>
<tr>
<th>Study</th>
<th>Deep</th>
<th>Strategic</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonas-Dwyer (2006) ASSIST1</td>
<td>0.86</td>
<td>0.90</td>
<td>0.83</td>
</tr>
<tr>
<td>Jonas-Dwyer (2006) ASSIST2</td>
<td>0.86</td>
<td>0.88</td>
<td>0.80</td>
</tr>
<tr>
<td>Speth, Namuth &amp; Lee (2007)</td>
<td>0.65</td>
<td>0.75</td>
<td>0.70</td>
</tr>
<tr>
<td>Entwistle (2000b)</td>
<td>0.84</td>
<td>0.80</td>
<td>0.87</td>
</tr>
</tbody>
</table>

An additional demographics section was included at the beginning of the first ASSIST to collect students' age, gender and level of comfort with technology (see Appendix B).

2. Log Books

The researcher was provided with access to the online unit via the university’s LMS and the templates for the logbook and reflection forms were uploaded to this system for the students. The forms were hidden from view in order to provide them in a timely manner when appropriate during semester. A section of the log book template is shown in Figure 3.3 (and shown in Appendix E). The students were informed that the purpose of the log was for them to record the amount of time spent studying both online and face-to-face (e.g. use of the LMS, resources, time spent using optical or virtual microscopes, time spent attending lectures, and time spent attending labs).
3. Reflections

Students were provided with a Word™ template to record their reflections and attitudes about their learning experiences in the unit. This reflections form contained three sections (Appendix F). Section 1 of the form (Figure 3.4) asked students to provide their name, student number and the level of education that they had achieved prior to undertaking their current studies.

The second section, shown in Figure 3.5, asked students to identify which microscope they used most of the time during the teaching period as well as asking four open questions about what they liked and disliked about both optical and virtual microscopes.

A third section, shown in Figure 3.6, asked students questions about their activities with microscopes, additional resources they used and ways to improve the learning experience in the unit.
Data for the study was collected at various times during the relevant semesters as previously outlined in Figure 3.7. Further breakdown of the timeline is provided by the inclusion of two figures showing separate timelines for the data collection in both the exploratory (Figure 3.7) and the main case study (Figure 3.21).
Prior to the students’ first laboratory class, a member of the teaching staff randomly allocated each student to either a virtual or optical microscope laboratory class for the 13 week teaching period. A small number of students were able to change their laboratory class if it clashed with other commitments.

Prior to the introduction of the virtual microscopes, in their first laboratory class (March 2006), students attended a presentation by the researcher explaining the study, informing them of the aims of the research, and describing what being a participant in the study entailed. The students were asked to give their consent to be part of the study by completing a consent form and were informed that they could withdraw from the study at any time without prejudice.

Students were asked to complete the demographic questions and first ASSIST survey. They were asked to fill in the ASSIST in relation to the unit they were taking. These data were then collected by the researcher. In the second week of semester, the logbook and reflection forms were uploaded to the LMS unit and students were emailed instructions about how to download and complete the forms. The students were then asked to upload their logbook and reflection form using the assignment tool in the LMS unit by 19 May 2006, but this deadline was extended to early June 2006 to allow for delays experienced by some students in submitting their assignments electronically. The researcher then downloaded the documents to her own computer for analysis. Students’ assessment grades for their log book, reflections and assignments were also accessed by the researcher in May 2006.
In their final laboratory class, in early June 2006, the students were asked to complete the second ASSIST in relation to the unit they were undertaking, which was distributed and collected by a research assistant (laboratory demonstrator) then placed in an envelope and subsequently collected by the researcher. The students’ exam grades were accessed in June 2006.

3.8.4 Data Cleansing

This section describes the pre-processing procedures for the demographic and ASSIST surveys and the treatment of the data for descriptive and frequency statistical analyses. It also explains the pre-processing procedures for the logbooks and the reflections in preparation for statistical analyses and interpretive content analyses. To maintain confidentiality of participant identity, which is part of the ethical considerations in this study, the names of participants were given a numeric code.

The students' demographic data and the results of the ASSISTs were entered into Microsoft Excel™ Spreadsheets and then imported into SPSS™. In addition, students were classified into the laboratory group to which they had been assigned — either Group 1 (O) or Group 2 (V). Figure 3.8, for example, shows student 1’s results in Row 1. Column 1 shows the code assigned to the student. Column 2 identifies the student’s laboratory group (1=Optical Group). Column 3 shows age (36 years). Column 4 shows gender (1=Female) and Column 5 shows her self-reported skill with computers as 3 (midway between 1 very skilled and 5 low skills).
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Figure 3.8 Fragment of SPSS™ worksheet illustrating identification codes, demographic data and self-ratings of computer skills

The data for all three sections of the ASSIST were also entered into Excel™ spreadsheet. Examples of the raw data for all three sections are shown in Figures 3.9, 3.10 and 3.11. Section A (Columns D to I) in Figure 3.9 shows the raw data for students’ conception of learning. Section B (Columns B1 to B8) in Figure 3.10 shows a section of students’ learning approaches data. Section C (Columns BJ to BQ) in Figure 3.11 shows data for the students’ preferences for different types of course and teaching. This data was then imported into SPSS™ for analysis.

The log book data is shown in Figure 3.12 and shows the time spent studying and the students mark. For example, in Row 9, Column A shows the students code (8); Column B the gender (F=female); Column C, Group (A=Optical Group); Column G, the total time spent studying (111 hours); Column H, final mark (60.54); and Column I grade (C=Credit).

Figure 3.9 Fragment of data for Section A of the ASSIST (Columns D to I)
Students’ reflections were entered into a separate Excel™ spreadsheet. For example, Figure 3.13 shows a fragment of the raw reflections data for students in Group A (Optical). Column J, Row 3 shows that Student 2 liked the fact that “you could see details at high magnification more clearly and the advantages of working in a group”.
Chapter 3

3.8.5 Data Analysis

The data were analysed in various ways using SPSS15™ for Windows. First, the demographic data was analysed for frequencies. Second, the students’ ASSIST data scores were analysed. Third, the quantitative data section of the reflections was analysed. The qualitative data component of the reflections was content analysed into themes with the units of analysis being comments.

The ASSIST data were analysed quantitatively as indicated by Entwistle, Tait and McCune (2000), i.e. by adding together the components for each of the instrument’s three sections to identify students’ conception of learning (Section A), learning approach (Section B) and preference for different types of course and teaching (Section C). The data were analysed for surveys completed both at the beginning and end of the teaching period (Jonas-Dwyer & Sudweeks, 2007). According to Entwistle, Tait and McCune (2000), the highest score indicates students’ preferred conception.
In Section A, six items identified students’ conceptions of learning (Figure 3.14) with three items for reproducing knowledge (a surface approach) and three items for personal understanding and development (a deep approach). In this study, more than a third of the students’ scores were equal.

In Figure 3.14 Fragment of conceptions of learning data showing the calculation for the reproducing knowledge score

Section B identified students’ preferred learning approach and comprised several subscales described in detail in the literature review and in Tables 3.5, 3.6 and 3.7. Each approach is comprised of several items (maximum value per item is 5) that are calculated to give a subscale (see Figure 3.15). Therefore, each of the four subscales (seeking meaning, relating ideas, use of evidence and interest in ideas) had a maximum possible score of 20, providing a total possible score for the deep approach of 80.

In Figure 3.15, Column A1_Deep_Score, Row 1, shows a score of 48/80 for Student 1. This procedure was followed for all three approaches (deep, strategic, surface) and the approach with the highest score indicates the student’s preferred study approach (Entwistle, et al., 2000). The scores were then normalised to a score out of 100 for each approach. For example, the score for Student 1 in Figure 3.15, 48/80, is normalised to 60/100.
One problem with calculating students’ ASSIST results in this way was that up to one third of the students’ results indicated that they had equal scores for their conceptions and for their different types of course and teaching sections of the ASSIST.

That is, although the analysis followed the scoring guide from the authors of the ASSIST (Entwistle, et al., 2000), the results did not fall neatly within the nominated categories as expected. This issue has been reported by others (Speth, Lee, & Hain, 2003; Speth, et al., 2007) and can be resolved by converting the ASSIST section totals for each student to standardised scores (z-scores).

Standardized scores take into account the means and standard deviations of any given set of scores and converting them into scores equal means and equal variances (Hatch & Farhady, 1982, p. 63). Z-scores reveal more about each individual’s score when compared to the group. Therefore, z-scores were calculated in SPSS™ for the three parts of the ASSIST, with the highest score indicating the dominant category for each part (e.g. students’ conceptual understanding of learning is shown in (Figure 3.16).

Scores from Section C identified students’ preference for different types of course and teaching (see Table 3.8). The highest score indicated their preference. In Figure 3.17, Row 1 shows Student 1’s score was 18 for supporting understanding and 16 and for transforming information, indicating the student’s dominant preference for different types of courses and teaching is one that is aimed at deep learning (supporting understanding).

Students’ final marks and grades were analysed using Pearson’s product-moment correlation test to determine whether there was any association between the students’ total amount of time spent studying and final grades (Figure 3.18).
Chapter 3

Figure 3.16 Fragment of SPSS data showing z scores and dominant conception of learning for Section A of the ASSIST.

<table>
<thead>
<tr>
<th>ZA2_SuppUnderst</th>
<th>ZA2_ReprodKnow</th>
<th>ASSIST2_PA_ConceptTotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.8473</td>
<td>0.05135</td>
</tr>
<tr>
<td>2</td>
<td>3.2428</td>
<td>1.24846</td>
</tr>
<tr>
<td>3</td>
<td>3.2428</td>
<td>-54771</td>
</tr>
<tr>
<td>4</td>
<td>-1.83756</td>
<td>-2.94392</td>
</tr>
<tr>
<td>5</td>
<td>-1.83756</td>
<td>-1.74582</td>
</tr>
<tr>
<td>6</td>
<td>-2.1618</td>
<td>-54771</td>
</tr>
<tr>
<td>7</td>
<td>-7.5664</td>
<td>0.05135</td>
</tr>
<tr>
<td>8</td>
<td>0.8473</td>
<td>85040</td>
</tr>
<tr>
<td>9</td>
<td>3.2428</td>
<td>0.05135</td>
</tr>
<tr>
<td>10</td>
<td>-1.83756</td>
<td>85040</td>
</tr>
</tbody>
</table>

Figure 3.17 Fragment of Section C showing scores for students’ preference for different types of course and teaching.

<table>
<thead>
<tr>
<th>CODE_ID</th>
<th>Gender</th>
<th>GroupOptic</th>
<th>A1 PartC TransInfoTotal</th>
<th>A1 PartC SupportUnderstTotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 1</td>
<td>0</td>
<td>18.00</td>
<td>18.00</td>
</tr>
<tr>
<td>2</td>
<td>2 1</td>
<td>0</td>
<td>16.00</td>
<td>20.00</td>
</tr>
<tr>
<td>3</td>
<td>3 2</td>
<td>0</td>
<td>20.00</td>
<td>12.00</td>
</tr>
<tr>
<td>4</td>
<td>4 2</td>
<td>0</td>
<td>20.00</td>
<td>12.00</td>
</tr>
<tr>
<td>5</td>
<td>5 2</td>
<td>1</td>
<td>17.00</td>
<td>15.00</td>
</tr>
<tr>
<td>6</td>
<td>6 2</td>
<td>1</td>
<td>20.00</td>
<td>10.00</td>
</tr>
<tr>
<td>7</td>
<td>8 1</td>
<td>0</td>
<td>20.00</td>
<td>11.00</td>
</tr>
<tr>
<td>8</td>
<td>9 1</td>
<td>0</td>
<td>16.00</td>
<td>14.00</td>
</tr>
<tr>
<td>9</td>
<td>10 1</td>
<td>0</td>
<td>9.00</td>
<td>17.00</td>
</tr>
<tr>
<td>10</td>
<td>12 1</td>
<td>1</td>
<td>20.00</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Figure 3.18 Fragment of statistical analyses of correlation between students’ time spent studying and their final mark.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>36</td>
<td>F</td>
<td>B</td>
<td>88</td>
<td>87.04</td>
</tr>
<tr>
<td>30</td>
<td>37</td>
<td>F</td>
<td>A</td>
<td>118</td>
<td>79.91</td>
</tr>
<tr>
<td>31</td>
<td>38</td>
<td>F</td>
<td>B</td>
<td>56</td>
<td>79.63</td>
</tr>
<tr>
<td>32</td>
<td>39</td>
<td>F</td>
<td>A</td>
<td>51</td>
<td>72.81</td>
</tr>
<tr>
<td>33</td>
<td>40</td>
<td>F</td>
<td>A</td>
<td>110</td>
<td>79.50</td>
</tr>
<tr>
<td>34</td>
<td>41</td>
<td>F</td>
<td>B</td>
<td>137</td>
<td>81.03</td>
</tr>
<tr>
<td>35</td>
<td>42</td>
<td>F</td>
<td>B</td>
<td>111</td>
<td>65.96</td>
</tr>
<tr>
<td>36</td>
<td>43</td>
<td>F</td>
<td>B</td>
<td>127</td>
<td>66.35</td>
</tr>
<tr>
<td>37</td>
<td>Pearson</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>38</td>
<td>Correlation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The data were also analysed in SPSS™ using ANOVA, involving one independent variable (factor), which has a number of different levels that correspond to different conditions (e.g. Section B – deep approach, strategic approach, surface approach) and one dependent variable (scores for the unit), to determine whether there was any relationship between the final mark and students’ conceptions of learning, learning approach and preference for different type of learning environment and teaching.

Content analysis is defined by Krippendorf (1980) as a “research technique for making replicable and valid inferences from data to their context” (p. 21). It is an unobtrusive context sensitive technique that is used to process symbolic forms and able to cope with large volumes of data (Krippendorf, 1980). The open-ended questions of the students’ reflection forms were content analysed to identify themes, with the unit of analysis being the comments. Boyatzis (1988) describes a particular type of content analysis called “thematic analysis” where the themes are derived inductively from the raw data and patterns are found in the data that describe, organise and/or interpret aspects of the phenomenon under investigation. He outlines three stages to be followed for analysis:

- **Stage 1: Sampling and design issues** – where the material coded represents a sub-sample of two or more specific samples used in the research. The raw information is used to develop a code.
- **Stage 2: Developing themes and a code** – five further steps are described in this stage: (1) reducing the raw information; (2) identifying themes within sub-samples; (3) comparing themes across sub-samples; (4) creating a code; and (5) determining the reliability or consistency of the code.
- **Stage 3: Validating a code** – code the rest of the information and validate it statistically or qualitatively.
These stages were followed in the development of the coding scheme to identify themes and are now described.

- **Stage 1:** In the exploratory study, students' reflective comments were grouped according to their laboratory allocation (optical/virtual) and a code developed.

- **Stage 2:** Steps 1 to 5 – the raw information was reduced by reading the comments, comparing the comments across the groups, looking for patterns and developing themes, rereading the comments and looking for the presence or absence of the themes, and then determining the reliability of the coding.

- **Stage 3:** The code was then applied to the main study reflective data.

An example of the development of the focus theme is described. The data was filtered to show students from one laboratory group (e.g. Optical Group) and then each comment was read to identify themes. Preliminary themes thus emerged from the comment, such as the Clarity of Focus theme shown in Figure 3.19.

| Group: A Optical | Answers | Theme: Clarity of Focus | Frequency: 12 | Quotes:
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>You could see details at high magnification more clearly... [OF2]*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the ability to zoom in and clarify cells [OM4]*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I didn't, perhaps got better quality of picture when zoomed in [OFS]*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the slides looked clearer and were quicker to use than the computer slides [OF9]*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.19 Fragment showing the comments in the theme Clarity of Focus

In Figure 3.19, several comments were placed under Clarity of Focus and the frequency of the comments in the theme noted. Where there were two or more themes in one comment, the relevant phrases were categorised under the relevant theme(s). For example, Student 1’s comment was:

Can view the slide naked eye first. There is lots of group input/discussion when working together at one station.
The first part of the comment (“Can view the slide naked eye first”) was placed under the theme *Authenticity* while the second part of the comment (“There is lots of group input/discussion when working together at one session”) was placed under the theme *Group Work*.

Using this process, 15 themes were identified with each theme having a positive or negative aspect, thus resulting in 30 categories.

The main coder’s coding was checked by an independent coder who coded 40 random comments using the 30 categories from the 15 themes. These were then compared to the main coder’s results. The inter-rater reliability was determined by calculating the reliability coefficient as outlined by Perreault and Leigh (1989, p. 144) using the following formula:

\[
Ir = \left\{ \left( \frac{Fo}{N} - \frac{1}{N} \right) \left( \frac{k}{(k-1)} \right) \right\}^{0.5}
\]

\(Ir\) = inter-rater reliability  
\(Fo\) = Number of judgements on which the judges agree  
\(N\) = Number of judgements made by each judge  
\(k\) = Number of categories

Using this formula the following inter-rater reliability measure of 0.9869 was calculated.

\(N = 40\)  
\(Fo = 39\)  
\(k = 30\)  
\[\left( \frac{39}{40} - \frac{1}{40} \right) \left( \frac{30}{(30-1)} \right) \]^{0.5} = 0.9869  
\(Ir = 0.9869\)

Grayson and Rust (2001) suggest that Perreault and Leigh’s formula is straightforward and is appropriate in many research circumstances where there are two coders.
3.8.6 Amendments to Methods

The exploratory case study used a small sample of participants and the results indicated that the research design was appropriate, the instruments robust and the methods elicited results that could address the research questions. However, it was expected that the results in the main study could be improved in some respects by adding student focus groups and interviews. Therefore, these methods were added to the main study to build a richer picture of the students’ learning approaches and experiences in this study. The log book and reflection forms were modified (see Appendices E.2 and F.2) based on the data collected from the exploratory case study, to make them simpler for students to use, and to enhance data transfer to Excel™ for later analysis. The log book was altered from a single spreadsheet by including multiple worksheets (i.e. Master Worksheet, Using OM, Using VM, Reviewing Lectopia (iLecture), Study txt Notes and LMS). The Master worksheet calculated the recorded hours spent studying from the other worksheets.

The reflections form was modified to include a section of statements about students’ learning with microscopes (Table 3.11) to which students chose an answer from a 5-point scale (1 strongly agree to 5 strongly disagree).

Table 3.11 Questions added to the reflections form

<table>
<thead>
<tr>
<th>No</th>
<th>Additional questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The degree of interaction in my laboratory group was very high.</td>
</tr>
<tr>
<td>2</td>
<td>All members of my laboratory group worked equally well.</td>
</tr>
<tr>
<td>3</td>
<td>Reaching consensus in the group was easy.</td>
</tr>
<tr>
<td>4</td>
<td>I enjoyed working with this group.</td>
</tr>
<tr>
<td>5</td>
<td>I found the laboratory group work to be an effective learning experience</td>
</tr>
<tr>
<td>6</td>
<td>I was able to understand many of the theoretical concepts taught in this unit by doing the group lab activities.</td>
</tr>
<tr>
<td>7</td>
<td>The LMS unit provides an environment that encourages active learning.</td>
</tr>
</tbody>
</table>
3.8.7 The Focus Groups and Interviews

The purpose of the focus groups was to triangulate data from the surveys and interviews. The focus groups' setting was formal with each group meeting being held in a room that had a large oval table, chairs and a whiteboard.

Morgan (1997) believes that focus groups expand researchers' options for matching research questions with qualitative methods and that they can be used in conjunction with other methods. Patton (2000) suggests that focus groups are a highly efficient way to gather data from several people at once, instead of one at a time. He also says that they are not discussions but interviews and that focus group participants tend to provide checks and balances on each other minimising extreme or false views. Stewart, Shamdasani and Rock (2007) also highlight that interviewers need to be aware that people behave differently when they are in groups to when they are alone. However, focus groups allow important issues and topics to be focused on and make it easy to see when participants have a shared view.

Patton (2000) outlines several weaknesses of focus groups. The weaknesses include: a limited number of questions that can be asked (maximum 10 in an hour); the interviewer needs to have good skills in facilitation and group processes to ensure that one individual does not dominate the group; it can be difficult to take notes at the same time as conducting an interview; and unexpected diversions can occur and conflicts or power struggles can arise. Steps can be taken to rectify these problems; for example, having a mixed age group can assist in eliciting diverse opinions as there is a tendency towards consensus when groups comprise older, similarly aged participants (Stewart, et al., 2007). Further, men tend to be more aggressive and women tend to conform more to group pressure; therefore, the moderator needs to ensure that there is an acceptable level of interaction between the two.
Patton (2000) says that there are six kinds of questions that can be asked: experience/behaviour, option/values, feeling, knowledge, sensory and background/demographic questions. The focus group questions were a mixture of demographic, dichotomous and open ended questions designed to obtain students’ perceptions and experiences of learning with microscopes. Questions were asked in a fixed sequence, beginning with some demographic questions, then a few dichotomous questions, moving to open ended questions. The focus group questions are presented in Table 3.13.

The interviewer’s stance can influence an interview, an interviewer can play a neutral role but interviewees can deliberately try to please an interviewer (Mayo, 2003) or their answers may err due to a faulty memory. Bias can also occur as a result of question sequence (primacy or latency effect) or the interviewer’s questioning technique (Fontana & Frey, 2005). In an attempt to increase effectiveness in questioning technique structured interview questions were devised by the researcher for the focus groups.

Initially it was intended to have two focus groups with four students from each learning approach (2 groups x 3 approaches x 4 students) so 18 students were invited to participate. Of these 18 students, only 12 accepted the invitation and were assigned to one of two focus groups. The focus groups met separately at times that were convenient to the students. Eventually only 10 of the 12 students who accepted actually attended the focus groups. For Focus Group 1, four students attended. For Focus Group 2, six students attended (see Table 6.35). Although the groups varied in size, each group were from the same discipline and cohort. There did not appear to be any indication of group think, (Janis, 1982) the dynamics of the group influencing responses.

To maximize the results of focus group interviews the researcher tried, as far as possible, that each group comprised of a mixture of learning approaches, gender and age. This was not always possible because all students are approximately the same age and
dependent on the availability of students. The researcher’s role was directive and the question format was structured.

At the beginning of the focus groups, the researcher explained to the participants how the session would be run. Students were provided with question sheets to write down their own answers to each of the 12 questions (see Appendix G) prior to the group discussing each question. The first question was not discussed as it involved the students’ own learning approaches.

The purpose of the individual interviews was to gather further data about individual students’ perceptions of learning with microscopes. The setting was the same as one used for the focus groups, however, the set up was more informal with two chairs being close together at one end of the table. The interview structure was semi-structured with the first question being demographic and the rest being open ended questions relating to the student’s experiences and perceptions of learning with microscopes. See Table 3.14 for the interview questions and Table 6.36 for details of the interview participants.

3.9 The Main Study

The procedures for the main study were almost identical as those used in the exploratory study. The differences between the two studies are discussed in the following sections.

3.9.1 Participants

For the main case study, there were 348 potential participants (285 second year and 63 third year students) who were studying histology and/or pathology as part of their undergraduate degree. The second year students were enrolled in BMS264 or VET244. BMS264 comprised students from Chiropractic, Biomedical, Forensic, Biological Science, Conservation Science
and Pharmacy, while VET244 comprised students from Veterinary Science. The third year students in CHI301 were studying Chiropractic. All students were on-campus students.

Table 3.12 shows the units, number of students in each unit and in each section of the data collection.

Table 3.12 Data collection by group

<table>
<thead>
<tr>
<th>Units</th>
<th>Total number of students</th>
<th>Demographics</th>
<th>ASSIST1 &amp; ASSIST2</th>
<th>Reflections</th>
<th>Log Books</th>
<th>Focus Groups</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMS264</td>
<td>176</td>
<td>138</td>
<td>43</td>
<td>137</td>
<td>132</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VET244</td>
<td>109</td>
<td>104</td>
<td>71</td>
<td>83</td>
<td>98</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>CHI 301</td>
<td>63</td>
<td>51</td>
<td>37</td>
<td>49</td>
<td>49</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>348</td>
<td>293</td>
<td>151</td>
<td>269</td>
<td>279</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Of the targeted students (348), 293 (84%) consented to participate in the study. Of these 293 students, only 151 completed both ASSISTs, thus giving a response rate of 44% for the second data collection component of the study. As in the exploratory study, all consenting students who completed the demographic questions were included in the demographic analysis. Only the 151 students (81 in the Optical Group and 70 in the Virtual Group), who completed both ASSIST surveys were included in the second part of the analysis as both ASSIST surveys were required to determine whether there was any change in students’ study approaches. The sample for the reflections analysis included 269 students’ reflections (77% response rate). The sample for the log book entries were 279 students (80% response rate). Two focus groups were held (Group 1, n=4, and Group 2, n=6) and four interviews (see Figure 3.20). With the consent of the participants, the focus groups and interviews were recorded and later transcribed by the researcher.
In this study, the learning environment was controlled by ensuring that all students received access to the LMS for their units, including supplementary information about histology and pathology. The demonstrators and lecturers for the labs were the same, the laboratory activities with microscopes were the same, even though there were two laboratory groups (Optical or Virtual) and the students in these laboratories used the optical or virtual microscopes accordingly. The groups were comparable in age and background.
Figure 3.20 Mixed methods and procedures used in the main study

Key
R=Reflections L=Log Books
O=Optical Group V=Virtual Group
3.9.2 Materials

The same materials were used in the main study as in the exploratory study with minor modifications being made to the log book and reflection forms (described in Section 3.8.6). Questions were developed for focus groups and semi-structured interviews. The focus group questions centred on the students’ learning experiences and on their use of microscopes in their histology and pathology laboratories during the semester (Table 3.13), while the interview questions (Table 3.14) sought to extract more fine grained information about individual students and their learning.

Table 3.13 Focus group questions

<table>
<thead>
<tr>
<th>Question number</th>
<th>Question description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What do you think your learning approach is? (deep, strategic or surface) (NOTE: students were provided with a description of these approaches)</td>
</tr>
<tr>
<td>2</td>
<td>In your lab group did you use optical or virtual microscopes?</td>
</tr>
<tr>
<td>3</td>
<td>Would you prefer to use optical or virtual microscopes in the future? (Give your reason why)</td>
</tr>
<tr>
<td>4</td>
<td>In your lab group work, did you find the guidelines were clear?</td>
</tr>
<tr>
<td>5</td>
<td>Was it clear to you what your role was in the lab group activities?</td>
</tr>
<tr>
<td>6</td>
<td>Did you feel you had sufficient opportunity to contribute to the lab group activities? (Give examples)</td>
</tr>
<tr>
<td>7</td>
<td>In what ways were you able to express your opinion in the lab group activities? (give examples)</td>
</tr>
<tr>
<td>8</td>
<td>In what ways were you able to influence your group to your way of thinking? (give examples)</td>
</tr>
<tr>
<td>9</td>
<td>What did you find most useful in the group work?</td>
</tr>
<tr>
<td>10</td>
<td>What did you find least useful in the group work?</td>
</tr>
<tr>
<td>11</td>
<td>What would you like to do more of in labs?</td>
</tr>
<tr>
<td>12</td>
<td>What would you like to do less of in labs?</td>
</tr>
<tr>
<td>13</td>
<td>If there was a difference between your identified study approach (ASSIST1) and your own perception of what you though it was, can you explain why?</td>
</tr>
</tbody>
</table>
Table 3.14 Interview Questions

<table>
<thead>
<tr>
<th>Question number</th>
<th>Question description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>At the beginning of the semester you completed the ASSIST, what approach do you think you identified?</td>
</tr>
<tr>
<td>2</td>
<td>How did you learn about histology/pathology in this unit? (what strategies did you use)</td>
</tr>
<tr>
<td>3</td>
<td>When using the microscope and identifying something on the slide that you did not expect to see, how did you find out more about it?</td>
</tr>
<tr>
<td>4</td>
<td>How did you find the workload influenced your studying in the unit?</td>
</tr>
<tr>
<td>5</td>
<td>How did other units impact the workload in this unit?</td>
</tr>
<tr>
<td>6</td>
<td>Did you change your approach to studying during the semester? (Can you describe how)</td>
</tr>
<tr>
<td>7</td>
<td>Is there anything else you would like to add?</td>
</tr>
</tbody>
</table>

3.9.3 Procedures

The data for the main study was collected throughout the teaching period in 2007 (Figure 3.21).

![Figure 3.21 Timeline showing data collection during main study](image-url)

The main case study followed the same procedures as the exploratory study with two additions. A discussion board (accessible to only the researcher and the students) was created in the LMS for each unit to enable questions about the study. A minor addition to the initial consent form was made (see Appendix A.2) to allow students to indicate whether they were prepared to be contacted later in the semester to take part in a focus group or interview and the additional procedures for the focus groups and interviews.
If students indicated that they were prepared to be contacted to be in a focus group or interview, they were also asked to complete a separate consent form (see Appendix A.3) and, if selected for a focus group or interview, participate in a focus group and/or interview. From the 58 students who indicated that they were prepared to be contacted to participate in a focus group or interview, 18 students were approached for two separate focus groups. Three from each study approach type (deep, strategic and surface) and three other students were approached for interviews. To try to maximize participation, two focus groups were held. Four students attended Focus Group 1 and six students attended Focus Group 2. Six students were invited for interview, with only four students participating, one with a strategic approach, two with a deep approach and one with a surface approach.

At the beginning of the focus group or interview, each student signed a separate consent form (Appendix A.3) and was also asked to indicate whether they were comfortable with the focus group or interview being recorded. All students indicated they were.

The two focus groups and the four interviews were transcribed by the researcher.

3.9.4 Data Cleansing

In this section the pre-processing procedures for the demographics, the ASSISTs, the log books and reflections are not described as they followed those used in the exploratory study. However the data cleansing procedures for the focus groups and interviews data is described.

The focus group data was transcribed into two separate Word™ documents and then compiled into an Excel™ spreadsheet to facilitate analysis (Figure 3.22).
The interviews were transcribed using a combination of notes and recordings into separate Word™ documents (Figure 3.23) in preparation for analysis. Notes were used when sections of the recordings were not audible.

### 3.9.5 Data Analysis

The main study data were analysed in the same manner as the exploratory study. The students’ reflective comments were content analysed by following the procedures as explained in the exploratory study. The inter-coder reliability was checked through an independent coder, who coded 40 random comments, using the 30 categories from the 15 themes identified in the exploratory study. These were then checked against the main coder’s results using Perreault and Leigh’s (1989) model of Inter-judge reliability (p. 144) (see Section 3.8.5) providing a coefficient of 0.8906.
\[
\text{Ir} = \left[ \frac{(F_0/N) - (1/N)[k/(k-1)]}{k} \right]^{0.5}
\]

Number of judgements made by each judge \((N) = 40\)
Number of judgements on which the judges agree \((F_0) = 32\)
Number of categories \((k) = 30\)
\[
\left[ \frac{(32/40) - (1/30)}{30/(30-1)} \right]^{0.5} = 0.8906
\]
\[\text{Ir} = 0.8906\]

Although Perreault and Leigh (1989) do not mention a specific level of the coefficient that is acceptable, the discussion implies that a figure of 0.70 is reasonable for exploratory research, a figure supported in previous research (Lombard, Snyder-Duch, & Bracken, 2002). This study meets the inter-coder reliability criterion; therefore, the codebook and the coder are deemed reliable.

The focus group and interview data were included in the data collection for the main study only and were analysed as described. The interviews were transcribed and then content analysed to find emerging themes. The researcher sent a transcript of the interview to individual participants asking for verification of the transcript but did not receive any replies. The focus group notes and recordings were also transcribed and then content analysed for themes. There was not enough data from the interview or focus groups to justify the use of qualitative software for content analysis (NVIVO™), therefore the content analysis was done using Excel™. The themes emerged from the participants’ own words and a bottom up approach to theme development was used.

**3.10 Conclusion**

This chapter outlined the methods and procedures used in both the exploratory and main case studies, including the changes made to the methodology after the exploratory case study. The researchers’ reasons for choosing the case study and for using mixed methodologies were also described. These methodologies allow real life situations to be
examined in context and the research questions to be answered. To assist readers understanding of the case, the case study the learning environment is described in detail in the next chapter.
CHAPTER 4

THE CASE STUDY LEARNING ENVIRONMENT

4.1 Introduction

Implementation of virtual microscopy into a curriculum includes both technological and educational components. To build a rich picture of the learning environment provided to students in this study and to highlight some prominent features of studying with optical and/or virtual microscopes, this chapter describes the case study in detail, including the background to the selection of the case.

In 2005, the researcher approached educators in the Health Sciences with the idea of introducing virtual microscopy into the curriculum. She then researched various options, such as hardware and software, associated costs, and the time that it would take to create a set of digital slides (based on the main glass slides used in optical microscopy) and implement virtual microscopy into the curriculum. The technological components were relatively straightforward, but there were some associated educational implications and limitations.

Digitising the slides was subcontracted to a third party, the Royal College of Pathologists of Australasia ("Royal College of Pathologists of Australasia (RCPA) Quality Assurance Programme Pty Limited [Homepage]," 2006). The only input required from the educators in Health Sciences was selection of appropriate examples of the original glass slides (with all key features included and minimal production artefacts), plus checking the digitised versions of the slides for quality and orientation. Initially, for the exploratory study, a wireless intranet was used to deliver the digitised slides. If the slides had been delivered using a DVD or preloaded onto laptops this may have overcome the occasional network
access problems reported by some students. In the main study, students were provided with DVDs.

The Health Sciences case was chosen for its accessibility and convenience, the cooperation and willingness of the lecturer concerned, and, because the students were able to be approached and encouraged to take part in the study.

The participants of the study comprised second and third year undergraduate students studying histology and pathology at Murdoch University in the Faculty of Health Sciences in one of three disciplines: (a) Chiropractic, (b) Veterinary Science; or (c) Biomedical Sciences (including forensic biology, and health and environment). Figure 4.1 illustrates the disciplines, units and student cohorts in the case study. Although the first year student cohort was excluded from the case, they are included in Figure 4.2 to help orientate readers to the histology and pathology teaching in the disciplines. Note that different lecturers were responsible for each unit; however, some of the lecturers taught across the cohorts in the practical classes in an effort to provide consistency across the case study (e.g. the laboratory classes and workshops for each of the units included in the case study were all taught by the same lecturer). The second year students had core lectures in common for the histology and pathology content, as did the third year students.
Figure 4.2 shows the student cohorts participating in the research, third year chiropractic for both the exploratory and main studies, and second year chiropractic, biomedical and veterinary science students in the main study.

Figure 4.2 The histology and pathology units and cohorts, years 2 and 3. Note: The yellow arrows in the figure indicate an optional pathway (VET108 was compulsory for Chiropractic and Veterinary students only).

Given that the researcher was unsure whether the introduction of virtual microscopes might negatively impact students’ learning approaches and their learning it was important to conduct an exploratory study to identify any problems. Third year chiropractic students were identified as suitable participants for the exploratory study as they do not need to use microscopes in their chosen careers and therefore would not suffer any disadvantage by reduced opportunity in developing microscopy operational skills.
For the main study, the second and third year students were chosen as suitable subjects because they had previously completed histology and pathology units using optical microscopes. The second year students were from all three disciplines (Chiropractic, Veterinary Science and Biomedical Science). First year students studying histology in Veterinary Science (VET108) were excluded from this research as they may not have had previous experience learning with optical microscopes and it was felt that they could be put at a disadvantage if they did not gain exposure to optical microscopes in their first year of study, since veterinary practitioners generally use optical microscopes in their practice.

To help the reader understand how microscopes are used to teach students about histology and pathology, Section 4.2 presents a concise summary of the skills and abilities that students need to develop in order to use optical microscopes effectively. Also, to distinguish between various aspects of the learning environment that may impact students’ learning, the two major components of the learning environment are described in Sections 4.3 and 4.4.

### 4.2 Microscope Skills

Students learning histology and/or pathology initially need to learn about naming various parts of optical microscopes, then learning how to use them (practice), finding the correct slide, putting it on the microscope stage with the right side up, adjusting the light and focus and navigating around the slide (a three dimensional process). They also need to learn about recognising and understanding the microscopic structure and function of tissue (theory). They are provided with microscopic images and gross images (naked eye view of an image, e.g. a whole organ). By learning how to use optical microscopes, both technically and in theory, students are also learning about how to analyse complex information (image) and extract data from it.
Several studies have suggested that optical microscope skills should be developed, even when virtual microscopes are introduced into curricula, especially in Medicine (Pratt, 2009) and Veterinary Science (Sims, et al., 2007), as it is a skill that is currently needed in those professions. This would not exclude virtual microscopes from use, but their use would be supplementary.

4.3 Individual Unit Descriptions

A short description of each of the second year (VET244 & BMS264) and third year (CHI301) units from the handbook (Murdoch University, 2007) is provided to assist the reader in building a richer picture of the units.

*Veterinary Physiology* (VET244) covers the functioning of the individual organs and tissues of the adult mammal, including nervous, muscular, cardiovascular, respiratory, renal and alimentary systems. The mechanism of actions is considered in terms of the cellular structure and physical processes necessary to maintain the healthy body. This includes a detailed study of the histology of each tissue. Control mechanisms are outlined. Special emphasis is placed on domestic species and practical exercises utilise computer simulations, supported by demonstrations using animals and humans, to illustrate and extend information covered in lectures. Weekly contact time is 4 hours of lectures and 4 hours of practical (Murdoch University, 2007). Table 4.1 lists the assessment component of the unit in 2007.

Table 4.1 Assessment components for VET244 (main study)

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Description</th>
<th>Mark (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflections and Log Book</td>
<td>Reflections on learning and Log of hours spent studying</td>
<td>5</td>
</tr>
<tr>
<td>Quiz 1</td>
<td>Nerves and muscle</td>
<td>10</td>
</tr>
<tr>
<td>Quiz 2</td>
<td>Respiratory and Cardiovascular</td>
<td>15</td>
</tr>
<tr>
<td>Quiz 3</td>
<td>Renal and Gastrointestinal</td>
<td>15</td>
</tr>
<tr>
<td>Presentations</td>
<td>Oral presentations</td>
<td>10</td>
</tr>
<tr>
<td>Final exam</td>
<td>Three hour theory examination – closed book</td>
<td>45</td>
</tr>
</tbody>
</table>
Biomedical Physiology (BMS264) covers the functioning of the individual organs and tissues of humans and other mammals, including nervous, muscular, cardiovascular, respiratory, renal and alimentary systems. The mechanism of action is considered in terms of the cellular and tissue structure and the physical processes necessary to maintain the healthy body. This includes a detailed study of the histology of each tissue. Control mechanisms are outlined. Practical exercises utilise computer simulations and human subjects. Weekly contact time is 4 hours of lectures and 4 hours of practicals (Murdoch University, 2007). Table 4.2 lists the assessment components of the unit in 2007.

Table 4.2 Assessment components for BMS264 (main study)

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Description</th>
<th>Mark (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflections and Log Book</td>
<td>Reflections on learning and Log of hours spent studying</td>
<td>5</td>
</tr>
<tr>
<td>Quiz 1</td>
<td>Nerves and muscle</td>
<td>10</td>
</tr>
<tr>
<td>Quiz 2</td>
<td>Respiratory and Cardiovascular</td>
<td>15</td>
</tr>
<tr>
<td>Quiz 3</td>
<td>Renal and Gastrointestinal</td>
<td>15</td>
</tr>
<tr>
<td>Presentations</td>
<td>Oral presentations</td>
<td>10</td>
</tr>
<tr>
<td>Final exam</td>
<td>Three hour theory examination – closed book</td>
<td>45</td>
</tr>
</tbody>
</table>

Processes in Human Disease CHI301 provides an understanding of the mechanisms by which disease is produced: pathological processes such as thrombosis, cardiovascular disturbances, inflammation, cell and tissue death, and diseases of abnormal DNA processing such as neoplasia and inherited conditions. Using case examples, the relationships between varying pathological processes are explored. Weekly contact time is 3 hours of lectures, 2 hours of histopathology workshops and 1 hour of problem-solving workshops. Table 4.3 and Table 4.4 list the assessment components of CHI301 in 2006 (exploratory study) and 2007 (main study) respectively.
Table 4.3 Assessment components for CHI301 (exploratory study)

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Description</th>
<th>Mark (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflections and Log book</td>
<td>Reflections on Learning and Log of hours spent studying</td>
<td>5</td>
</tr>
<tr>
<td>Practical review exam 1</td>
<td>Description, recognition &amp; interpretation of gross &amp; microscopic pathology</td>
<td>15</td>
</tr>
<tr>
<td>Mid-semester examination</td>
<td>1 hour theory examination – closed book</td>
<td>20</td>
</tr>
<tr>
<td>Mystery slide assignment</td>
<td>Write a report on a mystery slide</td>
<td>10</td>
</tr>
<tr>
<td>Practical review exam 2</td>
<td>Description, recognition &amp; interpretation of gross &amp; microscopic pathology</td>
<td>15</td>
</tr>
<tr>
<td>Final exam</td>
<td>Three hour theory examination – closed book</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 4.4 Assessment components for CHI301 (main study)

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Description</th>
<th>Mark (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log book &amp; Reflections</td>
<td>Reflections on Learning and Log of hours spent studying</td>
<td>5</td>
</tr>
<tr>
<td>Practical review exam 1</td>
<td>Description, recognition &amp; interpretation of gross &amp; microscopic pathology</td>
<td>15</td>
</tr>
<tr>
<td>Mid-semester examination</td>
<td>1 hour theory examination – closed book</td>
<td>20</td>
</tr>
<tr>
<td>Mystery slide assignment</td>
<td>Write a report on a mystery slide</td>
<td>10</td>
</tr>
<tr>
<td>Practical review exam 2</td>
<td>Description, recognition &amp; interpretation of gross &amp; microscopic pathology</td>
<td>15</td>
</tr>
<tr>
<td>Final exam</td>
<td>Three hour theory examination – closed book</td>
<td>35</td>
</tr>
</tbody>
</table>

As illustrated in Figure 2.2, the theoretical framework informed the design of the case studies. In each unit, the histology and pathology laboratory work was supported by the provision of a comprehensive laboratory manual which acted as an advance organiser to provide students with scaffolding for the histology and pathology theory they were learning. The laboratory manuals comprised of pictures, diagrams and textual descriptors of features to find on slides. The teachers concerned set the context through providing laboratory exercises designed for group work, thereby giving students a chance to articulate their emerging ideas and to either reject or accept other students’ ideas into their own knowledge base. It also provided the opportunity for social interaction about the topics. The activities
were authentic in that students were required to view either glass or virtual slides with microscopes, and to identify features of clinical interest. This is one of the activities that histologists and pathologists undertake on a daily basis.

4.4 The Physical Learning Environment

The students attended lectures in a lecture theatre. The lecture theatre had a lectern, a space for a laptop, a screen to project lecture notes on, a DVD player and a document camera that could also be projected on screen.

The laboratory physical environment differed for the optical and virtual laboratory groups. The Optical Group laboratory environment comprised a room that was set up with six multi-header microscopes (see Figure 1.1). Each microscope had ten binocular heads. Up to nine students were able to be accommodated at each microscope, with one space left vacant for the laboratory demonstrator to occupy during his/her rotation during the laboratory class. Only one student focused and manoeuvred (drove) the microscope while the other eight or fewer students looked through their own binocular viewer to see the slide. Each student saw the same view as well as a moveable arrow that the driver used to indicate any key features of the slide. The demonstrator had a central video microscope that could display the microscope image onto four wall-mounted monitors, to allow features to be demonstrated to the whole class simultaneously. The monitors could also display information from a computer, such as a PowerPoint™ presentation.

The Virtual Group laboratory environment comprised a room that was set up with 20 laptop computers. Each computer had the Aperio™ viewer software (ImageScope). The software allowed students to see a thumbnail of a virtual slide as well as to zoom in on particular parts of the slide (see Figure 1.2). The software also contained several handy tools, e.g. allowing exact coordinates to be seen for the section of slide that the student is focused on, a ruler to measure a section of slide, a camera that allowed students to take a
snapshot of a particular section of a slide, and an annotator that can be used to annotate sections of the slide. Normally two students sat together to use the virtual microscope (see Figure 1.2). A demonstrator moved around the room, as in the optical laboratory groups’ class. To address the class as a whole, the demonstrator had a virtual microscope projected onto a larger screen via a data projector.

4.5 The Virtual Learning Environment (VLE)

The learning environment used for students in these units was the LMS. The lecturer used this system to provide students with teaching and learning materials, activities and resources that were accessible at all times. Figures 4.3 to 4.14 show screenshots of the CHI301 VLE as examples of information provided for the students.

The homepage contained the unit information as well as additional tools and information provided by the researcher. The regular unit information included details about staff, assessment policies, etc:

- unit information (general information about the unit), lecturer/tutor details, assessment policies
- a study schedule
- lecture materials (PowerPoint presentations)
- online resources (links to websites and journals)
- a discussion board that shows “New Discussion” when new postings are waiting to be read
- a link to the iLecture homepage where all e-lectures can be accessed
- the pathology practicals
- the My Grades tool where students could access marks for assignments
- sample exam questions
- information about an assessment “Mystery Slide” activity
The home page also contained some additional information from the researcher:

- Log Book (a Microsoft Excel™ spreadsheet to record hours spent studying)
- the LMS Email tool which students could use to send emails to the lecturer or researcher
- Instructions about the Log Book
- A form for students to record their reflections about the unit (a Word™ Form template)

Students were able to access the general unit information guide as a Portable Document Format (PDF) file format (Figure 4.4). The guide includes information about the general structure of the unit, timetables, lecture venues, useful books, online resources, assessment details, and learning outcomes.
The study schedule was also available as a document that could be either read or downloaded (Figure 4.5).

<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>8.30</th>
<th>9.30</th>
<th>10.30</th>
<th>11.30</th>
<th>12.30</th>
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<tbody>
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</tbody>
</table>

Figure 4.5 Fragment of CHI301 study schedule
The weekly study slides, illustrated in Figure 4.6, were available online and further resources (e.g. pathology practical notes and lecture slides) could be downloaded or viewed online to support students in their learning in the pathology practicals.

Figure 4.6 CHI301 weekly study slides web page

Students were also able to view or download lecture materials in various formats, including ‘rtf’ (rich text format), ‘pdf’ (Portable Document Format) or ppt (PowerPoint), as shown in Figure 4.7. An example of lecture material in PDF format is also provided in Figure 4.8.

Figure 4.7 CHI301 fragment of lecture materials web page
Figure 4.8 Example of CHI301 lecture notes

Students were able to access lectures online through Lectopia, a digital recording system (Figure 4.9). The students reported on their use of this system, as well as the use of other resources in their log books.

Figure 4.9 Example of CHI301 Lectopia homepage
To minimise variation in teaching style and to increase uniformity in labs, group work was encouraged by asking students to complete the same worksheets, regardless of whether they were using optical or virtual microscopes. An example of a laboratory worksheet is shown in Figure 4.10.

**CHI301 Processes in Human Disease — Practical 1**

**Aim:** To understand and recognise the appearance of 'lesions.'

- We shall be comparing normal and diseased tissues in this session.
- We shall gain experience in microscopy.
- We will see that we need to know the normal tissue in order to recognise its abnormal counterpart!
- Some histology revision is involved, and so feel free to bring your histology atlas along if you have one.
- We will begin to get an understanding of what comprises a 'lesion.'
- We shall begin to develop skills in describing objectively what we see, then structuring our subjective interpretations, supporting them with evidence.
- We shall begin to develop our professional problem-solving skills and learn to use professional terms.

You will be working in groups of around six. Your group will review six pairs of normal and abnormal tissues. You will be assigned one of these six to review in more detail for the class. As a group review your selected slide pair along the guidelines below. After completing your assigned slide, review the other sets and discuss them together along similar lines. We shall then review all the sets as a class, and your group will lead the discussion of your assigned slide. You will be expected to understand all the slides in this practical, so it is important that your group does a good review for your colleagues, and that you understand their reviews too. Ask them questions if you are unsure about anything!

Figure 4.10 Example of CHI301 worksheet for laboratory groups

The students were also asked to submit an assignment, the Mystery Slide, and their Log Book and Reflections through the Assignments Tool shown in Figure 4.11.

Figure 4.11 CHI301 assignments web page
4.6 Conclusion

This chapter described the learning environment provided to students in the case study selected for this research. It included descriptions of the units as well as descriptions of both the physical and virtual environments to assist the reader in understanding the components of the learning environment and how they may influence student learning. The next chapter (Chapter 5) describes the exploratory case study in detail.
5.1 Introduction

As the introduction of virtual microscopes had the potential to negatively impact students' learning approaches and their learning, the researcher felt it was necessary to conduct an exploratory study to test the procedures, measurements and impact of the introduction of virtual microscopes into histology and pathology laboratory sessions. Case study methodology was used and both qualitative and quantitative analyses were applied to the data. The data included surveys, log books, reflections on learning and assessment results (which were used to determine the students' approaches to studying), total time spent studying, assessment achievements and learning experiences.

In Chapter 3, the research design and procedures were discussed. In this chapter, the results of the exploratory study are reported in detail as the findings contributed to an improvement in the design of the main research study (van Teijlingen & Hundley, 2001).

5.2 Participants

The participants for the exploratory study were described in detail in Section 3.8.1. In brief, the potential participants were 56 third-year chiropractic students studying histology and pathology. Of these, 47 consented to take part in the study, but not all the students submitted all data components. For the demographic section of the survey, 45 responded and their responses were analysed. There were also 45 students who submitted reflections and log books. However, only 35 students submitted both ASSIST surveys. The 35 students were comprised of 19 students in the Optical Group and 16 students in the Virtual Group.
5.3 Results

5.3.1 Demographic Information

Forty-five students provided demographic information, including age, gender, and previous level of education undertaken prior to commencing their current degree. There were approximately twice as many females (62%) as males (38%) who completed all of the requirements to be included in the study. This imbalance was not representative of the gender split of the whole class, which was more balanced (54% female, 46% male). The age range of the two groups (Optical and Virtual) was between 19 and 45 years, with the majority of students falling into the 20-24 year age group (Table 5.1).

Table 5.1 Students age range by group

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Optical Group (%) n=25</th>
<th>Virtual Group (%) n=20</th>
<th>Total (%) n=45</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=19</td>
<td>9</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>20-24</td>
<td>24</td>
<td>29</td>
<td>53</td>
</tr>
<tr>
<td>25-29</td>
<td>7</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>30-34</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>35-39</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>&gt;=40</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Missing</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

The Virtual Group and the Optical Group were almost equal in number and had a similar percentage of students in the 19 to 29 age brackets. However, there were more mature aged students in the Optical Group than the Virtual Group. As students were randomly allocated to the groups this imbalance could be simply a chance effect.

Students rated their skills using the Internet and computers. Figure 5.1 shows the majority of students in both groups rated themselves as possessing an above average level of skills. Only a small proportion of the group rated themselves as having little or no skills.
Roughly the same proportion of students in both groups felt they had average or better skills and almost the same proportion of students felt they had below average skills. However, there were a small percentage of the Virtual Group students who reported they had little or no skills. Students did not know which group they had been allocated to at the time this data was collected so the group allocation could not be responsible for the difference in the number of students indicating little or no skills in the Virtual Group. This result is somewhat anomalous in that there were more mature aged students in the Optical Group. One would expect more of these students to report little or no skills.

### 5.4 Approaches to studying

The survey used to measure students’ preferred approaches to studying was the Approaches and Study Skills Inventory for Students (ASSIST) (Entwistle, et al., 2000) which has been described in detail in Chapter 3. The following sections of this chapter discuss the results for each of the three sections of the ASSIST.
5.4.1 Section A of the ASSIST

Section A of the ASSIST identifies the students' conceptions about learning. Students' conceptions about learning identify whether they see learning as being about personal understanding and development (deep) or whether they see learning as reproducing knowledge (surface).

Table 5.2 shows the results of Section A of both ASSIST surveys for the Optical Group. At the beginning of the semester (ASSIST1), more than half the students (68%) indicated their view of learning involved personal understanding and development, and almost a third (32%) indicated their view of learning as reproducing knowledge. By the end of the semester (ASSIST 2), there was a decrease in the number of students selecting personal understanding and development (58%) and an increase in those selecting learning as reproducing knowledge (42%). Some researchers (Cope & Staehr, 2005; Cope, et al., 2002) suggest that the learning environment influences changes in student's learning approaches. Could there be something in the optical laboratory setting that influenced students’ approaches? Perhaps, as previously found by Kember and Leung (1998), the volume of work may have influenced them to change their conceptions.

Table 5.2 Section A of the ASSIST for the Optical Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Personal Understanding and Development (%)</th>
<th>Reproducing Knowledge (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>68</td>
<td>32</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>58</td>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5.3 shows the results of Section A of both ASSIST surveys for the Virtual Group. In ASSIST1, over half of the students (56%) indicated their view of learning involved personal understanding and development and just under a half (44%) indicated their view of learning as reproducing knowledge. In ASSIST2, there was a decrease in the number of students selecting personal understanding and development (50%) and a small increase in those selecting learning as reproducing knowledge (50%).
The different results across the two surveys were due to a small proportion of the students changing their conception of learning from personal understanding and development more towards reproducing knowledge; in other words, moving towards a surface approach. Perhaps this was due to workload factors too. There was no difference in the trends for each laboratory group, with both the Optical and the Virtual Group moving more towards the reproduction of knowledge conception.

Table 5.3 Section A of the ASSIST for the Virtual Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Conceptions of Learning</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Personal Understanding and Development (%)</td>
<td>Reproducing Knowledge (%)</td>
</tr>
<tr>
<td>ASSIST1</td>
<td>56</td>
<td>44</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

5.4.2 Section B of the ASSIST

Section B of the ASSIST identifies students’ individual approaches to learning. Table 5.4 shows the results of the Section B of both ASSIST surveys for the Optical Group. At the beginning of the semester (ASSIST1), 32% of students identified a deep approach to learning and 32% identified strategic and 37% identified a surface approach to their learning. At the end of the semester (ASSIST2), the number of students identifying a deep approach to learning had increased to 37% while there was a small decrease in strategic to 26% and no change to surface (37%). Given the small sample size for this exploratory study, the 5% change from strategic to deep represents only one student, so it does not really indicate a trend.

Table 5.4 Section B of the ASSIST surveys for the Optical Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Approaches to Learning</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep (%) Strategic (%) Surface (%)</td>
<td></td>
</tr>
<tr>
<td>ASSIST1</td>
<td>32 32 37</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>37 26 37</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 5.5 shows the results of Section B of both ASSIST surveys for the Virtual Group. At the beginning of semester (ASSIST1), a minority of students (19%) identified a deep approach to learning and a quarter of the students (25%) identified strategic with the majority of students (56%) identifying a surface approach to their learning.

Table 5.5 Section B of the ASSIST surveys for the Virtual Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Approaches to Learning</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep (%)</td>
<td>Strategic (%)</td>
</tr>
<tr>
<td>ASSIST1</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>25</td>
<td>37.5</td>
</tr>
</tbody>
</table>

At the end of semester (ASSIST2), there were some changes. Table 5.6 shows that there was a move towards the deep or strategic approach and no change or decrease in the surface approach. There were small changes in the Optical Group. However, some students in the Virtual Group moved from a surface to either deep or strategic approach. This could be due to students using Virtual Microscopes having more flexibility in their time and were able to study more strategically.

Table 5.6 Changes to Approaches to Learning by Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Approach to Learning</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep (%)</td>
<td>Strategic (%)</td>
</tr>
<tr>
<td>Optical</td>
<td>+5</td>
<td>-6</td>
</tr>
<tr>
<td>Virtual</td>
<td>+6</td>
<td>+12.5</td>
</tr>
</tbody>
</table>

5.4.3 Section C of the ASSIST

The third section of the ASSIST survey, Section C, determines students’ preference for different types of courses and teaching.

Table 5.7 shows the results of Section C of both ASSIST surveys for the Optical Group. At the beginning of semester (ASSIST1), more than one-half of the students (58%) displayed a preference relating to a deep approach (supporting understanding) and just under half of the students (42%) showed a preference relating to a surface approach
transmitting information). At the end of semester (ASSIST2), the number of students displaying a preference for a deep approach decreased by 5% with a corresponding increase of 5% of students displaying a preference for a surface approach. Again, this represents just one student moving from a deep to surface approach.

Table 5.7 Section C of the ASSIST surveys for the Optical Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Supporting Understanding (related to a deep approach) (%)</th>
<th>Transmitting Information (related to a surface approach) (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>58</td>
<td>42</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>53</td>
<td>47</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5.8 shows the results of Section C of both ASSIST surveys for the Virtual Group. At the beginning of semester (ASSIST1), just over one-third of students (37.5%) displayed a preference for supporting understanding (a deep approach) with just under two-thirds of the students (62.5%) showing a preference for transmitting information (a surface approach). There was no change over the semester. As third year students, they had both the time and experience to form opinions about courses and teaching.

Table 5.8 Section C of the ASSIST surveys for the Virtual Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Supporting Understanding (related to a deep approach) (%)</th>
<th>Transmitting Information (related to a surface approach) (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>37.5</td>
<td>62.5</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>37.5</td>
<td>62.5</td>
<td>100</td>
</tr>
</tbody>
</table>

5.4.4 Final Question in ASSIST

The final part of the survey asked students to rate themselves on how well they thought they had been doing in their assessed work so far, on a scale of 1 (very badly) to 9 (very well). To
simplify the results, the 9-point scale was collapsed to a 3-point scale. Students were directed to ignore this question in ASSIST1 as they had not completed any assessed work at that point in time. In ASSIST2, students were directed to answer the question as they were in the last teaching week. Table 5.9 shows that in both groups most of the students felt they were either doing very well, quite well or average. There were more students in the Virtual Group who felt they were doing not so well or rather badly.

Table 5.9 Students’ assessment of how well they had been doing in their assessed work for (Optical and Virtual Groups)

<table>
<thead>
<tr>
<th>Group</th>
<th>3 Very well or Quite well (%)</th>
<th>2 About average (%)</th>
<th>1 Not so well or rather badly (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical</td>
<td>42</td>
<td>53</td>
<td>5</td>
</tr>
<tr>
<td>Virtual</td>
<td>31</td>
<td>51</td>
<td>18</td>
</tr>
<tr>
<td>Whole Group</td>
<td>38</td>
<td>51</td>
<td>12</td>
</tr>
</tbody>
</table>

5.5 Time Spent Studying

Students were asked some questions on the reflections form about their study habits in the unit. The questions related to the students’ study practices in terms of location, collaboration, activities performed and their use of resources.

5.5.1 Location of Study

Table 5.10 shows the students’ responses to the question:

*Please identify whether you were mostly on campus, at home or elsewhere when doing activities with microscopes.*

Participants could respond to this question with more than one location. As can be seen by the results, the vast majority of both groups used microscopes on campus. Students in the Virtual Group did not use the virtual microscope at home, whereas there were students in the Optical Group who did. To use a virtual microscope at home, the students would have had to have copied some of the virtual slide images to a USB drive, as the images were not
available from the university network from home. So, although the virtual microscopes should have facilitated more flexibility in learning for these students, in fact it did not. Perhaps if the images had been available online they would have been used more.

Table 5.10 Location of study for the Optical and Virtual Groups

<table>
<thead>
<tr>
<th>Location</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On campus</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>At home</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>On campus and at home</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

5.5.2 Collaboration

Tables 5.11 and 5.12 show the students’ responses to the question:

*When doing activities with microscopes were you working mostly alone or with a group (please indicate the size of the group)?*

In both the Optical and Virtual Groups, a majority of students conducted their activities with microscopes while working in groups, although there were more students studying alone in the Virtual Group.

Table 5.11 Extent of collaboration for the Optical and Virtual Groups

<table>
<thead>
<tr>
<th>Working Mode</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alone</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>Group</td>
<td>96</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 5.12 shows that the size of the groups varied. Within the Optical Group, the collaborative groups varied from 2-3 students to 8-10 students. It is worth noting, however, that more than half of the group (56%) worked in large groups of 6-10 students. On the other hand, the Virtual Group worked either alone or in small groups of 2-3 students.
Since students in the Optical Group were accustomed to working in groups of nine in their laboratory sessions, they may have continued to work in large groups for study purposes. It is worth noting that the optical laboratories were set up in such a way that students have to sit together to examine slides, while one student drives the microscope the other eight watch. The virtual microscope laboratories are set up for smaller groups of 2-3 students to work together on a computer and this may have influenced these students’ choice for working in smaller groups.

5.5.3 Activities

Table 5.13 shows the students’ responses to the open question:

*How did activities with microscopes help your understanding of the course?*

The majority of students said that the activities helped them to link theory with practice. About a third of the Optical Group thought that the activities also promoted group discussion, whereas only 10% of the Virtual Group identified this characteristic. As mentioned previously, the set-up of the Optical Group labs promoted group discussion which also would have facilitated collaboration.
Table 5.13 Relationship between activities and understanding of the course

<table>
<thead>
<tr>
<th>Microscope Activity</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Both groups (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n=25 )</td>
<td>( n=20 )</td>
<td>( n=45 )</td>
</tr>
<tr>
<td>Linked theory with practice</td>
<td>72</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>Promoted group discussion</td>
<td>36</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>It didn’t help</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Participants identified more than one item; hence, the figures are greater than 100%.

5.5.4 Resources

Reading beyond set texts often indicates a deep approach to learning (Biggs, 2003, p. 35), so students were asked about their use of resources in the unit.

*If you read more than the required text please specify where you found most of your resources, e.g. web, library, lecturers, WebCT supplementary materials, other people, or other.*

Table 5.14 shows the students’ use of resources and the frequency of the responses by individual groups and in total. There were some interesting differences between the groups, with the majority of the Virtual Group (80%) using web or LMS materials and less than half (40%) using the library. This contrasts with only 44% of the Optical Group using the web or WebCT materials and 12% using the library. It appears that students using virtual microscopes became more comfortable with digital media. However, it should also be noted that 20% of the Optical Group did not respond to this question, so there may be a bias in these results.

Table 5.14 Student use of resources

<table>
<thead>
<tr>
<th>Resource</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n=25 )</td>
<td>( n=20 )</td>
<td>( n=45 )</td>
</tr>
<tr>
<td>Web</td>
<td>24</td>
<td>50</td>
<td>36</td>
</tr>
<tr>
<td>LMS materials</td>
<td>20</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>Lectures</td>
<td>16</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Library</td>
<td>12</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>Other text books</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Other people</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Tutorials</td>
<td>4</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: More than one type of resource could be identified by the same respondent.
5.5.5 Relationship between time spent studying and final mark in the unit

Students completed several assessments during the semester to provide a final mark out of 100% for the unit. The assessments included log book, practical reviews, mystery slide assignment and two exams. Through their log books, the students provided the number of hours they spent studying the unit during the teaching period. The students’ marks for their final grade and their total time spent studying were collected and analysed.

The total time spent studying by students in the Optical Group varied from 35 to 160 hours with an average of 88 hours and their average mark was 68. The total time spent studying by students in the Virtual Group varied from 56 to 139 hours with an average of 96 hours and the average mark was 71. Prima facie, the extra study time was rewarded with higher grades for the Virtual Group. However, the differences between the groups were not significantly correlated.

An independent-samples two-tailed t-test comparing the final marks and group also resulted in no significant difference for Optical \( (M=68.36, \ SD = 9.31) \) and Virtual \( (M=70.62; \ SD = 7.65) \); \( t(33) = -.774, \ p=.44 \) (two-tailed).
Table 5.15 Time spent studying and final grade for both groups

<table>
<thead>
<tr>
<th>Code</th>
<th>Optical (n=25)</th>
<th></th>
<th>Virtual (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Time</td>
<td>Final Mark</td>
<td>Code</td>
</tr>
<tr>
<td>1</td>
<td>124</td>
<td>74</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>137</td>
<td>77</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>59</td>
<td>57</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>53</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>111</td>
<td>61</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>86</td>
<td>58</td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>55</td>
<td>75</td>
<td>21</td>
</tr>
<tr>
<td>14</td>
<td>87</td>
<td>66</td>
<td>22</td>
</tr>
<tr>
<td>15</td>
<td>71</td>
<td>75</td>
<td>24</td>
</tr>
<tr>
<td>17</td>
<td>72</td>
<td>68</td>
<td>26</td>
</tr>
<tr>
<td>18</td>
<td>74</td>
<td>55</td>
<td>29</td>
</tr>
<tr>
<td>19</td>
<td>35</td>
<td>55</td>
<td>32</td>
</tr>
<tr>
<td>23</td>
<td>108</td>
<td>68</td>
<td>35</td>
</tr>
<tr>
<td>27</td>
<td>160</td>
<td>71</td>
<td>36</td>
</tr>
<tr>
<td>28</td>
<td>142</td>
<td>72</td>
<td>38</td>
</tr>
<tr>
<td>30</td>
<td>58</td>
<td>82</td>
<td>41</td>
</tr>
<tr>
<td>31</td>
<td>66</td>
<td>62</td>
<td>42</td>
</tr>
<tr>
<td>33</td>
<td>85</td>
<td>74</td>
<td>43</td>
</tr>
<tr>
<td>34</td>
<td>52</td>
<td>60</td>
<td>47</td>
</tr>
<tr>
<td>37</td>
<td>118</td>
<td>80</td>
<td>Average</td>
</tr>
<tr>
<td>39</td>
<td>51</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>110</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>110</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>109</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>88</td>
<td>68</td>
<td></td>
</tr>
</tbody>
</table>

5.6 Reflections

Students were asked to reflect on their learning experiences with microscopes and which microscope they had used most during the semester (all the students had used optical microscopes in their previous two years of study). The reflections were prompted by four open-ended questions relating to their likes and dislikes about virtual and optical
microscopes (see Figure 3.5). Students’ responses were split into the two groups (Optical Group and Virtual Group) and then classified into themes. Sometimes a response applied to more than one theme so some overlapping occurred. The results of the open-ended questions were thematically analysed in Microsoft Excel™ to reveal common themes and the frequency of the responses was calculated.

In the following sections, attitudes towards each type of microscope are discussed, the themes identified, and the thematic descriptors related to each theme are provided. Figures for each theme illustrate the students’ responses and groups for each microscope. Where relevant, each theme contains illustrative quotes which are coded (e.g. O=optical, V=virtual; M=mal F=female, Identity=1-45). All quotes are reproduced verbatim.

5.6.1 Attitudes to Optical and Virtual Microscopes

There were 15 themes identified by students in both the Optical and Virtual Groups about optical and virtual microscopes in their responses to the Attitude Survey. Each theme is then separated into positive and negative aspects, giving a total of 30 categories (Table 5.16).

Table 5.16 Themes about microscopes

<table>
<thead>
<tr>
<th>Attitude Themes</th>
<th>Optical Microscopes</th>
<th>Virtual Microscopes</th>
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Chapter 5 120
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In the following sections, each theme is presented with illustrative quotes. About a third of the students (Optical Group, 33% Virtual Group, 22%) left these questions blank or answered that they did not use one of the microscopes during the semester and therefore felt unable to comment on that particular microscope.

1. Use

Figure 5.2 shows the ease of use that both groups experienced with virtual and optical microscopes. Almost a third of all students (27%) found the optical microscopes difficult to use and said that they were complicated to operate and hard to focus. This is a finding that is consistent with a previous study (Heidger, et al., 2002). More than half of all the students commented that the virtual microscopes were much easier to use than the optical microscopes, although a small percentage (16%) of the Optical Group found the optical microscopes were easy to use too. It could be that this small number of students in the Optical Group only used the optical microscopes. Virtual microscopes do not require a lot of expertise to use.

Comments about using the optical microscopes covered the spectrum from easy to difficult to use.

The optical microscope [is] fast and easy to use, you could roam the slide very quickly [OM027].

Difficult to use, focus, find right slides, missing slides etc [OF010].

Can be a bit complicated to operate because of all the parameters that can be adjusted [OM019].

Comments about the use of the virtual microscopes generally indicated that they were easier to use than the optical microscopes, which has also been found by other researchers (Heidger, et al., 2002).

It is so much easier to use than optical. You can change the magnification quickly and easily [VM013].
It was convenient and easy to use. Slides were in correct order and easy to access [OF017].

Ease of use, don't need to know how to use a microscope and since I'll never have to use one in my career that is ideal for me [VM006].

![Image](image.png)

(a) Optical microscope use  
(b) Virtual microscope use

Figure 5.2 Use of microscope by group

2. Focus

Being able to focus clearly on slides is an important aspect of using a microscope. Obtaining a clear image of a histology or pathology slide is always desirable, as it then allows practitioners the best possible chance to identify the important histological or pathological features on the slide. Almost a quarter of the students (22%) found the glass slides were clearer than the virtual slides (Figure 5.3).

![Image](image.png)

(a) Optical microscope use  
(b) Virtual microscope use

Figure 5.3 Focus of microscope by group
The following comments represent students’ views about the clarity and focus of the optical microscopes:

The slides looked clearer and were quicker to use than the computer slides [OF009].

... I also found that at higher magnification it was a lot clearer to view slides in comparison to virtual [VF017].

The Virtual Group students asserted that the focus of the virtual microscopes is not always as good as the optical microscopes. A number of students (24%) in both groups identified clarity as an issue with the virtual microscopes, commenting that it takes a few moments for the virtual slides to come into focus when changing the optical zoom from x20 to x40.

[Virtual] Images at higher magnifications are not as sharp and clear [OF002].

Another problem that I’ve encountered is regarding the pixels. This has happened to me for a number of times, after I’ve zoomed in and out 1 slide for around 5 minutes, the slide clarity would then deteriorate, and all you can see when you want to zoom in (say x40) are random pixels [VF038].

sometimes needed to zoom in that bit extra but you couldn't [VM007].

The clarity is not always as good as the optical microscopes. When zoomed in to 40x the actual cell type can be difficult to distinguish sometimes [VM013].

out of focus on high resolution [VM047].

Virtual microscopes are an excellent resource for the study of pathology. They are simple to set-up, easy to navigate, show each slide in really high quality and detail… Probably the best part is that all the slides are there to use there is no need to sort through hundreds of glass slides to find the one you need [VM016].

Good slides that do not break /get dirty or stuff out… I only used the virtual microscopes once. It was easy to find the right slide. There was no confusion about whether we had the right slide or not [OF015].

It gives us perfectly clear images; we can zoom in or zoom out at the slides in barely 5 seconds. Not much gadgets are involved in order to get to the image piece you want [VF038].

3. Group work

Educators promote learning in small groups because of the opportunity afforded to students to discuss and learn from each other. Just under one third of all students (29%) felt that
optical microscopes facilitated group work and discussion (Figure 5.4). Over 30% of the Optical Group thought this was the case compared with 25% of the Virtual Group. Conversely, a small group of Optical Group students felt that the virtual microscopes facilitated group work; a larger proportion of both groups felt that the virtual microscopes actually hindered group work. This could be due to the physical structure of the optical microscope laboratories (groups of 8) versus the virtual microscope laboratories (groups of 2-3). A small percentage of students (9%) thought there was less discussion when using the virtual microscopes compared to optical microscopes. This is contrary to other research that found group work was promoted by the use of virtual microscopes (Goldberg & Dintzis, 2007) and is probably related to the use of the multi-header optical microscope set up used in this study as opposed to single use optical microscopes in other studies.

The following comments highlight the group work experienced with the optical microscope.

The group discussions were the most valuable, and being walked through all of the pathology and having our questions answered by [the teacher] [OF020].

The group atmosphere was probably the highlight of the optical microscopes [OF015].

![Figure 5.4 Group work by microscope and group](image)

(a) Optical microscope use  
(b) Virtual microscope use

A small percentage of students commented on the virtual microscope facilitating group work while others commented on its inhibiting group work.
That you could work in groups easier and point out things together [OF008].

You work alone with no input from peers [OF002].

I found it quite mundane to be alone in front of a computer screen, trying to figure out what I was looking at, compared to the group discussion experienced in the optical microscopes [VF036].

4. Control

A number of students from the Optical Group felt a greater sense of control with the optical microscopes than with virtual microscopes. This could be due to their being able to control the focus better with the optical microscopes. Some students from both groups also found that the optical microscopes hindered their sense of control. Some students (11%) felt that they were not in control when they worked in groups with the optical microscopes (Figure 5.5). As previously indicated, one student drives the microscope while the others just view. It could therefore be easy for some students to feel less engaged when they are not in control. A small number of students from the Optical Group felt they had more control with the virtual microscopes. This could be due to the fact that each student could control the virtual microscopes themselves, rather than having to follow what someone else was doing or that, when using the virtual microscopes, they worked in smaller groups of 2-3.

![Graph](chart.png)

(a) Optical microscope use  
(b) Virtual microscope use

Figure 5.5 Control by microscope and group
Comments that illustrate students’ feelings about being in control when using the optical microscopes include:

I was randomly selected to be in the optical microscope lab group. Most of the time, I’m the driver while using the microscope. I have always used the OM [optical microscope]. I find that the most beneficial thing about the OM is that I can measure the size of the exact specimen using a ruler before writing my lab report. I can’t do that using the virtual or maybe I don’t know how [OF033].

... Sometimes hard to use If there are others drivers (ie someone else is controlling focus etc) it can be abit anoying. [OM005].

Sometimes you want to look at something a bit longer or sketch something, but you don’t want to have to make the group wait [VM013].

I could look at what I wanted and focus better [OF020].

On the other hand, there was also one student who commented on feeling in control when using the virtual microscope “They were easy to view and I was in control of the slide” [OM028].

5. Health

Over a third of all students (36%) said that the optical microscopes caused health issues such as headaches and motion sickness (Figure 5.6). This has previously been identified in the literature (e.g. Golding, 2006; Kofler, et al., 2002; Thompson, et al., 2003). Conversely, both groups of students felt that the virtual microscopes reduced these health issues.

![Graph showing health by microscope and group]

(a) Optical microscope use  (b) Virtual microscope use

Figure 5.6 Health by microscope and group
Students commented about the detrimental effect of optical microscopes on their health.

They gave me constant headaches and sore eyes [OF008].

In addition, using the microscope gave me motion sickness when other people were operating it [VF026].

Students also commented on how the virtual microscopes did not affect their health. However, more students in the Virtual Group reported improvements in their health than those in the Optical Group.

No headaches either [OF015].

I found it very convenient and easy to use. I enjoyed using it as I had used the optical microscopes in other classes previously and with using it I experienced eyestrain and headaches. I did not experience this with the virtual microscope [VF029].

6. Time management

About a third of the Optical Group felt that the optical microscopes were time consuming to use (Figure 5.7(a)). This could relate to finding glass slides, correctly positioning each slide, and then having to focus the optical microscope and navigate to the areas of interest. A small group of students from both groups thought that their ability to manage their time improved with the virtual microscope (Figure 5.7(b)) because it was quick to set-up and use with no time wasted looking for lost or missing slides. The latter supports previous research findings concerning improvements in time management with the use of virtual microscopes (Kumar, et al., 2004).
Students commented on the detrimental impact of the optical microscopes on time management. With the optical microscopes, sometimes students put slides into the wrong box which was frustrating for other students because they could not find the slides or had to take extra time to find them.

The time spent looking for slides that had not been put back into the correct box [OF001].

Sometimes slides are missing – then we can’t look at things [OF040].

I find the optical microscopes more of a hindrance than a help. They take a lot longer to set up than the virtual microscope does, you have to find the slide, make sure you have it on the viewer correctly [VM016].

Some students commented on the virtual microscopes being easier to use, for example:

It is so much easier to use than optical. You can change the magnification quickly and easily. You can zoom into the exact area you want to look at without “stuffing” around [VM013].

7. Experience

It has previously been documented in the literature (e.g. Farah & Maybury, 2009; Kumar, et al., 2004) that students find optical microscopes difficult to use and that it takes time to develop skills in using them effectively. One student commented:
It takes experience to operate it efficiently. There is the tendency to always let one person drive if they are good at it and then when faced with wanting to use them alone, one finds it very difficult [OF002].

There were no comments about experience and virtual microscopes.

8. Authenticity

Students benefit from authentic learning experiences and activities that have real world relevance (Brown, et al., 1989). The optical microscopes provided an authentic experience for a small number of students from both groups (Figure 5.8(a)-(b)), while the virtual microscopes were perceived to be less authentic by a small group of students from the Optical Group due to a lack of tactile and visual elements. Even though virtual microscopes are used by pathologists, roughly the same proportion of students in both groups felt that the virtual microscopes provided a less authentic experience than the optical microscopes.

The following are some example comments about authenticity.

You get to see everything for real and you get experience using a microscope [OF014].

Give a realistic and relevant element to learning (i.e. its real tissue). Gets you to learn how to use a microscope and the problems you have with it. It is not just another simulation of what generally happens (it presents the real problems/anomalies faced in microscopy) [VM005].

Does not give the reality of observing tissue You are unable to use motor skills and you may get from using the optical microscope [OM005].

You feel more of a distance to what you are looking at when you can't "put hands" on it [OM019].

Does not give the reality of observing tissue you are unable to use motor skills and you may get from using the optical microscope [VM05].
A minority of students in the Optical Group felt that there was more teacher interaction with the optical microscopes. Representative comments from students include:

... once [the teacher] comes over to the table to explain the slide, everyone can discuss together compared to Virtual Microscope which only works in pairs. It save a lot of time by explaining in a group of 7 people [OF033].

It's very helpful when [the teacher] also joins in and shows us things directly. I can clearly see things in front of me [OF040].

Some students (16%) in the Optical Group, as opposed to none in the Virtual Group, identified this positive aspect. The set up of the optical microscope labs may mean that the teachers have more chance of interacting with each group during the laboratory sessions.

10. Comfort

All students had previously used the optical microscopes, which meant that a few students in the Optical Group (8%) had a sense of familiarity and comfort when using the optical microscopes. As the students in the Optical Group were using the optical microscopes for their laboratory work they may not have experienced using the virtual microscopes during the semester. A comment from an Optical Group student showed that he had a sense of:
“Comfort in using [the optical microscope], as used one previously, a sense of familiarity” [OM003].

11. Technology

Over a third of the students in the Virtual Group (35%) felt that the virtual microscope technology was unreliable. The following comments illustrate the problems encountered with the technology. This could be partly related to some network issues experienced during the semester.

The program crashing [VM045].

There were no real major negatives to the virtual microscopes, this was the first time we had used them and everyone in the class seemed to get along well with using them and found them useful. The only thing I found that was a bit of a negative was that one morning the computers wouldn't work, or the network so we lost a bit of time- but I guess that is the case with all technology [VM016].

Took too long to load up sometimes [VF035].

Sometimes the images wouldn't load or sometimes the whole Image Scope freezes [VF042].

12. Convenience

A few students (9%) found the virtual microscopes to be more convenient than the optical microscopes. This is probably due to the restricted access to the optical microscopes, which is mainly available during laboratory classes. The labs were used heavily during the day and there were few times that they could be accessed after class due to limited resources. Virtual microscopes on the other hand, could be used at home. It was possible for students to take a copy of the virtual slides home and install the software viewer onto their own computers.

Typical comments about the convenience of the virtual microscopes included:
...and above all convenient to use [OF002].

I found it very convenient and easy to use [VF029].

13. Access

Some students (16%) felt that the virtual microscopes offered them more freedom and accessibility than the optical microscopes (Figure 5.9(a)-(b)). Other research has reported that access was improved by using virtual microscopes (Blake, et al., 2003; Goldberg & Dintzis, 2007; Harris, et al., 2001; Sims, et al., 2007). Typical comments include:

- Easily accessible and there was no need to fiddle around with things in order to view the slide [VF042].
- It was easier to access outside class and off campus [OF020].
- The virtual microscope was very easy to use and it was available on a variety of computers, which made it very accessible [VF026].

This could be related to the students' abilities to use the virtual microscopes ability at home. A small number from both groups of students identified access as a restriction that they disliked about the virtual microscopes. For example:

- Can't use the program at home [OM023].
- Would be better if you could access the slides from home [VM006].

Perhaps these students were not aware that they could copy the virtual slides onto a USB drive to take home, and that they could install the viewer on their computers at home without cost. Maybe they would have preferred to be able to access the images over the web from their home computers.
(a) Optical microscope use  

(b) Virtual microscope use

Figure 5.9 Access by microscope and group

14. Learner engagement

A small number of students from both groups (9%) felt they experienced less enthusiasm, engagement and motivation when using the virtual microscopes. Students’ comments were mainly about working in small groups and a lack of teacher interaction in the laboratory sessions.

The problem is we works in pair. It takes so much time for the tutor, [the teacher] to go around and explain [OF033].

I was easily distracted and I found [the teacher] couldn’t adequately answer everyone’s questions as effectively as when using the optical microscopes [OF015].

You work alone with no input from peers [OF002].

I found it quite mundane to be alone in front of a computer screen, trying to figure out what I was looking at, compared to the group discussion experienced in the optical microscopes [VF036].

15. Microscope skills

More students felt they were developing practical skills using the optical microscopes than the virtual microscopes (Figure 5.10). A few students commented on developing skills with the optical microscopes:

You get to see everything for real and you get experience using a microscope [OF014].
Gets you to learn how to use a microscope and the problems you have with it. It's not just another simulation of what generally happens (it presents the real problems / anomalies faced in microscopy [OM005]).

Most students from both groups highlighted handy tools associated with the virtual microscopes. For example:

Allowed you to identify specific areas of underlying pathology and had handy tools such as a specific view finder, which allowed higher magnification of certain aspects of the slide while others were kept at lower magnification. Comparisons between slides such as between slides containing pathology and normal slides were easier to compare [the software could display two or more slides side by side], there was no need to change a slide over or adjust anything as would normally occur when using an optical microscope [OF017].

You can take photos of it and email to yourself (you can take it home virtually) [VM005].

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Figure 5.10 Microscopes skills by microscope and group

5.7 Conclusion

The results of the ASSIST surveys measured students’ conceptions about learning, their individual approaches to learning and their preferences for different types of courses and teaching. Section A of the ASSIST survey measured students’ conceptions about learning. Students’ conceptions about learning showed whether they saw learning as being about personal understanding and development (related more to a deep approach) or whether they saw learning as reproducing knowledge (related more to a surface approach). There was a decrease in both the Optical and Virtual Groups in personal understanding between the
beginning and end of semester. This therefore suggests that the groups had similar changes in students’ conceptions of learning from personal understanding to reproducing knowledge. This could be related to the workload in the unit.

Section B of the ASSIST survey measures students’ individual approaches to learning. In this section, the results indicated that there was an increase in deep learning for both groups, with some of the Optical Group changing from strategic to deep and some of the Virtual Group changing from surface to strategic or deep. One would expect that, as pressures mount with increased workload throughout the semester, students would discover strategies for minimising their work. However, it was interesting that students with a surface approach in the Optical Group did not change their approach while students in the Virtual Group with a surface approach changed to either deep or strategic.

Section C of the ASSIST survey determines students’ preferences for different types of courses and teaching. The two preferences are supporting understanding (related to a deep approach) and transmitting information (related to a surface approach). The two groups demonstrated different trends. Students in the Optical Group moved from a preference for a surface to a deep approach. There was no change in preference for students in the Virtual Group.

At the end of the semester, students rated themselves on how well they thought they had been doing in their assessed work. Overall, the Optical Group’s perception of their progress was more favourable than the Virtual Group’s. One explanation for this variance could be related to the greater amount of time, on average, that the Virtual Group spent studying, as this group moved towards either a deep or more strategic approach.

In addition to the ASSIST surveys, students kept a record of the amount of time they spent on their work throughout the semester. One would expect a relationship between the amount of time and their final mark. Although there was a relationship, it was not statistically
significant for either group. The time that the Virtual Group recorded could have been in exploring the new techniques of virtual microscopes. On the other hand, as more students in the Virtual Group changed to either a deep or strategic approach to studying, perhaps this group was engaging more in the wider discipline as they experimented with the novel technology. This is an interesting finding from the study, which needs further investigation, it is one that appears, prima facie, to support Russell’s claim that “[t]here is nothing inherent in the technology that elicits improvements in learning” (1999, p. xiii).

It must be stressed that the findings in this exploratory study are tentative as the numbers in each group (19 in Group A; 16 in Group B) were small. Richer data is required to investigate further the reasons for the changes in students’ approaches over the semester.

The results do show some differences between the two groups. Both groups showed a change in students’ conceptions of learning with a move away from personal understanding and development (deep) towards reproducing knowledge (surface); however, the change was greater for the Optical Group. Both groups also showed a change in approaches to learning from strategic to deep, but in the Virtual Group there was also a significant change from surface to strategic. Students in the Optical Group showed a change in their preference for different types of courses and teaching away from those using a deep approach towards those using a surface approach, while there was no change in the Virtual Group.

With the focus on encouraging teachers to move away from instructivist approaches of teaching to more constructivist approaches, particularly social constructivist approaches that involve more collaborative student activities, it is interesting to note that study approach inventories appear to lack any items that measure collaborative learning as part of the deep approach.
CHAPTER 6

THE MAIN STUDY

6.1 Introduction

The main study sought to investigate further how the introduction of virtual microscopes into histology and pathology laboratory sessions influenced students’ learning approaches. It also sought to determine whether there were any differences in the learning approaches and academic performance between the three groups of students in the study. As in the exploratory case study, the participants and the results are described. The materials used, the data collection, data cleansing, data analysis methods and modifications to the materials for the main study were outlined in Chapter 3. The results of the main study are presented in this chapter.

6.2 Participants

For the main study, the potential participants were 348 students studying second year Biomedical Sciences (BMS264), second year Veterinary Science (VET244) or third year Chiropractic (CHI301). Of these, 293 consented to take part in the study, but not all the students submitted all the data components. For the demographics part of the survey, 293 responded and their responses were analysed. There were 269 students who submitted reflections and 279 students who submitted log books. However, only 151 students submitted both ASSIST surveys. Of the 151 students, 81 were in the Optical Group and 70 were in the Virtual Group. Ten students took part in two separate focus groups, four in Focus Group 1, and six in Focus Group 2. Four students took part in interviews. A summary of the participants in the main study is provided in Table 6.1.
Table 6.1 Participants in each data component of the study

<table>
<thead>
<tr>
<th>Data</th>
<th>No of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td>293</td>
</tr>
<tr>
<td>Reflections</td>
<td>269</td>
</tr>
<tr>
<td>Log Books</td>
<td>279</td>
</tr>
<tr>
<td>ASSISTS</td>
<td>151</td>
</tr>
<tr>
<td>Focus Groups</td>
<td>10</td>
</tr>
<tr>
<td>Interviews</td>
<td>4</td>
</tr>
</tbody>
</table>

6.3 Materials

As in the exploratory study, the ASSIST instrument, demographic questions, modified reflection form and modified log book were administered to the students. Seven questions about laboratory work were added to the reflection form as previously described in Chapter 3 (Table 3.11). The log book was made easier for students to use by splitting it into several tabbed worksheets that automatically added the totals of time spent studying from each into the master worksheet (Figure 6.1).

Figure 6.1 Log book showing Master worksheet
6.4 Demographics

Two hundred and ninety-three students provided background information, including age, gender, and level of education undertaken prior to commencing their current degree. There were more females than males who participated in the study (Figure 6.2). This was representative of the gender split of the entire group.

![Figure 6.2 Gender by unit](image)

Students were randomly allocated to one of two laboratory groups (Optical or Virtual). The age range of the two groups was between 18 and 46 years with the majority of students falling into the <=19 and 20-24 year age groups (Table 6.2). The groups were almost equal in number and had a similar proportion of students in the 19-29 age groups. The Optical Group had slightly more mature students (30-40+) than the Virtual Group.
Table 6.2 Students age range by laboratory group

<table>
<thead>
<tr>
<th>Age group</th>
<th>Optical (%) n=156</th>
<th>Virtual (%) n=137</th>
<th>Total (%) n=293</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=19</td>
<td>20</td>
<td>18</td>
<td>38</td>
</tr>
<tr>
<td>20-24</td>
<td>22</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>25-29</td>
<td>5</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>30-34</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>35-39</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>=&gt;40</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Students rated their skills using the Internet and computers on a scale of 1 (very skilled) to 5 (little or no skills). Figure 6.3 shows that the majority of the students in both groups rated themselves as possessing above average levels of skills and almost a third rated themselves as having average skills. A small proportion of students rated themselves as having little or no skills. The proportion of students identifying with each level of skill was roughly the same, regardless of laboratory group allocation.

![Figure 6.3 Students self-rating of ICT skills by group (n=293)](image)

Students were also asked to indicate their level of education prior to undertaking their current study (Figure 6.4). The majority had completed secondary study, while a small proportion had previous tertiary or technical qualifications.
Students were asked to identify whether they would use a microscope in their career (Figure 6.5). Approximately two thirds of the students said that they expected to use a microscope in their career. As stated previously, chiropractors are less likely to use microscopes in their career. Further analysis was therefore required on the unit category. Figure 6.6 shows that this is indeed the case, with 97% of veterinary science or biomedical sciences students responding positively to this question.
Figure 6.6 Students identifying potential microscope use in their career by unit

6.5 ASSIST Survey

The survey used to measure students’ preferred approaches to studying was the Approaches and Study Skills Inventory for Students (ASSIST) (Tait, et al., 1998), which has been described in detail in Chapter 3. The following sections of this chapter discuss the reliability of the instrument and the results for each of the three sections of the ASSIST. In each section, the results are presented for Optical and Virtual Groups first, followed by unit level results.

6.5.1 Reliability of the ASSIST

The reliability of the ASSIST has been discussed in Section 3.8.2. The Cronbach alpha for each section of the ASSISTs is shown in full in Appendix D while each of the three study approaches in Section B for both ASSISTs in the main study is shown in Table 6.3. Cronbach’s alpha scores for deep (0.77 and 0.83), strategic (0.82 and 0.86) and surface (0.78 and 0.84) were comparable to the reliability scores of other studies for Section B of the ASSIST and are also provided in Table 6.3.
Table 6.3 Examples of studies reporting reliability of ASSIST by Cronbach’s alpha

<table>
<thead>
<tr>
<th>Study</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep</td>
</tr>
<tr>
<td>Entwistle (2000)</td>
<td>0.84</td>
</tr>
<tr>
<td>Speth, Namuth, and Lee (2007 p.110)</td>
<td>0.65</td>
</tr>
<tr>
<td>Main Study ASSIST1</td>
<td>0.77</td>
</tr>
<tr>
<td>Main Study ASSIST2</td>
<td>0.83</td>
</tr>
</tbody>
</table>

6.5.2 Section A of the ASSIST

Section A of the ASSIST focuses on students’ conceptions about learning. Students’ conceptions about learning identify whether they see learning as being about personal understanding and development (deep) or whether they see learning as reproducing knowledge (surface).

Table 6.4 shows the results of Section A of both ASSIST surveys for the Optical Group. The results indicate that, towards the end of the teaching period, the number of students who conceived of learning as being about personal understanding and development increased, while those who conceived of learning as reproducing knowledge decreased.

Table 6.4 Section A of the ASSIST for the Optical Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Conceptions of Learning</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Personal understanding and development (%)</td>
<td>Reproducing knowledge (%)</td>
</tr>
<tr>
<td>ASSIST1</td>
<td>41</td>
<td>60</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>56</td>
<td>44</td>
</tr>
</tbody>
</table>

Figure 6.7 shows unit level detail of the Optical Group students’ conceptions of learning. In each unit, students in the Optical Group displayed a shift in their conception of learning away from reproducing knowledge (surface) towards supporting understanding (deep).
Table 6.5 shows the results of Section A of both ASSIST surveys for the Virtual Group. These results show there was also an increase in the number of students who conceived of learning as personal understanding and development and a decrease in those who conceived learning as reproducing knowledge.
Table 6.5 Section A of the ASSIST for the Virtual Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Personal understanding and development (%)</th>
<th>Reproducing knowledge (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>47</td>
<td>53</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>58</td>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

The conceptions of learning for the Virtual Group are similar to the Optical Group. In all units, students in the Virtual Group displayed a change in their conception away from reproducing knowledge (surface) (Figure 6.8(a)) towards supporting understanding (deep) (Figure 6.8(b)). At the unit level, the greatest change in conception was in the biomedical students.
Changes to students’ conceptions over the teaching period are summarised in Table 6.6. To ascertain if the changes were significant a chi-square test for independence (with Yates continuity correction) was carried out. The results indicated no significant association between group and conception of learning, $X^2(1, n=151)=.04$ ($p=.84$). A further chi-square test for independence was carried out on the association between unit and conceptions of learning. The results of this test indicated no association, $X^2(2, n=151)= 2.57$ ($p=.27$). A similar test on all the factors (group, unit and conception of learning) also revealed no significant difference $X^2$ (virtual group 2, $n=70 = 4.36$ ($p = .12$)), (optical, 2, $n = 81 = .74$ ($p = .69$)).

Table 6.6 Changes to conceptions of learning over the teaching period

<table>
<thead>
<tr>
<th>Group</th>
<th>Personal understanding and development (%)</th>
<th>Reproducing knowledge (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical</td>
<td>+15</td>
<td>-16</td>
</tr>
<tr>
<td>Virtual</td>
<td>+11</td>
<td>-11</td>
</tr>
</tbody>
</table>
In summary, there was a trend in both groups moving from a conception of learning as reproducing knowledge to one of supporting understanding, but the trend was not significant.

### 6.5.3 Section B of the ASSIST

Section B of the ASSIST identifies students’ individual approaches to learning. Table 6.7 shows the results of the Section B of both ASSIST surveys for the Optical Group. At the beginning of semester (ASSIST1), more students identified a deep approach to learning than strategic. The largest proportion of students (39%) identified a surface approach to their learning. At the end of semester (ASSIST2), the number of students identifying a deep approach to learning remained the same. There was a slight increase in the strategic approach, and surface approach decreased slightly. These results indicate that there was little change in the students approaches to learning during the teaching period.

Table 6.7 Section B - Approaches to learning for the Optical Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Learning Approach</th>
<th></th>
<th></th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep (%)</td>
<td>Strategic (%)</td>
<td>Surface (%)</td>
<td></td>
</tr>
<tr>
<td>ASSIST1</td>
<td>32</td>
<td>28</td>
<td>39</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>32</td>
<td>32</td>
<td>36</td>
<td>100</td>
</tr>
</tbody>
</table>

In Figure 6.9, each learning approach is grouped by unit. Even though VET244 students moved from a deep approach (Figure 6.9(a)) to either a surface (Figure 6.9(b)) or strategic approach (Figure 6.9(c)), overall there was no change in the overall proportion of students using a deep approach during the teaching period. However, there was a slight increase in the proportion of students using a strategic approach and decrease in the number of students using a surface approach. This could be due to students focusing on assessments towards the end of the semester.
Figure 6.9 Optical Group students’ learning approaches by unit
Table 6.8 shows the results of Section B of both ASSIST surveys for the Virtual Group. At the beginning of semester (ASSIST1), the greatest proportion of students identified a surface approach to their learning. Fewer students identified a deep approach or strategic approach. At the end of semester (ASSIST2), the number of students identifying a deep approach to learning had decreased slightly and there was a very small decrease in strategic with a larger increase in surface. The number of students identifying either a deep or strategic approach decreased slightly while there was a small increase in surface approach.

Table 6.8 Section B - Approaches to learning for the Virtual Group

<table>
<thead>
<tr>
<th>Survey</th>
<th>Deep (%)</th>
<th>Strategic (%)</th>
<th>Surface (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>30</td>
<td>31</td>
<td>39</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>27</td>
<td>29</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 6.10 shows students approaches to learning by unit. In BMS264 there was a move from both deep and surface approaches to strategic, which could be explained by students’ focusing on assessments (workload). In VET244 there was large shift from strategic to either deep or surface approaches. This could be due to some students trying to understand the subject and others focusing on just passing the unit. In CHI301 there was a small change from deep to strategic approach, which again may be explained by workload.
Figure 6.10 Virtual Group students' learning approach by unit

(a) Deep approach

(b) Strategic approach

(c) Surface approach
Table 6.9 shows that, in the Optical Group, a small proportion moved away from a surface approach to a strategic approach whereas in the Virtual Group a small proportion moved away from deep and strategic approaches to a surface approach. This result was explored further using the chi-squared test of independence. A chi-square test of independence indicated no significant association between group and learning approach, \( \chi^2 (2, n=151) = 1.143, p=0.56 \) or between units and learning approach, \( \chi^2 (4, n=151) = 8.028, p=0.91 \).

Table 6.9 Changes to learning approaches over the teaching period

<table>
<thead>
<tr>
<th>Group</th>
<th>Learning Approach</th>
<th>Deep (%)</th>
<th>Strategic (%)</th>
<th>Surface (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical</td>
<td></td>
<td>0</td>
<td>+4</td>
<td>-4</td>
</tr>
<tr>
<td>Virtual</td>
<td></td>
<td>-3</td>
<td>-3</td>
<td>+6</td>
</tr>
</tbody>
</table>

Previous research (Entwistle & Peterson, 2004) has indicated that there may be a relationship between conceptions of learning and students’ learning approach. However, a chi-square test of independence showed no significant association between these two factors, \( \chi^2 (virtual, 2, n=70) = 4.68, p=0.096 \), \( \chi^2 (optical, 2, n=81) = .08, p=0.96 \), in this study.

In summary, although there were a small proportion of students who changed their learning approaches during the teaching period, the changes were not significant.

### 6.5.4 Section C of the ASSIST

The third section of the ASSIST survey determines students’ preference for different types of courses and teaching. Table 6.10 shows the results of Section C of both ASSIST surveys for the Optical Group. At the beginning of semester (ASSIST1), just over one half of the students displayed a preference relating to a deep approach (supporting understanding) and almost half of the students showed a preference relating to a surface approach (transmitting information). At the end of semester (ASSIST2), the number of students displaying a preference for supporting understanding (a deep approach) increased slightly and those displaying a preference for a surface approach decreased slightly.
Table 6.10 Section C - Preference for different types of course and teaching for the Optical Group (n=81)

<table>
<thead>
<tr>
<th>Survey</th>
<th>Encouraging understanding (related to a deep approach) (%)</th>
<th>Transmitting information (related to a surface approach) (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>51</td>
<td>49</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>54</td>
<td>46</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 6.11 shows the proportion of students’ preferences for different types of teaching and environment by unit for the Optical Group. The largest movement was in the biomedical unit, where 9% of the students changed from transmitting information (surface) to encouraging understanding (deep).

(a) Encouraging understanding
(b) Transmitting information

Figure 6.11 Section C - Preference for different types of course and teaching for the Optical Group by unit

Table 6.11 shows the results of Section C of both ASSIST surveys for the Virtual Group. At the beginning of semester (ASSIST1), almost half of the students displayed a preference for supporting understanding (deep approach) and more than half of the students showed a preference for transmitting information (surface approach). At the end of semester (ASSIST2), there was a small movement from surface to deep approach.

Table 6.11 Section C - Preference for different types of course and teaching for the Virtual Group (n=70)

<table>
<thead>
<tr>
<th>Survey</th>
<th>Supporting understanding (related to a deep approach) (%)</th>
<th>Transmitting information (related to a surface approach) (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>47</td>
<td>53</td>
<td>100</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>51</td>
<td>49</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 6.12 shows the preferences for different types of course and teaching for the Virtual Group at a unit level. The trend that was identified in Table 6.11 appears to have occurred in the chiropractic students only. The trend, however, was found to be not significant: chi-square tests for independence (with Yates continuity correction) indicated no significant association between group and preference, $X^2(1, n=151) = .126, p=0.72$ or between unit and preference $X^2(2, n=151) = 1.061, p=0.59$. 

CHI301 | VET244 | BMS264 | Total |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSIST1</td>
<td>50%</td>
<td>45%</td>
<td>57%</td>
</tr>
<tr>
<td>ASSIST2</td>
<td>45%</td>
<td>45%</td>
<td>48%</td>
</tr>
</tbody>
</table>
(a) Encouraging understanding

(b) Transmitting information

Figure 6.12 Section C - Preference for different types of course and teaching for the Virtual Group by unit

6.5.5 Final Question in ASSIST

The final part of the survey asked students to rate themselves on how well they thought they had been doing in their assessed work so far, on a scale of 1 (very badly) to 9 (very well).

To simplify the results and to highlight overall trends, the 9 point scale was collapsed to a 3 point scale. Students were asked to answer this question in ASSIST1 but to base it on how well they thought they would do in their assessed work. In ASSIST2, in the last teaching
week, students answered the question as it was stated “How well are you doing in your assessed work in this unit so far?” The students had not yet taken this final exam, so the responses related to their assessments.

In ASSIST 1 (Table 6.12), most of the Optical Group students expected to do well or average, while only a very small proportion expected not to do well. A similar pattern was revealed for the Virtual Group students with slightly more expecting not to do so well.

Table 6.12 Students’ assessment of how well they expect to do in their assessed work at the beginning of the teaching period (ASSIST 1) for the Optical and Virtual Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>3 Very well or quite well (%)</th>
<th>2 About average (%)</th>
<th>1 Not so well or rather badly (%)</th>
<th>No response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical</td>
<td>56</td>
<td>41</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Virtual</td>
<td>50</td>
<td>46</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

In ASSIST2 (Table 6.13), both the Optical and the Virtual Groups showed similar trends. About one third said they were doing well and about half the students believed they were doing average. Of interest in these results is that there were twice as many students in the Virtual Group who thought they were not doing well. This result is not surprising as previous research has shown that students often over-estimate their expected academic achievement and actual performance due to factors such as egocentrism and extent of difficult of tasks (Chevalier, Gibbons, Thorpe, Snell, & Hoskins, 2009). It may also be due to students answering the initial question in a way to provide the researcher with the answer they thought they wanted to hear, “the halo effect” (Pike, 1999).
A paired-samples $t$-test was conducted to evaluate whether there was any difference between students’ expected assessment achievement at the beginning of the teaching period (Time 1) and their actual assessment achievement believes towards the end of the semester (Time 2). There was a statistically significant decrease in scores from Time 1 ($M = 6.35$, $SD = 1.484$) to Time 2 ($M = 5.50$, $SD = 1.931$), $t(149) = 5.178$, $p < .000$ (two-tailed). The mean decrease in scores was 0.85 with a 95% confidence interval ranging from 0.52 to 1.17. The eta squared statistic was 0.17. According to Cohen’s (1988) guidelines, the effect was large.

A paired-samples $t$-test was conducted to determine whether there were any significant changes in students’ assessment of how well they thought they would do and how well they had done in their assessed work. There was a statistically significant decrease in scores for both groups from Time 1 to Time 2. For the Optical Group, the result was Time 1 ($M = 6.44$, $SD = 1.557$) and Time 2 (Optical Group, $M = 5.53$, $SD = 2.168$), $t(80) = 3.821$, $p < .005$ (two-tailed). The mean decrease in scores was 0.91 with a 95% confidence interval ranging from 0.44 to 1.39. The eta squared statistic 0.16. For the Virtual Group, the result was Time 1 ($M = 6.23$, $SD = 1.395$) and Time 2 (Virtual Group, $M = 5.46$, $SD = 1.623$), $t(68) = 3.498$, $p < .005$ (two-tailed). The mean decrease in scores was 0.77 with a 95% confidence interval ranging from 0.33 to 1.21. The eta squared statistic was 0.15).

It is not clear why more of the Virtual Group students thought they would not do so well compared to the Optical Group students, but in order to determine whether the virtual microscopes played any part in this perception is an area that should be explored in the future.
6.6 Reflections

The reflections form was a pre-formatted Word™ document that was placed on LMS for students to download and complete. It contained several parts. The first part collected students’ educational experience prior to beginning their current course. The second part collected information about the type of microscope they used in their laboratories and what they liked and disliked most about both types of microscopes. In the third and fourth parts they were then asked questions about their study habits in the unit. These questions related to the students’ study practices in terms of location, collaboration, activities performed and their use of resources.

In the following sections, the results of the responses to study habits are presented, followed by the students’ attitudes to microscopes. To determine whether there was any relationship between the time spent studying and the students’ final grade a statistical analysis was conducted in SPSS™ (see Section 6.6.2).

6.6.1 Location of Study

Table 6.14 shows the students’ responses to the question:

*Please identify whether you were mostly on campus, at home or elsewhere when doing activities with microscopes.*

The results show that the vast majority of both groups used microscopes on campus, but almost a third of both groups also used microscopes at home (probably the virtual microscopes) and a small group used them at friends’ houses.
Table 6.14 Location of study for the Optical and Virtual Groups

<table>
<thead>
<tr>
<th>Location</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On campus</td>
<td>79</td>
<td>67</td>
</tr>
<tr>
<td>At home</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>Other (e.g. friends)</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: Participants could respond to more than one location

6.6.2 Time Spent Studying and Final Grade

Students reported spending varying amounts of time studying, ranging from 3 hours to 364 hours. There was variation between groups (Table 6.15). The chiropractic students spend the most amount of time studying.

Table 6.15 Time spent studying by unit and group

<table>
<thead>
<tr>
<th>Time studying (Hours: minutes)</th>
<th>Optical</th>
<th>Virtual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CHI301</td>
<td>43.09</td>
<td>23.78</td>
</tr>
<tr>
<td>VET244</td>
<td>15.23</td>
<td>7.65</td>
</tr>
<tr>
<td>BMS264</td>
<td>44.87</td>
<td>50.99</td>
</tr>
<tr>
<td>Total</td>
<td>34.11</td>
<td>39.63</td>
</tr>
</tbody>
</table>

The students’ final marks (grade) for their unit are shown in Table 6.16. While the results varied between units and groups they were not significantly different.

Table 6.16 Final grade by unit and group

<table>
<thead>
<tr>
<th>Final grade</th>
<th>Optical</th>
<th>Virtual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CHI301</td>
<td>67.97</td>
<td>7.85</td>
</tr>
<tr>
<td>VET244</td>
<td>70.65</td>
<td>10.76</td>
</tr>
<tr>
<td>BMS264</td>
<td>57.41</td>
<td>13.09</td>
</tr>
<tr>
<td>Total</td>
<td>64.06</td>
<td>12.96</td>
</tr>
</tbody>
</table>
Independent samples $t$-tests, paired samples $t$-tests, correlation tests, ANOVA, two-way ANOVA and chi-square tests were conducted to determine whether there was any relationship between: (i) time spent studying and group; (ii) learning approach and time spent studying; (iii) final grade and group; (iv) time spent studying and final grade; (v) individual learning approaches and final grade; and (vi) learning approach, group and time spent studying. The General Linear Model (GLM), Univariate Analysis of Variance test was used to determine whether there were multiple effects between: (vi) final grade, group, unit, gender and learning approach; and (viii) time spent studying, group, unit, gender and learning approach. The results for each test are reported.

The results of the independent samples $t$-test comparing time spent studying and groups showed that there was no significant difference in times between Optical ($M=34.11$, $SD=39.63$) and Virtual ($M=35.14$, $SD=29.67$); $t(277)=0.247$, $p=0.80$ (two-tailed).

To determine whether there was any difference in the time spent studying when students were grouped according to their learning approaches (deep, strategic or surface), a second independent samples $t$-test was conducted. The results showed that for students with a deep approach, there was no significant difference between Optical ($M=35.87$, $SD=32.61$) and Virtual ($M=21.46$, $SD=17.75$); $t(39) = -1.65$, $p=.10$ (two-tailed). Similarly, for students with a strategic approach, there was no significant difference in time spent studying between Optical ($M=29.00$, $SD=20.21$) and Virtual ($M=24.28$, $SD=11.84$); $t(43) = -0.925$, $p=.36$ (two tailed). Lastly, for students with a strategic approach, there was no significant difference in time spent studying between Optical ($M=31.40$, $SD=30.88$) and Virtual Groups ($M=52.62$, $SD=71.18$); $t(57) = .029$, $p=.14$ (two-tailed).

Results of an independent samples $t$-test comparing students’ final grade in the unit and group showed that there were no significant differences for Optical ($M=64.06$, $SD=12.96$) or Virtual Groups, ($M=66.07$, $SD=12.6$); $t(287) = -1.33$, $p=.18$ (two-tailed).
The relationship between *time spent studying* and *final grade* for all students was investigated using Pearson product-moment correlation coefficient. There was a weak, negative correlation between the two variables \((r = -.14, n=275, p=.019)\), with less time spent studying associated with higher grades. Perhaps students who understood the subject studied less than students who did not. The Pearson product-moment correlation coefficient test was also used to determine whether there was a relationship between the *time spent studying* and *final grade* for both groups. There was no significant correlation between the two variables for the Optical Group \((r = -.158, n=148, p=.05)\) and for the Virtual Group \((r = -.129, n=127, p=.15)\). This finding may be due to the smaller sample size as the larger whole group sample showed a weak relationship.

To compare the mean scores of more than two different groups or conditions, a one-way analysis of variance (ANOVA) can be used. “[ANOVA] compares the variance (variability in scores) between the different groups (believed to be due to the independent variable) with the variability within each of the groups (believed to be due to chance)” (Pallant, 2007, p. 242). When significant differences are found, effect size should be calculated (e.g. eta squared is one measure of effect size used in ANOVA) and post-hoc tests (e.g. Tukey HSD) can be used to find where the differences lie (Pallant, 2007). To determine whether there was any significant relationship between the three *learning approaches* (deep, strategic or surface) and students’ *final grades*, a one-way between groups analysis of variance (ANOVA) was conducted. Subjects were divided according into their learning approach. There was a statistically significant difference at the \(p<.05\) level in final grade between the three learning approaches, \((F(2, 146)=3.30, p=.04)\). Despite reaching statistical significance, the actual differences in mean scores between the approaches were quite small. The effect size, calculated using eta squared, was .02. Post-hoc comparisons using the Tukey HSD test indicated that the mean scores for a deep approach \((M = 71.02, SD=10.07)\) was significantly different from a surface approach \((M=66.13, SD=10.16)\), while a strategic approach \((M=69.65, SD=9.86)\) did not differ significantly from either deep or surface approaches.
A two-way between-groups analysis of variance (TWO-WAY ANOVA) was conducted to explore the impact of learning approaches and group (Optical and Virtual) on time spent studying. As before, subjects were divided into their pre-determined learning approaches (deep, strategic or surface). The interaction between learning approach, group and the time spent studying was not statistically significant, $F(2,139) = 2.76, p=.07$. There was no statistical significance for learning approach, $F(2,139) = .851, p=.54$ or group, $F(1,139) =.004, p=.96$.

The General Linear Model (GLM), Univariate Analysis of Variance test was conducted to determine whether students’ total final grade for the unit was influenced by group, unit, gender or learning approach. The results shown in Table 6.17 indicate that there was a significant effect between final grade for the unit and learning approach. Students with a deep approach had a higher grade than students with a strategic or surface approach. Students with a surface approach had a lower mark than students with either a deep or strategic approach.

Table 6.17 Results of GLM for final grade

<table>
<thead>
<tr>
<th>Final grade</th>
<th>F</th>
<th>DF</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (Optical, Virtual)</td>
<td>0.464</td>
<td>1</td>
<td>0.497</td>
</tr>
<tr>
<td>Unit Code (VET244, CHI301, BMS264)</td>
<td>2.908</td>
<td>2</td>
<td>0.580</td>
</tr>
<tr>
<td>Gender</td>
<td>0.861</td>
<td>1</td>
<td>0.355</td>
</tr>
<tr>
<td>Learning Approach</td>
<td>3.399</td>
<td>2</td>
<td>0.036</td>
</tr>
</tbody>
</table>

The GLM was also used to explore any significant differences between group, unit or gender and time spent studying. The results shown in Table 6.18 show there was a statistically significant difference for the time spent studying by unit and by dominant learning approach. Students with a deep approach studied less than students with either strategic or surface approaches. There was a statistically significant difference for the time spent studying and unit code, with VET244 students studying less than CHI301 and BMS264 students.
Table 6.18 Results of GLM for Time spent studying

<table>
<thead>
<tr>
<th>Time spent studying</th>
<th>F</th>
<th>DF</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (Optical, Virtual)</td>
<td>0.184</td>
<td>1</td>
<td>0.668</td>
</tr>
<tr>
<td>Unit (VET244, CHI301, BMS264)</td>
<td>18.922</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>1.230</td>
<td>1</td>
<td>0.269</td>
</tr>
<tr>
<td>Learning Approach</td>
<td>3.467</td>
<td>2</td>
<td>0.034</td>
</tr>
</tbody>
</table>

Apart from the weak negative correlation between time spent studying and final grade, and a statistically significant difference between deep and surface learning approaches and final grade, the statistical tests did not show any strong statistical significance. As students’ may have a preference for a particular learning approach but may not be competent in its use (Cuthbert, 2005) the results between learning approaches and final grade is not surprising.

6.6.3 Collaboration

Tables 6.19 and 6.20 show the students’ responses to the question:

*When doing activities with microscopes were you working mostly alone or with a group (please indicate the size of the group)?*

In both the Optical and Virtual Groups, the majority of students’ performed activities with microscopes while working in groups. In the Optical Group, the size of the collaborative groups varied from 2-10, with about half working in large groups of over 4. Almost all of the Virtual Group worked alone with microscopes or in small groups of 2-3.

Table 6.19 Extent of collaboration for the Optical and Virtual Groups

<table>
<thead>
<tr>
<th>Collaboration</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=146</td>
<td>n=123</td>
</tr>
<tr>
<td>Alone</td>
<td>31</td>
<td>41</td>
</tr>
<tr>
<td>Group</td>
<td>69</td>
<td>59</td>
</tr>
</tbody>
</table>
Table 6.20 Size of the collaborative groups in Optical and Virtual Groups

<table>
<thead>
<tr>
<th>Collaborative group size</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=146</td>
<td>n=123</td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>41</td>
</tr>
<tr>
<td>2-3</td>
<td>10</td>
<td>44</td>
</tr>
<tr>
<td>4-5</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>6-8</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>8-10</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>unknown</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

It is interesting to note that the results from the final question in ASSIST 1 and ASSIST 2 showed that the Virtual group had lower expectations of performance when compared to the Optical group. Also in the Attitude Survey the Virtual group students reported that they also tended to study alone more than the Optical group (Table 6.14) therefore may have been more likely to feel isolated and were perhaps not able to benefit from scaffolding by peers.

Students also responded to seven statements about their laboratory group (Table 6.21) by choosing an answer from a 5-point scale (1 Strongly Agree, 2 Agree, 3, Neither Agree or Disagree, 4 Disagree, 5 Strongly Disagree).

Table 6.21 Statements about laboratory work by group

<table>
<thead>
<tr>
<th>Statement</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SA 1  A 2  N 3  D 4  SD 5</td>
<td>SA 1  A 2  N 3  D 4  SD 5</td>
</tr>
<tr>
<td>1. The degree of interaction in my laboratory group was very high</td>
<td>29  51  15  3  1</td>
<td>37  40  19  3  2</td>
</tr>
<tr>
<td>2. All members of my laboratory group worked equally well</td>
<td>16  38  20  18  6</td>
<td>37  38  17  6  2</td>
</tr>
<tr>
<td>3. Reaching consensus in the group was easy</td>
<td>21  51  24  5  1</td>
<td>30  54  11  6  0</td>
</tr>
<tr>
<td>4. I enjoyed working with this group</td>
<td>36  38  18  5  3</td>
<td>54  31  10  5  0</td>
</tr>
<tr>
<td>5. I found the laboratory group work to be an</td>
<td>38  40  13  5  3</td>
<td>45  37  10  7  2</td>
</tr>
</tbody>
</table>
To illustrate the information in Table 6.21 more clearly, the 5-point scale was collapsed to a 3-point scale (1 Agree, 2 Neutral, 3 Disagree) and represented in Figures 6.13-6.19. Figure 6.13 shows that the majority of students from both groups felt the degree of interaction in their laboratory group was very high.

Many more students from the Virtual Group agreed that all the members of their laboratory group worked equally well together (Figure 6.14). This may be due to the set up of the optical laboratory in that only one student drives the microscope while the other seven...
follow. In the virtual laboratory, on the other hand, students worked in smaller groups of two to three, which may have led to more equal work.

Figure 6.14 Responses to “all members of my laboratory group worked equally well”

Figure 6.15 shows a difference in responses between the groups. It seems that more students in the Virtual Group found it was easy to reach consensus than students in the Optical Group. This is no doubt due to the smaller group size in the virtual laboratory.

Figure 6.15 Responses to “reaching consensus in the group was easy”

Figure 6.16 shows that more students from the Virtual Group agreed with the statement, “I enjoyed working with this group”. Again, this may be related to Virtual Group students working in smaller groups than the Optical Group students. Or, it could be, that they enjoyed the novelty of the virtual microscopes so had a favourable impression of the whole experience.
Figures 6.17 and 6.18 relate to the learning experience. Figure 6.17 shows that slightly more students in the Virtual Group found that the laboratory work was effective as a learning experience than students in the Optical Group.

Figure 6.18 indicates that there were more students in the Virtual Group who thought that the laboratory activities helped them to understand many of the theoretical concepts taught in this unit. This could also be related to the smaller group sizes in the Virtual Group. These results about the learning experience suggest that the virtual microscopes provided a novel environment which appears to have encouraged the Virtual Group to engage more with both the theoretical and practical aspects of their courses.
Figure 6.18 Responses to “I was able to understand many of the theoretical concepts taught in this unit by doing the laboratory activities”

Figure 6.19 shows that both Optical and Virtual Group students agreed that the LMS environment encouraged active learning. This is not unexpected as both groups had the same experience in using the LMS and all students would have also used it in their other units.

Figure 6.19 Responses to “The LMS unit provides an environment that encourages active learning”

Summary

The groups’ responses to the statements varied with both groups agreeing that the degree of interaction in their groups was high and that the LMS unit environment encourages active learning. The groups differed on the rest of the statements with the Virtual Group indicating higher agreement than the Optical Group.
6.6.4 Activities

Table 6.22 summarises students’ responses to the question:

Describe how the activities with microscopes helped your understanding of the course material?

Major themes emerging from this question included: linked theory with practice, visualisation, authentic activities and group discussion. To review how the themes were determined, see Section 3.8.5. In the following sections, each theme is discussed. Where relevant, each theme contains illustrative quotes which are coded to identify group, gender and identity (e.g. O=optical, V=virtual; M=male, F=female, Identity=1-269).

Table 6.22 Responses to “Describe how the activities with microscopes helped your understanding of the course materials”

<table>
<thead>
<tr>
<th>Activity themes</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Linking theory with practice</td>
<td>36</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>2 Visualising</td>
<td>17</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>3 Authenticity</td>
<td>12</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>4 Group discussion</td>
<td>12</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>5 Revision</td>
<td>5</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>6 Building skills in tissue identification</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7 Teacher guidance</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>8 Engagement</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>9 Convenience</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>10 Time management</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>11 Focus</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12 Developing microscope skills</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Participants comments could be placed in more than one activity theme

**Activity Theme 1: Linking theory with practice**

Nearly equal numbers of students from both laboratory groups (Table 6.23) thought that the activities with microscopes helped to link the theory of histology and pathology with practice. This is not surprising given that histology and pathology are visual sciences.
Table 6.23 Activity Theme 1 - Linking theory with practice (by group)

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linking theory with practice</td>
<td>36</td>
<td>34</td>
<td>35</td>
</tr>
</tbody>
</table>

In the Optical Group, students said that, by seeing how the tissue structures enabled functions to occur in organ, it made the lectures come to life and assisted their understanding of histology and pathology.

It made the lectures come to life in a sense. It made it easier to absorb when you see first hand what they are talking about [OF08].

Understanding the structure made it easier to understand function [OM125].

I was able to understand how the structures of the tissues enable certain functions to occur in the organs [OF120].

relates the lecture materials to actual slides [OF127].

The Virtual Group students also said that activities helped them to learn better by providing a link to what the lecturer taught and helped to make things make more sense.

could see it at a cellular level and could really understand why it is structured to function optimally, it was really useful to have the microscopes!!! [VF281].

Taking theoretical information and applying it, stimulating different thoughts and helping to learn better, getting a feeling of a more rounded understanding through the practical element [VM274].

Provided a link to what [the lecturer] lectured about and what we read in text books [VM290].

it increased my understanding of the different tissues in the body and how those differences (on a cellular level) allow them to function within th body and to maintain homeostasis. it just seemed to make things make more sense! [VF277].

**Activity Theme 2: Visualising**

Students from both groups (Table 6.24) found that the microscope activities helped them to visualise concepts and to remember images. The Optical Group also found the activities made it easier for them to remember concepts and images at exam time, while the Virtual Groups’ comments reinforce the importance of visualising what is learned. In other words, the students appear to be creating mental maps of what they learn.
Table 6.24 Activity Theme 2 - Visualising (by group)

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%) n=146</th>
<th>Virtual Group (%) n=123</th>
<th>Total (%) n=269</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualising</td>
<td>17</td>
<td>22</td>
<td>19</td>
</tr>
</tbody>
</table>

The comments from the Optical Group students illustrate the helpfulness of the activities in developing their visualisation skills.

Being able to visualise what we discussed was extremely helpful and surprisingly the images were easy to remember [OF115].

It helped understand and visualise many concepts [OF74].

The microscopes were useful in helping me visualise a concept or description taught in lectures and it also makes it easier to remember come exam time. Also trying to find the characteristics of tissues on microscope slides myself allowed me to test my understanding and helped me realise what i already knew and what i may have needed to work on [OF066].

It was easier to visualise the material covered in the histology lectures. It helped my understanding of structures of organs and I was able to retain information about the structures more easier [OF073].

The Virtual Group found the activities helped them to visualise what it was they were actually learning and with remembering some of the characteristics of the organs.

It helps in remembering the features/characteristics of the various organs [VF192].

gave a visual idea of how the specimens looked and how the structures of them looked also [VF213].

Allows you to visualise what it actually is that you were learning about. Allows for revision [VM316].

to better visualise the structures other than looking at a textbook. helped clarify their form [VF288].

Activity Theme 3: Authenticity

Students from both groups thought the microscope activities were authentic (Table 6.25). Authentic activities are ones that have real life application and are often featured in constructivist learning environments.
Table 6.25 Activity Theme 3 - Authenticity (by group)

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n=146$</td>
<td>$n=123$</td>
<td>$n=269$</td>
</tr>
<tr>
<td>Authenticity</td>
<td>12</td>
<td>15</td>
<td>13</td>
</tr>
</tbody>
</table>

It is interesting to note that the Optical Group students found the activities to be real, while the Virtual Group students found it helped them to see how things work at a cellular level, rather than it just being a bunch of slides. The Optical Group students’ comments show that using the optical microscope was perceived to be authentic.

Looking at something on a slide is much different from looking at it in a book. The whole process of using a microscope made whatever I was looking at so much more real instead of just a picture [OF62].

In class when we saw pictures of magnified material it was hard to imagine it in real life. When using the microscope you can look at the slide first with your naked eye and then zoom in progressively to see the detail and put it into perspective [OF140].

The Virtual Group students’ also found the virtual microscope to be authentic.

The course material is just a bunch of slides when working on microscope gives us the opportunity to realize how things work [VM199].

It showed what is going on at the cellular level so it was possible to see all the changes that inflammation had in detail and not just read about it in a book, you could actually see it going on. Especially with neoplasia that is something that I had such a different idea about and then I got to see it down the microscope it made it so much more relevant. I think it was really valuable I never missed a lab [VF011].

**Activity Theme 4: Group discussion**

Although both groups identified group discussion as one of the things that assisted them to understand the course material, more of Optical Group students identified this issue than the Virtual Group (Table 6.26). As mentioned previously, this could be due to the physical structure of the optical laboratory, with one student driving and seven other students following. The opportunity for group discussion could be greater than in the Virtual Group where the laboratory is set up for 2-3 students per microscope.
Several comments from the Optical Group show how students worked together and discussed the activities in their groups:

- Discussing things in a group and feeding off each others ideas, answering each others questions. Looking at the slides rather than just pictures from a book helped, seeing what the nerves actually looked like. Putting things into practice. [OF124].

- Everyone in the group would pick out something they saw and we would discuss what it is, what it does and what structures could possibly be around it [OF094].

- the co-operation of everyone and group learning, friends helping each other out and learning by teaching peers [OF056].

The following comment typifies the comments from a few Virtual Group students.

- We able to explore the whole slide instead of just being given a section picture of it in lectures. Working in a group was excellent, were able to utilise each others strenghts and could discuss the slides, allowing you to come to the correct conclusions and identify the right things [VM280].

**Activity Theme 5: Revision**

Both Optical and Virtual Groups found that the activities helped them to revise the materials, as shown in Table 6.27.

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revision</td>
<td>5</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

The Optical Group students mentioned various ways that the activities helped them, such as, being able to view slides from different perspectives and zooming into specific areas.

- I found using the microscope was a good revision tool for me. It was a quick way to view all the tissues, and identify their specializations. It is also a good way to view the tissue as a whole, and then to zoom in on the areas that are of more interest to you. The lectures were good, but pictures on a page can be a little restrictive. The
microscope was a good way to comprehend the 'big picture' of the tissue and its parts [OF070].

I used microscope as review material. On lecture power points, there is usually one part on one slide. It might have different shapes and looks on different occasion and specimen, so using microscope was useful to test myself to see if I can identify specific parts. Also by doing this, I can visualise how the part I am looking at associates with surrounding parts [OF185].

The Virtual Group students also mentioned the revision aspect of activities, though they were more general in their comments:

- Tutorials were great, and easy revision meant I would look for something in a sample rather than just skim over it [VF224].
- These microscopic activities were good revision, and gave me good expression how a particular structure looks like in real specimen [VF313].

**Activity Theme 6: Building skills in tissue identification**

A small number of students in both groups said that their skills in tissue identification were developed by doing the activities (Table 6.28).

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building skills in tissue identification</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

The Optical Group students were able to gain experience in identifying lesions and structures, as were the Virtual Group, who found that the activities helped to stimulate their memories and with histological identification.

gave me experience with identification of lesions [OM041].

The microscope activities helped me to identify structures. The study of tissues helped me to better understand gross or organ system physiology. The group environment allowed discussion of what the structures were, and their functions etc [OF183].

helped with tissue recognition and helped understand substances produced by certain cells in certain organs or tissues. It was like a memory stimulant for other areas [VF228].
it gave me more practice at identifying histological specimens [VF262].

Activity Theme 7: Teacher guidance

A small group of students from each group (Table 6.29) felt that the activities were made meaningful due to the guidance they received from their teacher. In some cases, the teacher was a laboratory demonstrator, while in other cases, the teacher was the lecturer.

Table 6.29 Activity Theme 7 - Teacher guidance (by group)

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher guidance</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Typical comments from both groups about the scaffolding provided by the teacher are:

- having [the lecturer] help with the histology classes made the identification of different tissue and structures a lot easier [OM99].
- it enabled me to see different aspects of the slides but mainly [the lecturer] explaining it helped the most [OF178].
- microscope activity only really helpful when explained properly [by the lecturer or the demonstrator] [VM310].
- [the lecturer] going through the slides with us in class was extremely helpful, made things easier to understand [VF003].

Activity Theme 8: Engagement

In addition to helping with revisions, a few students (Table 6.30) thought that the activities with microscopes helped them to be more engaged in the material.

Table 6.30 Activity Theme 8 – Engagement (by group)

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Some typical comments that illustrated the enjoyment aspect of the activities were:
Using the microscopes made the course material a bit more interesting and easier to understand than by just looking at textbook diagrams etc [OF128].

Well when you're searching yourself for particular structures that you should keep and eye out for it becomes more interesting doesn't it [VM293].

Activity Theme 9: Convenience

A small number of students from both groups (Table 6.31) identified the convenience of the virtual microscope as a contributing factor to their increased understanding, with students from the Virtual Group claiming they studied at home in the middle of the night.

Table 6.31 Activity Theme 9 - Convenience (by group)

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=146</td>
<td>n=123</td>
<td>n=269</td>
</tr>
<tr>
<td>Convenience</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Comments about the virtual microscopes show that it is convenient and accessible to students from home. This finding supports other research regarding the convenience and greater access of virtual microscopes (Goldberg & Dintzis, 2007; Harris, et al., 2001).

The virtual microscope made it easy to study at home in my own time I had access to all the study materials in the middle of the night [VF314].

The virtual microscope was most useful for me as I was about to see what I needed in the privacy of my home and practice. Having a tute was useful for going over things I didn't know [OF155].

Activity Theme 10: Focus

A few students (2%) in the Virtual Group commented that being able to focus the microscopes had assisted them with understanding the course material, e.g. “As I only used the virtual one most of the time, I find it really useful as I can have a bigger magnification and it did assist me with my studies” [VF292].
Activity Theme 11: Time management

A small proportion of the Virtual Group (4%) found that they were able to manage their time better when using the virtual microscopes.

I was able to find what I was looking for in less time [VF244].

“Went faster was able to save an image to ask questions about later [VF250].

This finding supports similar findings in other research (Kumar, et al., 2004; Sims, et al., 2007).

Activity Theme 12: Developing microscope skills

A small proportion of students from both groups (Table 6.32) thought their microscope skills were developed by their doing activities with the virtual microscopes and this contributed toward their understanding of the material.

Looking at slides was important, applicable for job later on, important to use microscope properly [VF157].

with the added annotation, it’s easier to understand the physiology with histology e.g. drawing in the kidney structures on the histology slide [OF222].

Table 6.32 Activity Theme 12 – Developing microscope skills (by group)

<table>
<thead>
<tr>
<th>Activity theme</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=146</td>
<td>n=123</td>
<td>n=269</td>
</tr>
<tr>
<td>Microscope skills</td>
<td>0.5</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Summary

Twelve activity themes were identified, with the top five being: (i) linked theory with practice, (ii) visualise, (iii) authentic, (iv) group discussion and (v) revision. Both groups had similar comments about four of these themes. The main difference was in the theme of group discussion where students found the optical microscopes more convenient to group work.
On the other hand, students using virtual microscopes commented on features such as engagement, convenience, time management, focus and skills. As virtual microscopes become more widely used, students will expect the flexibility and mobility that the virtual microscopes provide.

### 6.6.5 Resources

Reading beyond set texts often indicates a deep approach to learning (Biggs, 2003, p. 35), so students were asked (Table 6.33) to indicate:

*If you read more than the required text, please specify where you found most of your resources, e.g. web, library, lecturers, LMS supplementary materials, other people, or other.*

Table 6.33 Resources used

<table>
<thead>
<tr>
<th>Resource</th>
<th>Optical Group (%)</th>
<th>Virtual Group (%)</th>
<th>Total group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=146</td>
<td>n=123</td>
<td>n=269</td>
</tr>
<tr>
<td>Web</td>
<td>13</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>LMS material</td>
<td>16</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Lectures</td>
<td>9</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Library</td>
<td>11</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Other text books</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Other people</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: More than one type of resource may have been identified by the same respondent.

The results were similar across both groups, with minimal differences between the groups. Both used the web, LMS materials, lectures, library, other text books and other people as resources.

### 6.6.6 Attitudes to Optical and Virtual Microscopes

Students were asked to reflect on their learning experiences with microscopes and which microscope they used most during the semester. All the students had used optical microscopes in their previous years’ study. The reflections were prompted by four open-
ended questions relating to their likes and dislikes about virtual and optical microscopes (see Figure 3.4). Students’ responses were split into Optical and Virtual Groups and then classified into themes. Sometimes a response applied to more than one theme so some overlapping occurred. The results of the open-ended questions were thematically analysed in Excel™ to reveal common themes and the frequency of responses was calculated, as well as, the inter-rater reliability of the coding as described in Chapter 3 (see Sections 3.8.5 and 3.9.5).

The themes identified by both groups about microscopes are summarised in this section. Table 6.34 illustrates the positive and negative themes identified by the students of both optical microscopes and virtual microscopes, and the percentage of students identifying the theme in each group. One fifth of the students left these questions blank or answered that they did not use either the optical or virtual microscope during the semester and therefore felt unable to comment on that particular microscope.

Table 6.34 Attitude themes about microscopes

<table>
<thead>
<tr>
<th>Attitude themes</th>
<th>Optical Microscopes (%)</th>
<th>Virtual Microscopes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=146</td>
<td>n=123</td>
</tr>
<tr>
<td></td>
<td>OG</td>
<td>VG</td>
</tr>
<tr>
<td><strong>Use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Difficult</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enhanced</td>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>Diminished</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><strong>Group work</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilitates</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Hinders</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Less</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td><strong>Health</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improves</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Detracts</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td><strong>Time management</strong></td>
<td>Facilitates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hinders</td>
</tr>
<tr>
<td>7</td>
<td><strong>Experience</strong></td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Required</td>
</tr>
<tr>
<td>8</td>
<td><strong>Authenticity</strong></td>
<td>More</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Less</td>
</tr>
<tr>
<td>9</td>
<td><strong>Teacher engagement</strong></td>
<td>Encourages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discourages</td>
</tr>
<tr>
<td>10</td>
<td><strong>Comfort</strong></td>
<td>Familiarity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unfamiliarity</td>
</tr>
<tr>
<td>11</td>
<td><strong>Technology</strong></td>
<td>Reliable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unreliable</td>
</tr>
<tr>
<td>12</td>
<td><strong>Convenience</strong></td>
<td>More</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Less</td>
</tr>
<tr>
<td>13</td>
<td><strong>Access</strong></td>
<td>Easy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Difficult</td>
</tr>
<tr>
<td>14</td>
<td><strong>Learner engagement</strong></td>
<td>Encourages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discourages</td>
</tr>
<tr>
<td>15</td>
<td><strong>Developing Microscope skills</strong></td>
<td>Developed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Developed</td>
</tr>
</tbody>
</table>

In the following sections, attitudes towards each type of microscope are discussed and the thematic descriptors related to each theme are provided. Figures for each theme illustrate the students’ responses and groups for each type of microscope. As in the activity themes, where relevant, each attitude theme includes illustrative quotes that are coded (e.g. O=optical, V=virtual; M=male, F=female, Identity=1-269). All quotes are reproduced.
verbatim. Several of the attitude themes (group work, authenticity and microscope skills) overlap with the themes developed for the activity themes.

**Attitude Theme 1: Use**

About a quarter of the students found the optical microscopes difficult to set up, focus and drive, whereas a minority found them easy to use (Figure 6.20(a)). This result of optical microscopes being easier to use supports Heidger et al.’s (2002) research. However, unlike this study, the Heidger et al. had their students use both optical and virtual microscopes, rather than mainly one or the other throughout the teaching period.

Comments were made by students from both groups that showed the difficulty they encountered when using the optical microscopes:

- Sometimes difficult to use and set up [VM290].
- Difficult to drive [OF054].
- Sometimes it was hard to focus the microscope and sometimes it gave me a headache [OF015].

Almost half the total students found the virtual microscopes were easier to use than the optical microscopes (Figure 6.20(a)-(b)), although, when calculated by group, more students from the Virtual Group thought the virtual microscope was easier to use than the optical microscope. This is probably related to the virtual microscopes automatic focus of the slides, which meant that students did not need to make adjustments, unlike the multi-header optical microscopes, where each student had to individually adjust their eye pieces to be in focus. Again, this supports the results of earlier research that found virtual microscopes were easier to use (Heidger, et al., 2002) than optical microscopes.
Students from both groups commented about how easy the microscope was to use:

It was much easier to use and to navigate around [VF200].

easy to use and focus was always right [VF213].

It’s very easy to use and very clear to follow. The specimens are so easy to distinguish [OM098].

it was so easy to use and really good for revision at home [OF119].

Not all students in the Optical Group used the virtual microscopes and this could explain the difference in the frequency of comments between the groups. A small proportion of the students from both groups (3%) found the virtual microscope difficult to use, as shown in the comments provided:

it is a little hard to use. you need to have a medium level of understanding about computers to use it [OF090].

scrolling around was sometimes tricky with the laptops and occasionally you lost the thing you were looking at when you zoomed and then you had to find it again [OF015].

**Attitude Theme 2: Focus**

An important component of any microscope is its focus. Images need to be clear to allow practitioners to identify both normal and pathological features. Being able to focus on a slide is an important part of using a microscope. It takes practice to focus an optical microscope because focusing is a manual skill. Optical microscopes have a finer focus than virtual
microscopes because they have a z-plane which allows the brain to integrate the slide information in three dimensions (Nicholls, 2010). Virtual microscopes essentially focus themselves as the images have been scanned in focus. As students move from one part of a slide image to another, the image may blur (pixelation) then come into focus. This is a function of a slight delay as the computer processes the image.

Students commented on the ease or difficulty of focusing each type of microscope and about the clarity of slide images (Figure 6.21(a)-(b)). Typical comments about the focus of optical microscopes included:

- able to move around and focus on particular areas of interest [OF105].
- The most thing that i like about it is easy to find the depth of the tissue and organs very clearly [VF205].
- hard to see at times and focus [OF111].

Focusing the microscope was difficult at times and finding specific structures in the tissue slides was hard [OF120].

![Graph showing focus enhancement comparison between optical and virtual microscopes](image)

(a) Optical microscope  
(b) Virtual microscope

Figure 6.21 Focus by microscope and group

Almost the same number of students from both groups found the focus of the virtual microscope was enhanced in comparison to the optical microscopes. This is probably due to their not having to focus them. Slightly more students from both groups found that the focus was diminished for the virtual microscope. This was probably due to their not being able to adjust the focus as they could on the optical microscopes. Clearly, the groups were divided about the focus.
Attitude Theme 3: Group work

The benefits of group work are well known by educators (e.g. Biggs, 2003; Brown, et al., 1989). As mentioned previously, the physical structures of the optical microscope laboratories were set up in a way that encouraged group work. However, given that only one student can drive the optical microscope and the other nine in the group have to follow, there is the potential for some students to not participate equally. Some students, therefore, expressed their frustration with this aspect of group work. Figure 6.22 shows that more students thought that optical microscopes facilitated rather than hindered group work.

![Figure 6.22 Group work by microscope and group](image)

(a) Optical microscope  (b) Virtual microscope

Comments about optical microscopes facilitating group work included:

- the microscope was used in groups, therefore it easy to discuss the materials between groups members [OF058].
- its interactive so the whole group can decide on things on the slide [OM080].
- Efficiency, one slide to many students [VF192].
- the general set-up of the room is fantastic and being able to see exactly the same thing as someone else on a different microscope is fun [OF062].

Comments about the optical microscope hindering group work were mostly related to students who were not driving the microscope and indicated their frustration at not being able to be in control:
When the person sitting at the controlling microscope doesn't focus the image or use the microscope properly - this can be a little bit frustrating and very unhelpful [OF055].

having the multi-optical set up was beyond frustrating!! and i was reluctant to go to the labs (althoug i did), having to examine each tissue at the pace of the entire group didn't give me enough time to grasp the main aspects of a tissue, and in some cases gave me too much time. individual microscopes is the way to go! [OF104].

When i used them in VET108 in 2006 i found it hard to explain to the driver what you wanted them to look at and the bigger groups less productive [VF229].

Although a small group of students (Figure 6.22(b)) commented about the virtual microscope hindering group work, most of these comments were made by students in the optical laboratory group, who were probably using the virtual microscopes only for self-study. However, there was one comment from a student in the virtual laboratory group who said that the virtual microscope made it "Hard to discuss [work] with your other table group members [VM038]". This comment relates to the smaller group sizes in the virtual laboratory and was also mentioned by students in the optical laboratory.

Unless multiple people crowd around a single PC, it seems a bit isolating in that you're on your own. Also large file sizes are a bit of a pain, but I guess it comes with the territory" [OM043].

less of a group orientated activity [OM041].

Attitude Theme 4: Control

Figure 6.23(a) shows that just as many students felt they had more control over optical microscopes as students who felt they had less control. Some students commented that they were in control of what they saw, as they were able to change the microscope settings, including the focus. The following comments are representative of this:

Able to control what you see [OF054].

that you could zoom at your own will and focus on any part of the image, allowing you to see normal as well as abnormal [OM030].

The ability to adjust functions such as degree of focus and magnification exactly rather than at pre-determined levels. More importantly is the hands-on feeling of physically manipulating the microscope and eventual image of the histological section [VF232].
The 'reality' component - you can change microscope settings etc for your own view. You can see the slide with the naked eye, and the impression you can get is vastly different to the 2D computer screen [VF261].

With multiple users if the person driving the microscope has different vision to you, what is in focus for them is not in focus in you. You can sometimes get a bit sick from the scrolling [OF093].

Others commented on their frustration with the lack of control:

I could not really learn at my own pace because I have to keep up with the group. Also the adjusting and focusing of the microscope was a problem [OF071].

no control over where it's going most of the time [VF253].

![Control by microscope and group](image)

(a) Optical microscope  
(b) Virtual microscope

Figure 6.23 Control by microscope and group

Similarly, there were contradictory options about the amount of control over the virtual microscopes from both the Optical and Virtual Groups.

It gives you the freedom to use it when ever you want and see images again and again, so revision is easy. It also gives you the freedom to take as much time as you need without being rushed along. I loved having the program with me as it was easier for me to connect what I saw on screen to what is in my text book [OF069].

Not able to control what you see [OF054].

**Attitude Theme 5: Health**

A quarter of all students found that optical microscopes caused them to have headaches, eyestrain and nausea (Figure 6.24(a)), while a small proportion found the virtual microscopes improved their health in that these health issues were reduced (Figure 6.24(b)).
These findings also support other studies that found health issues in users of optical microscopes (Golding, 2006; Kofler, et al., 2002; Thompson, et al., 2003).

![Graphs showing health by microscope and group](image)

(a) Optical microscope  
(b) Virtual microscope

Figure 6.24 Health by microscope and group

Students made many comments about the negative impact of optical microscopes on their health, particularly in relation to headaches, eye strain and nausea:

- I can't look through it for very long as I get headaches [OF311].
- It gave me a headache and I had trouble focusing it [OF088].
- Time consuming and straining on the eyes [VM296].
- Felt sea sick when using [VF207].
- I get travel sickness from the optical microscope [OF089].
- I became sick whenever I used optical microscope [VF312].

Generally, students were positive about virtual microscopes in relation to their health.

- doesn't strain eyes, no bending over, easily seen [VM308].
- No more headaches and can work with stuff at home on the software provided [VF013].
- It did not hurt my eyes, it was fun to use, you could take pictures, make notes save stuff it was much better [VF250].

However, there were a small number of students who mentioned health issues, including travel sickness (nausea) and eye strain with virtual microscopes.

- Not compatible with Macintosh and still gave me travel sickness [OF089].
It is dependent on the pixels of the computer. Which causes the images to be slightly hazy, making it difficult for me to use, without getting eye strain [OM025].

**Attitude Theme 6: Time management**

A few students thought that the optical microscopes hindered their time management (Figure 6.25(a)), as the microscopes were time consuming to set up, find slides and focus. On the other hand, students in the Virtual Group thought that the virtual microscopes facilitated their time management (Figure 6.25(b)) as they did not need to have the time consuming preparation needed for the optical microscopes. This supports similar findings about veterinary students’ time management improving with the use of virtual microscopes as opposed to time management and their using optical microscopes (Mills, et al., 2007).

![Time management by microscope and group](image)

(a) Optical microscope  
(b) Virtual microscope

**Figure 6.25 Time management by microscope and group**

Students from both groups commented about the time consuming nature of using optical microscopes:

- The time it takes to set up and search around before you can see anything interesting [VM295].
- It took a long time to find certain structures when studying for a test [VM276].
- Obtaining the slides I wanted was annoying [OM028].

Some students, mostly from the Virtual Group commented on the time saving nature of the virtual microscopes.
Much faster to move in, out, around, can save files with info from slides which has great potential, I feel it is a sufficient and relatively convenient format for my education as a chiropractor [VM274].

It saves some time (don't need to manually look for the slide you want). Also can do it at home [OF001].

**Attitude Theme 7: Experience**

A few students (2%) said that they needed to gain experience using the optical microscopes in order to develop the skills that they required to use them properly. The difficulty in students becoming skilled in using optical microscopes is well known. Kumar et al., (2004) state that medical students’ dislike for optical microscopy and glass slides in histology was evident in their research and that they hoped the introduction of virtual microscopes would improve this. In this study students’ comments indicated that they felt they needed to develop more skills to be able to use the optical microscopes properly:

need more skill sto use [VM317].

That I had not the skills adequte to obtain images of quality that I desired. Also the movement of the microscope across the slide when scanning did have an minor affect on my eyes [OF116].

Only one student from the Virtual Group made a comment suggesting that previous experience was not required to use the virtual microscope: “Its easy to learn how to use and its more practical in the sense that I can use it to study with at home and/or anywhere where there is a computer accessible [VF234]”.

**Attitude Theme 8: Authenticity**

Authentic activities have real world relevance and are the ordinary practices of a domain’s culture (Brown, et al., 1989). Almost a quarter of the students felt that the optical microscope (Figure 6.26(a)) provided a more authentic experience of using a microscope than the virtual microscope did (Figure 6.26(b)). In their comments about the optical microscopes, students
used the word “authentic”, to mean real or the experience of a tactile/visual sensation, which are some aspects of authenticity:

more authentic [OM099].

could see the specimin with our own eyes rather than just a virtual impression [VF281].

It was real and in front of you [OM129].

Be able to actually handle the microscope and slides. Physically seeing with my own eyes the slides [OM086].

It feels more real compared to using the program [OM081].

That we were actually viewing real material [OM035].

Both groups felt that the virtual microscope was less authentic than the optical microscope.

Not real [OM051].

It didn't feel the same as the optical microscope [OF093].

Not real enough, as we won't use computer to do microscope things after we grad [VM317].

you cant see everything, its not as good as the real thing [OF068].

The slide wasn't physically in front of you so it didn't feel real. You couldn't touch it and physically handle it [0F015].

This is an interesting perception, given that virtual microscopes are used in the ‘real’ world by pathologists. For example, in Italy, a virtual pathology institution (made up of a consortium of seven Cancer Institutes) provides second opinions in the diagnosis of cancer from around Europe (Isabelle, Teodorovic, Oosterhuis, Riegman, & The TuBaFrost Consortium, 2006). However, students may not be aware of this recent development.
(a) Optical microscope  (b) Virtual microscope

Figure 6.26 Authenticity by microscope and group

Attitude Theme 9: Teacher engagement

A small number of students from both groups thought that the optical microscope laboratories were interesting because of the teacher and that this encouraged teacher engagement (Figure 6.27(a)). Teacher engagement was also identified by both groups in the virtual laboratory; however, there were also several students who thought that the virtual microscopes discouraged teacher engagement (Figure 6.27(b)).

(a) Optical microscope  (b) Virtual microscope

Figure 6.27 Teacher engagement by microscope and group

Comments from students indicated that they engaged with the teacher when using the optical microscopes:
Preferred the virtual microscope. Best thing about the optical microscope was doing the lab because they were taken by [the teacher]. He was informative and made histology interesting [OF088].

The lecturer will be teaching and explaining some of the features of the cells to us while looking at it [OF092].

Students’ comments about virtual microscopes indicated that they found their laboratory teacher actively encouraged engagement: “Having the instructions to follow from the books and the instructor to ask questions [OF124]”. However, some Optical Group students said virtual microscopes discouraged engagement.

Hard to use without [the teacher] around as a guide [OM125].

the least that i didn't like was the fact of not receiving one on one comments from [the teacher] as in the optical classes [OM098].

This could be due to their using the virtual microscopes for self-study purposes rather than in the laboratory setting where teachers are present. It is interesting to note that, using the optical microscopes for self-study would also not normally include a teacher being present.

**Attitude Theme 10: Comfort**

A few students in the Optical Group (2%) said they were comfortable using the optical microscopes because they were already familiar with them.

Closely resembles microscope I use at home [OF096].

I liked most about it, is the fact that I can use one and find structures in specimens [OM098].

On the other hand, students’ comments about the virtual microscopes indicated they were more comfortable viewing slides on a computer screen instead of looking down a microscope.

having the image on the computer screen- not having to look down a microscope [VF301].

Open screen, can view slide from a distance, not looking down microscope [VF211].
Attitude Theme 11: Technology

There were no comments relating to technology and optical microscopes. However 3% of students from both the Virtual Group and 6% from the Optical Group identified the virtual microscope technology as sometimes unreliable. The technology issues identified included computer capacity, large image files and software incompatibility with Macintosh computers. However, with the introduction of any new technology, technical issues are experienced and resolved over time.

Some of the pic files didn't work for me but i think that was a problem with my computer [OF128].

sometimes the computer stalls.and where that happens the picture is pixelated [VF198].

Program gets stuck sometimes on my computer [OF127].

The loading time for images (slow) [OF183].

Attitude Theme 12: Convenience

About one in ten of all students found the virtual microscopes to be more convenient than the optical microscopes. This could be an issue of access, as use of the optical microscopes was restricted due to heavy use for teaching, and there was limited after hours access to the laboratory. Virtual microscopes could be used at home, or at university, or whenever students wanted to use them. Previous research has also reported access and convenience as one of the advantages of virtual microscopes (Becker, 2006; Dee, 2009).

Optical Group students identified virtual microscopes as being more convenient than optical microscopes:

Slides can be viewed at my own convenience [OM081].

The convenience of it. I was able to view histology slides at any time of the day when I was at home or at uni and clarify something or learn something without the need to travel down to the microscope lab. This was also useful for revision before tests [OF116].
very convenient - use it anywhere, anytime. easy to capture images to send via email. can add annotations to mark items of interest. can use the ruler to measure dimensions. all the slides are within reach [OM167].

Virtual microscope is presented on CD-ROM, more convenient [VF208].

**Attitude Theme 13: Access**

Related to the theme of convenience is access. Almost a third of the students found that it was easier to access the virtual microscopes than the optical microscopes (Figure 6.28(a)-(b)). Again this may relate to the restricted availability of the optical microscopes in the laboratory.

- easy to take home and sue in our own time [VF281].
- easy to access anywhere whether at library or at home [OF058].
- Easy access (any time, any place), no fiddling with microscope set-up prior to histology session and easy to navigate around the slide [VF287].
- It gave the option of looking at the slides at home. you did not need to go into the microscope room and ask for time with the microscopes. you could load the virtual ones on any computer [OF090].
- The convenience of it. I was able to view histology slides at any time of the day when I was at home or at uni and clarify something or learn something without the need to travel down to the microscope lab. This was also useful for revision before tests [OF116].

Students’ comments confirm that the difficulty in accessing optical microscopes was due to the room being unavailable at a time when students wanted to use it, and that they could not access them from home but had to go to university to use them.

- Having to go to uni to use it, and find a time when there wasn’t a class in there [VF251].
- Perhaps a moot point, but I wish I could use it longer after hours… ie: They kick you out too early! [OM043].
- It was very hard to find one that was available to use [OM087].
- that it could only be accessed at the university [OM126].
Attitude Theme 14: Learner engagement

Farah and Maybury (2009) believe that their study showed that student engagement was encouraged by the use of virtual microscopes, with over half the class of medical students saying that learning with the virtual microscopes was “fun”. They did not, however, compare the students’ experiences with optical (light) microscopes but did say that students found them difficult to use and that this was one of the factors that led them to trial the virtual microscopes.

In this study students’ comments indicate that both the optical and the virtual microscopes encouraged their engagement with the course (Figure 6.29). Typical comments about the virtual microscopes support Farah and Maybury’s (2009) previous findings but they also show why some students found the optical microscopes to be engaging.

- the microscope was used in groups, therefore it easy to discuss the materials between groups members [OF058].
- that you could use it while working with other people at the same time, to collaborate your understanding/information [OF119].
- it is fun playing around with the various magnification [VF198].
- Its more practical because you will use it in the field rather than virtual microscope. I think it also makes you orientate yourself more with the specimen [VF234].
Students pointed out that the virtual microscopes were helpful when studying or revising, which highlights their motivation and engagement:

It is very helpful when studying for the tests [OF112].

Ability to check own answers if need be (to be sure that I understood slide) [OF136].

**Attitude Theme 15: Developing microscope skills**

Figure 6.30(a) shows that 19% of students commented on the skills they were developing by practising with the optical microscopes. The comments included:

They are just better because we can practise on them [VM199].

The chance to practice my microscope driving "skills" [VF287].

It gave the chance to learn how to use the microscope and it had an arrow to point at the features of interest [OF090].

You got hands on practical experience with the microscopes that you would be using in the workplace. I like the feel of working with the actual microscope, adjusting the focus and the lighting and scrolling with the stage [OF093].

Students using the virtual microscope generally felt that their microscope skills were not being developed, with only one student identifying the development of their microscope skills by using the virtual microscope: “Clear Images, able to highlight and circle object and go back to them later on [VF206]".
not using a microscope and developing techniques [VF206].

Didn't develop actual microscope skills [VM219].

when at home can't ask questions etc. also don't learn any focusing skills [OF107].

does not give you practical skills of using a microscope [OF143].

I didn't further develop my microscopic technique because it was fun to use the virtual microscope [VF246].

While it is true that the Virtual Group were not developing skills with using the optical microscope while they were in their laboratory, they were developing other skills with using virtual microscopes, such as histology and pathology specimen recognition. It appears that the practical microscope skills developed when using virtual microscopes are less valued by the students. Veterinary science students need to use optical microscopes in their careers and some of them might have preferred to build their optical microscope skills than use the virtual microscopes. This viewpoint has also been reported in recent research (Sims, et al., 2007).

![Graph](image)

(a) Optical microscope  (b) Virtual microscope

Figure 6.30 Microscope skills by microscope and group

Summary

Analysis of the students' reflective comments in the main study allowed the same 15 themes to emerge as in the exploratory study. The main issues found were:

- Virtual microscopes were easier to use than optical microscopes and the focus of the optical microscopes were superior to the virtual microscopes.
The responses about group work were mixed. While there were positive comments about both types of microscopes enhancing group work, some thought the virtual microscopes diminished the opportunities for group work.

Students experienced health issues such as headaches, eye strain and sickness (nausea) when using optical microscopes, which were improved with using the virtual microscopes.

Students also felt that their time management was improved by using the virtual microscopes as they did not need to waste time setting up or looking for slides.

There was a perception that the optical microscopes were more authentic than the virtual microscopes.

Students felt that when they were using the optical microscopes they were building their microscope skills; conversely, they did not feel they were developing their microscope skills when using the virtual microscopes. This result was surprising given that students were actually extending their skills by learning how to use virtual microscopes in addition to optical microscope skills.

**General Comments**

The students suggested two areas in which the histology and pathology units could be improved: slides and laboratory activities.

One suggestion was that students should be provided with more examples for each type of tissue in the virtual slides to show variety and annotate slides with labels showing main features and have them toggle on and off.

more variation in the stains and numbers and variation of slides so we can look for different things in the same specimens! [VF281].

i think annotations for each of the slides would have been really beneficial … more examples of histological slides with annotations for revisions [OF119].

overall the experience was positive, however sometimes it was difficult to decide on what was what: having labelled images to us would be very helpful and having more images to compare would be beneficial too [OF62].
the unit was very good, but perhaps maybe some more annotated file for the virtual microscope would be good. so you could try to find the point of interest your self and then turn on the annotations, in kind of a self test situation [OF90].

The other suggestion was that students should be provided with more laboratory activities, such as pre-laboratory questions, to orient them to the topic. They also suggested that they have shorter and more frequent laboratories and be provided with both types of microscopes and more demonstrators in the laboratories.

perhaps for each histology lab, there is a series of questions required to be answered (mandatory) before lab begins. They could be designed to have the students research or label a particular slide or draw their own interpretation of a given topic. This is because sometimes I do feel that histology is least important and always last on my priority list to study for, despite knowing that it will be assessed in this unit and possibly very important for future studies [OF56].

I think the histology aspect of the unit is very good already … each lab covered quiet a large amount of material over a long period of time (4 hours). I feel that I could have gained more from the labs if they covered less material and were not so long (eg maybe 2 hours) but were maybe more frequent (eg maybe twice a week) [OF57].

Labs which involved both types of microscopes [VM37].

More staff during lab classes to help identify details better [VM310].

6.7 Focus Groups

The focus group methodology and process has been described in detail in Chapter 3. For Focus Group 1, four students attended. For Focus Group 2, six students attended (Table 6.35).
The first question was not discussed as it involved the students’ own learning approaches. This first question asked students to record, on the question sheet, their perception of what their learning approach would be, based on the first ASSIST survey. Once they had responded to this question, the researcher then informed the students individually of their calculated learning approach. Four of the 10 students correctly identified their learning approach, while 6 did not.

The questions were categorised into the main topics of preferred microscope; laboratory work; and group work. Finally, the response to the questions about what students liked most and least are discussed.

The question sheets were collected by the researcher at the end of the session and transcribed onto a single Excel™ spreadsheet and content analysed. The comments quoted in this section are identified by pseudonym, learning approach and group, “Ross, surface, V”.

Table 6.35 Focus group participants

<table>
<thead>
<tr>
<th>Participants*</th>
<th>Code</th>
<th>Course</th>
<th>Course Level</th>
<th>Focus Group</th>
<th>Learning Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janet</td>
<td>VF224</td>
<td>Veterinary Science</td>
<td>2</td>
<td>1</td>
<td>Surface</td>
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<tr>
<td>Sue</td>
<td>OF150</td>
<td>Veterinary Science</td>
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<td>1</td>
<td>Strategic</td>
</tr>
<tr>
<td>Rose</td>
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<td>2</td>
<td>1</td>
<td>Strategic</td>
</tr>
<tr>
<td>Claire</td>
<td>VF253</td>
<td>Veterinary Science</td>
<td>2</td>
<td>1</td>
<td>Strategic</td>
</tr>
<tr>
<td>Jean</td>
<td>VF007</td>
<td>Chiropractic</td>
<td>3</td>
<td>2</td>
<td>Deep</td>
</tr>
<tr>
<td>Dianne</td>
<td>OF006</td>
<td>Chiropractic</td>
<td>3</td>
<td>2</td>
<td>Deep</td>
</tr>
<tr>
<td>Sandra</td>
<td>OF004</td>
<td>Chiropractic</td>
<td>3</td>
<td>2</td>
<td>Deep</td>
</tr>
<tr>
<td>John</td>
<td>VM037</td>
<td>Chiropractic</td>
<td>3</td>
<td>2</td>
<td>Deep</td>
</tr>
<tr>
<td>Bob</td>
<td>VM034</td>
<td>Chiropractic</td>
<td>3</td>
<td>2</td>
<td>Surface</td>
</tr>
<tr>
<td>Mary</td>
<td>OF001</td>
<td>Chiropractic</td>
<td>3</td>
<td>2</td>
<td>Strategic</td>
</tr>
</tbody>
</table>

* All participants’ names are pseudonyms
6.7.1 Preferred Microscope

Of the 10 students, four used the optical microscopes and six used the virtual microscopes for their laboratories. Students were asked whether they preferred to use optical or virtual microscopes in the future. Six of ten preferred optical, two preferred virtual and two preferred both. Students who preferred the optical microscopes did so for several reasons: they felt they had greater control; they encouraged collaboration; they were more authentic; or they assisted them with building their microscope skills.

I like the fine control of light focus of the optical [Janet, surface, V].

… and the multi-headed scopes are useful for collaborative study [Janet, surface, V].

More real when the slide is a physical thing, you can picture more easily where the tissue comes from [Sue, strategic, O].

I would like to have the skills to use the optical microscopes so that I can use them in my future career, if need be [Rose, strategic, V].

Each of the quotes supports one of the attitude themes (focus, group work, control, authenticity and microscope skills) previously identified in the students’ reflections (Table 6.34). As discussed in Section 6.6.6, these themes were also highlighted by students in their responses to questions about their attitudes to virtual and optical microscopes in the reflection form.

Students who preferred the virtual microscopes identified health improvements as the main reason, as well as ease of use and control. Again, these themes align with those identified in Section 6.6.6.

Remove the nausea associated with extended periods of looking down the microscope while the image moves/changes [Sandra, deep, O].

Virtual is much easier, you don’t have to deal with analogic machines (e.g. focusing, lighting, etc) and there is more control and no eye strain [Bob, surface, V].

The students preferring both types of microscopes said that each microscope contributed differently to their educational experience in that optical microscopes were authentic and had better focus while the virtual microscopes were convenient.
The act of looking through a [optical] microscope adds to the educational experience. I like the convenience of the virtual microscopes [Claire, strategic, V].

Both, virtual is good for initial conceptualization. Optical is good for higher resolution and identifying fine details of processes [John, deep, V].

These comments also support three of the attitude themes (authenticity, convenience and focus) previously identified in Section 6.6.6. In the discussions with the focus groups, the students came to the general consensus that the optical microscopes provided greater control over light and focus but that the virtual microscopes provided more freedom and accessibility. In the discussions, the students who were studying Veterinary Science strongly stated their need to develop optical microscope skills for use in their future careers.

6.7.2 Group work in laboratories

All ten students said that they thought that the guidelines for the laboratory activities were clear. Nine felt that their role in the laboratory group activities was clear (e.g. “good background theory, notes and directions” [Sue, strategic, O] while one did not, “Everyone was autonomous. No fixed roles” [Dianne, deep, O]).

Students were also asked whether they had sufficient opportunity to contribute in their laboratory groups. In the virtual laboratory, most students said that they asked questions and that everyone provided their input, which indicates that they were actively engaged in their groups:

I asked questions and participated in constructive discussion about various structures. I did a lot of pre-study, so I was able to help discern structures [Janet, surface, V].

Everyone gave input as encouragement lead to words, thinking out loud, no right or wrong, then compile [Jean, strategic, V].

This supports the earlier responses made by students in their reflections (see Figure 6.13 and Figure 6.14).
The students in the optical laboratory also commented that they were actively engaged in their laboratory group work; however, one student did not agree. The students elaborated further, stating it really depended on the group they were in and if they felt comfortable.

Suggestions were always informed, input was encouraged and some participants felt comfortable airing any ideas [Sandra, deep, O].

... Though quieter people were not encouraged to speak [Dianne, deep, O].

The above comments support the earlier responses made by students (see Figure 6.13 and Figure 6.14). In their reflective comments, a few students also mentioned sometimes losing interest when they were not driving the optical microscope and feeling passive in the group.

When discussing the group work in the virtual laboratory, Bob said the “Group was mature – very cooperative between participants” [Bob, surface, V]. Note that in Figure 6.15, a difference is illustrated between the students working in the optical and virtual laboratories. More students in the virtual laboratories thought it was easier to come to a consensus than in the optical laboratories. Therefore, Bob’s comment supports the earlier findings.

On the other hand, Claire and John claimed that participation was not always equal in their laboratories, and in some instances, the more confident students dominated:

During the groupwork, but when lab leader took over, I felt like this diminished. Frustrating, only having one leader – having another student there helped slightly [Claire, strategic, V].

All contributed in same groups. Larger group discussions were more dominated by those more confident [John, deep, V].

When asked to describe how they influenced their group’s thinking during laboratory activities, students in the optical laboratory said they referred to evidence, reasoned with the group or asked questions:

Logical discussion, backed up with notes [Mary, strategic, O].

Good reasoning used. Having reference material available. Although I was not necessarily out to influence but more to find the best answer [Dianne, deep, O].
questions – e.g. what do you think that funny are there is? Could it be ‘XYZ’? What do you think? Any more ideas on that? [Sandra, deep, O].

Students in the virtual laboratory said they influenced their groups by making suggestions, using textbooks, providing examples or asking their teachers questions:

Back it up with text book examples, or illustrate counter examples, or get back-up from demonstrators [Janet, surface, V].

By giving suggestions as to what I thought was occurring in the slides – even if they were wrong [Claire, strategic, V].

When asked to identify the most and least useful things about group work during their laboratory sessions different aspects were discussed. The things that students liked are discussed first, followed by the things they disliked about their group work.

Sue, who was using the optical microscopes, found the group discussion the most useful. Other students using the virtual microscopes found the group discussions, teaching, small group sizes and ratio of computers to students the most helpful.

Being able to work through things together, if I didn’t know what something was, changes are someone else would. Made me think about it more, rather than just being told by tutor [Sue, strategic, O].

Different people with different ideas conversing on the correct interpretation [Janet, surface, V].

Enthusiasm of teaching staff and genuine interest of other students. No one person is all knowing, group work helps all [Jean, strategic, V].

Group discussions and lecturer instructions. 2:1 people per computer good [John, deep, V].

Small group size, working with friends [Rose, strategic, V].

The lecturer and lab staff. Lots of computers – ratio of computer to students [Bob, surface, V].

Dianne, who was using the optical microscope, found the least useful aspect was that there were not enough gross images. Students using the virtual microscope mentioned unengaged students, waiting for staff and only having one computer screen between three:
Gross pictures need more copies of them – we only had 1 between 7 people [Dianne, deep, O].

People who weren’t interested in participating or were carrying on unrelated conversations [Janet, surface, V].

Waiting for staff to help out [Claire, strategic, V].

One computer screen between three [Rose, strategic, V].

When asked what they would like to do more of in their laboratories, the students who used the optical microscopes said they would like more individual work as practice for the exam, to practice at a pace required for the exam, and to use both optical and virtual microscopes.

Introduce a bit of individual work as preparation for exam [Dianne, deep, O].

Use of both optical and virtual as opposed to one or the other. Activity similar to exam (more individual work) [Mary, strategic, O].

Students who used the virtual microscopes made similar comments in that they would like more individual work, more access to demonstrators and more exam practice.

Driving, more access to demonstrators. Discussion with someone who knows what we are looking at, rather than 10 people guessing [Janet, surface, V].

Individual interpretation [Claire, strategic, V].

Activities matching exam – somehow prepare us for the rapid pace of prac-exam – or slow down prac exam [Bob, surface, V].

The students discussed different aspects about using microscopes that they disliked. The things students said they found least useful for the optical microscopes were the length of sessions and group work.

Got bored after a while – maybe two shorter sessions [Sue, strategic, O].

Less group, more individual [Dianne, deep, O].

One comment from Bob related to the ergonomic aspect of working in the virtual laboratory: “The stools are bad for your back” [Bob, surface, V].
Summary

The focus groups did not reveal anything new; however, it did allow for some of the themes to be explored in more detail and confirmed. Students' suggestions for improving the learning experience were similar to the suggestions made in the reflections, with one exception. In the reflections about learning, the students suggested that the virtual microscope slides be annotated to assist them with learning at home. This issue was not discussed in the focus groups as this study did not concentrate on the microscopes as self-directed tools. This issue was passed to the lecturer concerned and was not identified as a separate theme.

6.8 Interviews

Four students were interviewed as summarised in Table 6.36. The results are categorised and presented in four sections: learning approach, learning strategies, workload and likes and dislikes.

Table 6.36 Interview participants

<table>
<thead>
<tr>
<th>Participant*</th>
<th>Code</th>
<th>Course</th>
<th>Level</th>
<th>ASSIST1</th>
<th>ASSIST2</th>
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<tbody>
<tr>
<td>Sarah</td>
<td>OF166</td>
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<td>2</td>
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<tr>
<td>Tina</td>
<td>VF232</td>
<td>Veterinary Science</td>
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<td>Strategic</td>
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<tr>
<td>John</td>
<td>VM037</td>
<td>Chiropractic</td>
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</tr>
<tr>
<td>Brenda</td>
<td>OF173</td>
<td>Veterinary Science</td>
<td>2</td>
<td>Surface</td>
<td>Surface</td>
</tr>
</tbody>
</table>

* All participants' names are pseudonyms

6.8.1 Learning Approach

The interviewees represented all three learning approaches. It was interesting to note that Sarah, John and Brenda correctly identified their learning approach as measured by ASSIST1 at the beginning of the teaching period and their comments aligned with their
individual learning approaches. For example, Sarah focused on her overachieving personality, which is representative of a strategic approach where the most efficient means for attaining the best results is taken. John highlighted the fact that he focused on understanding the concepts, which is representative of a deep approach. Brenda focused on the readings and her lecture notes, which may be representative of a surface approach.

I am an overachiever, who likes to get good grades. A good mark means that I understand the material (Sarah – strategic approach, O).

I like earning to learn to understand concepts and skills and linking knowledge and rationalising basic concepts (John – deep approach, V).

I would also look at what the lecturer said in the class and combined with readings (Brenda – surface approach, O).

Tina identified her learning approach as being strategic but the results of the ASSIST1 showed a deep approach. However, by the end of the teaching period, ASSIST2 showed she had shifted to a strategic approach and her comments about how she determined what was important to learn appear to support the strategic approach, rather than deep.

I go to lectures closer to assessments to determine what’s important. The subject is time consuming, memory is an issue, for understanding you need to understand the principles rather than learning (Tina – strategic approach, V).

When asked whether they thought their approaches had changed during the teaching period, Sarah, Tina and John thought that it had, while Brenda didn’t really answer the question. The results of the ASSISTs, however, show that only Tina had actually changed her approach.

6.8.2 Learning Strategies

The students used several learning strategies to learn about histology and pathology, e.g. activating prior knowledge, using textbooks, CDs, and histology PowerPoint resources provided by the lecturer. Both Sarah and Tina used textbooks and, in line with their strategic approach, used the CDs at the end of the semester closer to the assessments. John
mentioned using all the resources available, as well as working with other people and verbalising. This is also a major feature in the social construction of knowledge as outlined in social constructivist learning theory and an indicator of a deep approach. Brenda talked about using the CDs, readings and self-study.

previous learning (108) so nothing was foreign. I used the text books a lot, I didn’t use the CDs (virtual slides) until the end of semester… the lecturer’s histology PowerPoint (Sarah – strategic approach, O).

The two CDs were really useful, with textbooks at hand to visualise…used the virtual microscopes (Tina – strategic approach, V).

Notes and labs. Working with another person, verbalise study partner. WebCT was good for PPTs of practical stuff. DVDs alone at home. (John – deep approach, V).

Mostly for histology CDs useful to look at and in class, combine readings. Take CDs and the tutorials online and use to study with them. (Brenda – surface approach, O).

When students were in their laboratory groups doing activities with microscopes they sometimes identified something on a slide that they did not expect to see. The strategies they employed to solve the problem included consulting a textbook, asking a teacher, referring to lecture notes, and/or asking other students for assistance. All four students interviewed said they talked to other students in their group, or asked the teachers for assistance. However, Brenda, who took a surface approach to her learning, said that she would take their word, which is indicative of a surface approach.

Used a textbook or in the group ask the demonstrators who may have to move on. More demonstrations and answer questions (Sarah – strategic approach, O).

Usually share screen – talk to person next to me. Use the features or ask for help from demonstrator (Tina – strategic approach, V).

In lab ask someone else, use the atlas – textbook, or if the lecturer was around ask (John – deep approach, V).

If someone in the group noticed it and talked about it. Ask the lecturer…the group was at the same table…usually someone had seen it before and I would take their word for it (Brenda – surface approach, O).
6.8.3 Workload

Three of the students’ comments suggest that they perceived the workload in the course as high with some units’ outcomes being unclear, and units being described as stressful and time consuming. Sarah thought that both histology and anatomy were stressful, while Tina thought that histology was manageable but anatomy took up a lot of her time. Both these students took a strategic approach to their learning. On the other hand, John who took a deep approach to his learning, thought the workload was manageable while Brenda’s comments supported a surface approach to her learning by saying that she reviewed labs the night before.

I was never caught up with everything. Histology was really stressful, only one lab every other week and a lot to do – looked at histology slides. It needs it’s own class. If you went to the labs you could do fine. Fair way to grade you, in the final you got it. .. Anatomy stressful and time consuming. Not clear you have got to teach yourself. Biochemistry - second half difficult, histology took a back seat. Quizzes and tests were all in one week (Sarah – strategic approach, O).

Histology manageable. The other units impacted on it... Anatomy took up all my time 70% of the final grade Low on the list was histology as there was not enough time to do it. I didn’t have to identify histological features. Timing of assessments they were a lot of work. Continuous assessments are good but timing is an issue. Physiology – oral presentation final week. Components are fair. (Tina – strategic approach, V).

Reasonable. I made a concentrated effort to discuss pathology on a regular basis to keep in mind assessment – easier not with other exams have to be passed or failed… Pathology unit very polished … a lot of work is done. Makes it easier to study. The other units don’t have that. No, assessments were well spaced out and weightings spread out too. Was a reasonable amount of time. (John – deep approach, V).

Connected to physiology - a lot of information… Anatomy took the most time. If I didn't have 3 core units I would have done more. It was study 3 hours in the lab and review the night before.(Brenda –surface approach, O).

6.8.4 Likes and Dislikes

Sarah liked several things about the unit which included the CDs, web resources, the virtual microscopes and the lecturer making it fun, while Brenda liked the virtual microscopes for studying. Sarah disliked it when a few people dominated in her laboratory group and she found the physical structure of the laboratories cramped. Even though Brenda said she felt
sick when using the optical microscope, she thought it was important to develop her microscope skills as she would need them in the future when she became a veterinary practitioner.

Disks were a great idea and the web resources. The lecturer makes it fun and will always apply it to help you to make the connection. I appreciate the microscope... I took snapshots and took it to the lecturer and asked him if it was what I thought... Group contribution – a few people dominated, other people would help teach you things. Too cramped, tables where you can’t put books down (Sarah – strategic approach, O).

Virtual idea is really good as a backup and study material but its important to be able to use the optical microscopes as a vet. It was difficult for people who didn’t have a background with it. One person drives is find and you can discuss that really easier. Everyone needs to know how to work it. You have to use it yourself. Communication is key and a key factor in how you are willing to learn. Microscopy if someone else is driving I feel sick, and I need to build skills using it. (Brenda – surface approach V).

Sarah suggested that the unit could be improved by introducing a session to demonstrate how to use the virtual microscopes at the beginning of each teaching period.

Summary

The interviews provided in-depth information about students’ experiences with microscopes but did not reveal any new themes. One issue that could have been explored more in other parts of the study that of workload, both in the units themselves and in the course as a whole did emerge.

6.9 Conclusion

This chapter presented the results of the main case study, which included a summary of the participants in each data component of the study, a description of the materials used (ASSIST, reflections form, log book, focus group and interviews), demographics (age, gender, students self-rating of their ICT skills, previous educational qualifications and potential microscope use) and the results of the ASSIST where a trend for both the Optical and Virtual Groups was found with some students changing their conception of learning from reproducing information (surface) toward supported understanding (deep). In both groups
there were changes in students’ learning approaches but they were not statistically significant. As students learning approaches are not fixed but change in relation to the learning context, the changes could be explained by students focusing on study for their final exams towards the end of the semester. A weak negative relationship between the reported total time spent studying and students’ final grade in the unit was found, with less time spent study being associated with higher grades. Students’ reflections about their learning with optical and/or virtual microscopes revealed fifteen attitude themes. The focus groups and student interviews supported many of the attitude themes thereby triangulating the data. The interviews provided more in-depth information about several students’ learning with microscopes and highlighted an area that could be explored further in future studies, e.g. workload.

In the next chapter (Chapter 7), the study as whole is discussed in depth and conclusions are provided.
CHAPTER 7

DISCUSSION AND CONCLUSIONS

7.1 Introduction

This study explored the impact on students’ learning resulting from the introduction of virtual microscopes in histology and pathology laboratories. In particular, the study evaluated if this new technology would influence students to take a deep approach to their learning.

These issues were examined through an exploratory study and a main study. The exploratory study comprised of a group of third year chiropractic students. The analysis of the exploratory study showed that the instruments and methods used were sound and, apart from minor amendments, were subsequently used for the main study.

The main study, an embedded case study, was conducted with students from three different units: year 2 veterinary and chiropractic students; year 2 biomedical students; and year 3 chiropractic students. Students were randomly assigned into two groups: Optical and Virtual Groups. Students worked in collaborative groups of varying sizes while doing activities with microscopes. A summary of the participants in the study and their demographics (age, gender, students self-rating of their ICT skills, previous educational qualifications and potential microscope use) was provided.

The ASSIST survey developed by Tait, Entwistle and McCune (1998), which identifies students' conceptions of learning, learning approaches and preferences for different types of course and teaching, was administered twice to students: once at the beginning of the teaching period and again at the end of the teaching period. The results of the three sections of the ASSIST were reported for both the Optical and the Virtual Groups. The ASSISTs could only provide a snapshot of students’ approaches at two points in time.
and provided scores only for their approaches; they did not provide insight into students’ thoughts about using microscopes for learning. These were obtained through reflective comments, focus groups and interviews, thereby filling in this gap.

The survey included questions about the students’ attitudes towards microscopes and learning. The students’ reflective comments from the Attitude Survey were content analysed, revealing fifteen attitude themes. The last section of the survey relating to students’ laboratory activities included interaction, reaching consensus in a group and their learning experiences. The students’ comments on these activities were content analysed separately, revealing twelve activity themes, eight of which were the same as the attitude themes.

Students also kept a log of their time spent studying, including whether they studied at home, at university or at friends’ homes. The time spent studying and the final grades for both the Optical and Virtual Groups were statistically compared to determine whether there were any significant differences between the groups. Statistical analyses were also conducted to determine whether there were any significant differences between the three learning approaches and the time spent studying.

Two focus groups were held and many of the students’ comments provided support for the attitude themes previously identified. Interviews were conducted with four students whose comments and learning strategies aligned with their individual learning approaches.

The next section in this chapter discusses the research questions and the results of the main study. In Section 7.3 the limitations of the study are presented, while in Section 7.4 modifications to the units as a result of the findings in this research are described. In Section 7.5, recommendations for future implementations of virtual microscopes are provided and Section 7.6 suggested some future research directions.
7.2 Research Questions

The overarching question that guided the research was:

How does the introduction of virtual microscopes into histology and pathology laboratory classes affect students’ learning approaches and learning?

This question was addressed through five sub-questions.

1. What factors influence students’ learning with virtual microscopes?

2. Do students’ learning approaches change with the introduction of virtual microscopes?

3. Do students learning approaches alter differentially with virtual and optical microscopes?

4. Do virtual microscopes encourage deep learning?

5. Are virtual microscopes easier to use than optical microscopes?

Each of these questions will be discussed separately in the following sections.

7.2.1 What factors influence students’ learning with virtual microscopes?

This question was explored by analysing the students’ reflective comments about their learning with virtual microscopes and optical microscopes. Table 7.1 summarises the factors that students identified as important to their learning with microscopes in histology and pathology.
Table 7.1 Factors students identified as important about virtual and optical microscopes

<table>
<thead>
<tr>
<th>Develops</th>
<th>Factors</th>
<th>Virtual</th>
<th>Optical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microscope</td>
<td>Set-up</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Skills</td>
<td>Find slide</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Position slide</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Focus</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Navigate</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Theory</td>
<td>Pattern recognition</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Tissue features</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Learning</td>
<td>Link theory with</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Activity</td>
<td>practice</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visualise</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Authentic</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Group work</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Revision</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

In order to fully understand the issues relating to virtual microscopes, it is necessary to discuss both types of microscopes in relation to the students’ activities, so both optical microscopes and virtual microscopes will be discussed in the following sections.

**Optical Microscopes**

Students’ reflections about their learning experiences with optical microscopes highlighted some key themes (Figure 7.1) showing how optical microscopes assisted students with their learning. The themes include the students’ perceptions that the optical microscopes provided a more *authentic* experience than the virtual ones. This may be important as, according to Jonassen (1994), authentic tasks are one of the components in social constructivist learning environments. The students also felt more in *control* of the optical microscopes, which may be related to their being able to control the focus and other features. Students had contrasting perceptions of the *ease of use* of the optical microscopes with students reporting them either easy or difficult to use. This indicates that individual differences between students exist when using optical microscopes.
The physical set-up of the optical microscope laboratory was thought to have encouraged *group work* and, when combined with the factors in Figure 7.1 it helped the students to be more engaged with the subject. Students identified another important aspect in the optical laboratory environment: *the teachers/demonstrators* were seen as essential to their learning in the subject as they were scaffolding their learning. Students in the optical laboratory frequently commented on the demonstrator moving around the room and providing comments (scaffolding), e.g. highlighting features in tissues to their group. As the optical laboratory set-up and the multi-header microscopes force students to work in groups of 8-9, this may also have encouraged some students to engage more in the laboratory activities. However, as discovered in the students’ reflective comments, not all students felt this way, as some did not engage with the group when they were not driving the microscope.

Students raised two key issues that negatively affected students’ learning when using optical microscopes. The first was the difficulty in setting up and using the optical microscopes. This issue has also been identified by previous research (Kumar, et al., 2004). The second issue was that they caused a range of health related issues, e.g. headaches, eye-strain, nausea, motion sickness, which was also identified in previous research involving professional microscope users (Golding, 2006; Kofler, et al., 2002; Thompson, et al., 2003).
Although the students found the optical microscope difficult to use, they commented that they were able to develop microscope skills, such as, setting up, finding slides, positioning slides, focussing slides and navigating slides to find relevant features. In theory, they were also learning about tissue features and pattern recognition. The laboratory group learning activities helped them to link theory with practice and allowed them to visualise and recall tissue features later (e.g. in their assessments).

The optical microscopes were not used for revision, probably due to the lack of access as the laboratories were used heavily for teaching purposes during the week, and are locked after hours. Although students could make arrangements to use them after hours by liaising with the technicians, it was an additional barrier.

**Virtual Microscopes**

The students using the virtual microscopes found similar attractive features to those identified for the optical microscopes (Figure 7.2). In particular, more students found the virtual microscopes easy to use, than students who found the optical microscopes easy to use, but interestingly a very small number of students found the virtual microscopes difficult to use. However, more students found the optical microscopes difficult to use. Heidger et al., (2002) reported that students found virtual microscopes easier to use than optical microscopes and this study therefore supports this previous research.

The virtual microscopes also gave students a sense of control over the microscopes as they were easy to use and focus. The computer software automatically adjusts the image to provide a focused slide on the screen. Students were able to move through various magnifications (0.6, 2x, 4x, 8x, 10x, 20x to a maximum of 40x). The magnification was as good as with the optical microscope.
The virtual microscopes provided students with *improved health*, relieving them from the headaches, eyestrain and nausea that had previously been experienced while using the optical microscopes. This finding supports recent research that reported a reduction in health issues with virtual microscopes (Kumar, et al., 2009). Also, easy access to the virtual microscopes enabled students to use them at their *convenience*, from home, or at university which, in turn, helped them to *manage their time*. This adds weight to similar findings by previous researchers about virtual microscopes being *convenient* and assisting students in their *time management* (Goldberg & Dintzis, 2007; Harris, et al., 2001).

Figure 7.2 shows the relationship between different factors, including the reciprocal relationship between *easy access* and more convenience. As it was easy to access the microscopes at all times and places (home or at university) that suited the students. This, in turn, helped the students to better manage their time.

Similar to the optical microscopes, students felt the virtual microscopes encouraged *engagement with the teacher/demonstrator* in the laboratory. In the focus groups, each of the Virtual Group students thought that they had been able to contribute equally to their groups, allowing them to ask questions and be actively engaged in their activities.

Students’ reflective comments indicated that some were concerned they were not developing their optical *microscope skills* when using the virtual microscopes. The concern
raised is valid for veterinary science and biomedical science students, who may need to know how to use the optical microscopes in their future careers. This finding supports previous research reporting veterinary students’ concern with their development of optical microscopy skills when using virtual microscopes (Mills, et al., 2007). Some students also felt that the virtual microscopes were less authentic than the optical microscopes. While this may be a valid concern, there is an increasing trend in the use of virtual microscopes and virtual slides in pathology, of which the students may not be aware.

A concern was also raised about the technology being unreliable. This could be due to some technical glitches experienced with the computer networks in the laboratories during the teaching period, as no students specifically made any comments about their being technically unreliable whilst being used at home. A small number of students though, complained that the software did not work on Macintosh computers. In 2007, a white paper was published providing advice to Macintosh users about setting up the software (Aperio, 2007) so this may be less of an issue in the future.

In summary, the virtual microscopes did not need to be physically set up like the optical ones. Once the browser was installed on the students’ computers, they could place the DVD into their computer and choose the slide that they wanted to view, which would then be displayed on their computer screen. Students were developing navigation skills as the whole slide could be navigated to find the relevant features. The students were also learning about tissue identification and pattern recognition. The laboratory group activities also helped them to link theory with practice, visualise tissue, and discuss the slides in their groups, which helped them to learn. Unlike the optical microscopes, the virtual microscopes were used for revision, probably because the students could access them from home or university at times that were convenient to them. Finally, students’ final grade in their unit was not influenced by the type of microscope they used in their laboratory.
The evidence from students’ comments, therefore, supports that the impact of virtual microscopes on student learning includes ease of use, more convenience, improved health, and enhanced focus without affecting academic performance. What appears to be lost, however, is the feeling of authenticity and control over fine focus.

7.2.2 Do students’ learning approaches change with the introduction of virtual microscopes?

To date, there is no literature that documents how students’ approaches to learning may change in response to the introduction of virtual microscopes. To determine whether students’ learning approaches changed when virtual microscopes were introduced into histology and pathology laboratory teaching at Murdoch University, 151 students completed two ASSIST surveys, one at the beginning, and one towards the end of the teaching period.

The ASSIST survey contained three sections that measured different aspects of the learning experience: Section A measured students’ conceptions of learning; Section B measured students’ learning approach; and Section C measured students’ preference for different types of course and teaching. Each section is now discussed separately.

Part A - Conceptions of Learning

Overall, the students’ conceptions of learning changed from reproducing knowledge (surface) to personal understanding and development (deep). Although this was consistent across both the Optical and Virtual Groups, and across the three units within each group (see Table 6.6), it was not significant as the results of the Chi-square tests indicated (see Section 6.5.2). Students may have changed their conceptions of learning because, towards the end of the semester, they were more aware of what was required to succeed in histology and pathology.
Part B - Approach to Learning

Previous research has shown that students' approaches to learning can change in response to the teaching and learning environment, teaching and/or perceived assessment demands (Biggs, 2003; Entwistle & Peterson, 2004). In this study, it was found that a small number of students in both the Virtual and Optical Groups changed their approach to learning. However these changes were also not statistically significant, as indicated by the results of the Chi-square test (see Section 6.5.3). In the Optical Group, students changed from a surface to a strategic approach; in the Virtual Group, students moved from both deep and strategic approaches to a surface approach (Table 7.2). Neither group of students reported spending more time studying than the other; however, group interaction and group dynamics may provide a possible explanation to these results.

Table 7.2 Changes in Approaches to Learning (by group)

<table>
<thead>
<tr>
<th>Group</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical</td>
<td>Surface</td>
<td>Strategic</td>
</tr>
<tr>
<td>Virtual</td>
<td>Deep/Strategic</td>
<td>Surface</td>
</tr>
</tbody>
</table>

Across the individual units within the groups, varying results were displayed (Table 7.3). In the Optical Group, CHI301 students moved from a surface approach to a deep approach; the VET244 students had equal numbers of students move from a deep approach to both strategic and surface approaches; and the BMS264 students moved from a surface approach to either a strategic or deep approach. Possible factors for the CHI301 students' results may be that they had shorter laboratory sessions and were into the third year of their course. The change in the VET244 and BMS264 students may be attributable to workload; in particular, the BMS264 could have moved to strategic as they were concentrating on exam preparation and thus focusing on understanding the material. Further research may be
necessary to establish whether students change their approach depending on the demands of their courses during semester.

Table 7.3 Changes in Approaches to Learning (by unit)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Optical Group</th>
<th>Virtual Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>BMS264</td>
<td>Surface</td>
<td>Strategic/Deep</td>
</tr>
<tr>
<td>VET244</td>
<td>Deep</td>
<td>Strategic/Surface</td>
</tr>
<tr>
<td>CHI301</td>
<td>Surface</td>
<td>Deep</td>
</tr>
</tbody>
</table>

In the Virtual Group, BMS264 and CHI301 students moved from a surface or a deep approach to a strategic approach, while VET244 students moved from a strategic approach to either a deep or a surface approach. Perhaps the VET244 students were concentrating on completing assignments and exams and their change in approach reflected this.

Researchers have reported students’ conceptions of learning can influence students’ learning approach (Entwistle & Peterson, 2004), but this does not appear to be the case in this study as the results of the Chi-square test showed no statistical significance between students’ conceptions of learning and their learning approaches for either the Optical or Virtual Group (Section 6.5.3).

Part C - Preference for Different Types of Course and Teaching

The approaches used by students are known to change in response to the learning environment, teaching, assessment demands and perception of workload (Entwistle & Peterson, 2004).

A pattern was evident for this section, with both groups changing their preferences from transmitting information (surface) to encouraging understanding (deep). However, across units within the Optical Group, CHI301 and BMS264 students moved from surface to deep while VET244 students showed no change in preference. In the Virtual Group as a whole, there was a shift towards deep. Across the group, though, only students from CHI301
changed their preference from surface to deep while VET244 and BMS264 showed no change in preference. CHI301 students were in their third year of their course and may have gained insight into what knowledge and skills they needed to develop.

In summary, changes to students' learning approaches were relatively minor and suggest that virtual microscopes did not influence students’ approaches to learning; however, students’ conceptions of learning and preference for different types of course and teaching shifted overall towards deep learning. This may be explained by the students having developed more of an understanding about what histology and pathology is, and perhaps they now realised the conceptual knowledge and the skill development necessary to successfully complete their units. These factors may have influenced the actual approaches used during the teaching period.

7.2.3 Do students learning approaches alter differentially with virtual and optical microscopes?

This question was addressed by the results of the ASSIST surveys and statistical tests. As discussed in the previous section (7.2.2), the results showed that the learning approaches of students using the virtual microscopes did not appear to differ substantially from the learning approaches of students who used optical microscopes.

7.2.4 Do virtual microscopes encourage deep learning?

According to the results of the ASSIST surveys, the use of virtual microscopes in histology and pathology laboratories does not encourage deep learning any more than the use of optical microscopes. It does, however, enable students to study at times and locations that are convenient to them, such as after hours and at home, as reported by some students in their reflections, the focus groups and the interviews. This study did not examine the virtual microscopes as self-study tools; rather, it set out to determine whether their use in the
laboratories would encourage students to adopt deep approaches to their learning. However, self-study activities could perhaps play a role in encouraging students to use a deep approach to their learning, as some students said that they would like to be able to use the virtual microscopes for self-directed and/or in informal group study. Many of the students in this study suggested that the virtual microscope slides could contain labels to alert them to the structures that they needed to identify.

7.2.5 Are virtual microscopes easier to use than optical microscopes?

As mentioned in Section 6.6.6, much of the research reported in the literature points out that students often have difficulty in learning how to use optical microscopes (e.g. Golding, 2006; Kofler, et al., 2002; Kumar, et al., 2009; Kumar, et al., 2004; Thompson, et al., 2003). The students’ reflection comments confirm previous research findings and show that, in this study, students found the virtual microscopes easier to use than the optical microscopes. This is probably due to the technical process (autofocus) when virtual slides are initially captured, which means the slides appear focused on the computer screen. Another possible reason is that the virtual slides cannot be incorrectly placed, as can occur with the glass slides that are used with optical microscopes. Navigation is also easier with the virtual microscope, because a map on the top right of the screen shows where you are on the slide as a whole, so that some sense of location and scale is always present, and because there are also multiple ways of moving around the image (click and drag image, or click an area on low power, or use a joystick tool, or use arrows at the four compass points of the screen edges). Virtual slides also reduce the risk of human error, such as misplaced or broken glass slides.

A representation of the main research findings is shown in Figure 7.3. As can be seen, students’ learning approaches do not appear to be influenced by their use of virtual microscopes.
Many researchers studying students’ learning approaches only measure students’ learning approach once, usually at the beginning of their studies. This research sought to determine whether there was any change in students’ learning approaches by measuring their preferred learning approach twice; at the beginning, and again towards the end of a teaching period. Students’ learning approaches are fluid and can change in response to the learning environment. In this study, students’ learning approaches in both the optical and the virtual groups did alter but the change was not statistical significance. It has been suggested (Donald & Jackling, 2007; Watkins & Hattie, 1981) that students move more towards a deep learning approach with age, maturity and life experience. In this study, this does not appear to be the case.

Simultaneously students’ conceptions of learning and preferred teaching and course preferences changed from surface to deep, but the changes were not statistically significant.

As the ASSIST only provides a numerical indication of students’ learning approaches, further data was gathered by reflective comments, focus groups and interviews.

Students’ reflective comments did reveal that they thought they encouraged learner, and teacher engagement as well as facilitated their time management. The majority of students thought the virtual microscopes were easier to use and focus and were more convenient to use than the optical microscopes. The comments also revealed that the students perceived virtual microscopes as hindering group work. This may have been due to some students choosing to study from home, which inevitably meant they used them alone. Students also identified several things that they disliked about optical microscopes, the main one being they were difficult to use, set up and focus. Although these procedures may be mitigated by electing a more experienced student to drive the optical microscope, this means that the other students would not be learning one of the skills required for optical and virtual microscope use, that of being able to navigate around slides. Additionally, some students revealed that they felt less engaged when they were not driving the microscope and
therefore were less likely to actively participate within their group. Another frequently mentioned dislike was the health problems (headaches and nausea) experienced by students using optical microscopes. While this is not directly related to learning it has the potential to significantly impact it. It is difficult to engage in anything with a headache or when feeling nauseous.

The focus groups and interviews showed that some students preferred using the optical microscopes for their learning as they perceived them to: be more authentic, enable group work, provide finer control over focus and build their microscope skills. While others preferred the virtual microscopes as they found they improved their health, were easier to control and use. These findings also supported students’ reflective comments about microscopes. Students from both groups thought that their roles in their laboratory groups were clear and that they were able to engage in learning in groups with virtual and optical microscopes, with only one student commenting on disengagement from groupwork as a result of not driving the optical microscope while in their group. Students from both groups would like more time with laboratory demonstrators and more individual work to be set at an exam pace.
Figure 7.3 Summary of research findings
7.3 Limitations of the Study

This research was an embedded case study of three groups of students studying histology and/or pathology at Murdoch University in the Health Sciences discipline and therefore is not intended to be generalizable to other settings. As this was primarily interpretive research, the case study environment was manipulated minimally. The only changes to the current unit structure were an independent lecturer randomly allocated students to one of two groups for their laboratories, both groups completing the same activities and receiving 5% of their grade for submitting their reflective comments and log books. The study did not include any participant observation of students’ learning with microscopes; rather; it was limited to surveys, focus groups and interviews. The focus groups could have been larger and more interviews conducted. The small response may be attributed to the voluntary nature of the study. The addition of participant observation of the laboratory classes may have added another dimension to the study.

An alternative approach may have been to investigate multiple cases. However, the case was convenience sampling. It was selected through negotiation and the lecturer was keen to compare the current multi-headed optical microscopy set-up (up to 9 students per microscope) with the projected implementation environment (2-3 students per laptop) for the virtual microscopes.

Another limitation was that students were limited in the number of digital slide sets to which they had access. The lecturer concerned chose the best glass slides specimens for scanning for the digital slide set used in the laboratories; however, this was a limitation as there was more than one glass slide set available in the optical microscope labs, thereby increasing the number of natural variations seen for the same slide.
As is common in research, it is possible that students tried to answer the ASSIST survey questions based on what they thought the researcher wanted to hear, rather than what they truly felt. However, students were asked to choose their answer based on their initial response rather than think about the answers for a long time before responding.

The interview questions may have been too structured, thereby limiting the students’ responses, it may have been better to follow an interview guide to allow more free flowing conversation.

This study did not specifically measure students’ perception of work, although it was a factor that emerged through the focus groups and interviews. More questions about perceived workload may have been beneficial. As discussed previously in Chapter 2, Cope, Staehr, and Horan (2002) reported that they were able to move students towards a deep approach through the manipulation of the learning environment and workload over a five year period, specifically, they found that students’ perceptions of workload was a measure in helping them to adjust workload.

### 7.4 Modifications to Units in Response to Feedback from the Research

Throughout the course of this study, the researcher collaborated with the primary lecturer involved with the research.

As a result of the exploratory study, several changes were made to the histology and pathology laboratories. In the laboratories, a large monitor screen was placed in a central location to ensure that students could see the demonstrator’s virtual slide, thereby allowing students to view areas of interest first on this screen and then to find the area on their own computer (virtual microscope viewer). Also students are now all provided with DVDs containing all the virtual slides so that they can access them when they choose, at home or at university.
As a result of the main study, the slides are now on the hard drives of all the laboratory computers to ensure that the shortest possible time is taken to display the virtual slides in the laboratories. The lecturer has also purchased software (Digilab, 2010) that allows demonstrators to take control of individual student’s monitors to display on the main screen monitor in the laboratory room. This will allow further sharing, collaboration and discussion about areas of interest on virtual slides.

Feedback from the students also indicated that the optical slides were sometimes difficult to obtain, so the lecturer has now combined several tissues samples onto one slide and is building a class set to help alleviate this problem. The students also indicated that they disliked having to find the glass slides from the class box sets and in response, as part of the preparation for the optical laboratory classes, 3-6 glass slides are placed on a slide tray ready for the students to use. These two changes were for the student convenience, rather than being theoretically based. The lecturer is also developing histology-in-context slide sets to allow students to view a cross-section of a whole animal on their slide that also contains multiple tissues on the slide.

### 7.5 Recommendations for Integrating Virtual Microscopes into the Curriculum

This study highlighted a number of issues that educators need to consider when introducing virtual microscopes. The following recommendations focus on learning and the curriculum in relation to the implementation of virtual microscopes.

There appears to be no reason why virtual microscopes could not be introduced more widely into the teaching of histology and pathology. However, educators must be mindful that some students will need to use optical microscopes in their careers (e.g. veterinary science students). For these students, it is currently essential that they continue to develop skills in using optical microscopes, perhaps in conjunction with developing virtual
microscope skills. Indeed, this is already happening in some veterinary schools (see Sims, et al., 2007). In some medical schools, there is a trend towards moving entirely to virtual microscopes and virtual slides to teach pathology (Kumar, et al., 2004; Weinstein, et al., 2009). In fact, Dee (2009) reported that, by 2007, up to one third of medical schools in the USA had already implemented virtual microscopes into their curricula.

Equally, when students do not need to use optical microscopes in their future careers but do need to learn about histology and pathology (e.g. chiropractors), virtual microscopes could be used instead of the optical microscopes. Using virtual microscopes in fact, for some students, it may be preferable (e.g. those students who experienced health issues or difficulty using the optical microscopes). It would also conserve the optical microscope laboratory for students who need to develop their skills in using them. In the Health Sciences, recent changes with radiography and ultrasound mean that, rather than producing only physical representations, virtual ones are being produced. In fact, radiographs and ultrasounds can be sent via email with specialised software to doctors and other health professionals. It is possible that, sometime in the near future, virtual microscopes will replace optical microscopes entirely.

Technical expertise and funding is not encompassed in these recommendations but it is obvious that, to obtain the most benefit from the technology, technical staff support and maintenance of any hardware and software is essential.

The recommendations that emerged from the results of this research are illustrated in a Virtual Microscope Implementation Model (VMIM) (Figure 7.3). The VMIM shows how virtual microscopes can be integrated into the curriculum (e.g. histology and pathology) by developing microscope skills in students through authentic activities, group work and social interaction, knowledge construction in laboratory settings and scaffolding by teachers who set up these environments and actively assist (scaffold) students with their laboratory work. The model also shows the relationship between the factors that interact to provide an
integrated approach to introducing virtual microscopes into a curriculum. The model was guided by the theoretical framework described in Figure 2.2 and includes each of the six elements in that framework. Four main factors, - microscope skills, authentic activities, linking theory with practice and group work - need to be considered when integrating virtual microscopes into curricula and are now discussed separately.
Figure 7.4 Virtual Microscope Implementation Model.
7.5.1 Microscope Skills

First, educators should determine whether students need to use optical or virtual microscopes in their future careers. If students do require optical microscope skills, these skills should be developed as part of their course. This means students could be taught how to use them early in the course and the skills reinforced throughout the course. This does not preclude the use of virtual microscopes; however, at this point in time they would not be used alone. In this instance, they could be introduced as a supplementary learning tool or for self-study purposes; or, alternatively, used on alternate weeks in the laboratories. Veterinary science and biomedical science students in this study expressed a desire to continue developing their optical microscope skills. For students who do not need to develop optical microscope skills for their future careers, e.g. chiropractic students, virtual microscopes could be used exclusively for teaching histology and pathology without hindering their career pathways.

7.5.2 Authentic Activities

Activities are an important issue with virtual microscopes. The students using optical microscopes felt these microscopes provided a more authentic experience than the virtual microscopes, even though virtual microscopes are being used by pathologists for diagnostic purposes. This view may be influenced by the veterinary and biomedical students, some of whom will need to use optical microscopes in their future careers. Some students referred to the aspect of tactile/visual sensation as meaning authentic rather than the intended meaning of “real”. Veterinary practitioners are sometimes required to take a sample of tissue from an animal on the spot (typically a skin scraping with which to check for parasites, fungi or bacteria, or a needle aspirate, rather than a tissue slice) and place the sample onto a glass slide to view the specimen with an optical microscope to diagnose diseases or problems in the animals brought to them.
Students should be informed about how virtual microscopes are currently being used, right now, in practice, as this may help them to understand that virtual microscopy is also an authentic activity that they may need to know how to perform in the future. For chiropractic students, authenticity may be less of an issue as it is unlikely that they will be using optical or virtual microscopes in their careers.

In this study, there were several glass slide sets that could be used by students in the optical microscope laboratory whereas only one slide set was digitised for use in the virtual microscope laboratory. Students commented that they would like to have more example slides of the same tissue (as in the glass slide sets) so that they could see and learn from minor variations in tissue samples. A recommendation is to digitise more slide sets to provide more examples of the same tissue sets as in the glass slide sets.

7.5.3 Linking theory with practice

This research shows that, to integrate virtual microscopes into a histology or pathology curriculum, several factors need to be taken into consideration. These include: alignment of assessments and teaching and learning activities with the unit outcomes; integrating the microscope activities into the curriculum; monitoring changes to students learning approaches; and being responsive to students’ suggestions and comments about histology and pathology laboratory activities and learning experiences. All of the factors in the model can theoretically lead to students linking theory with practice. However the main factor identified by the students that contributed towards knowledge construction and the application of theory to practice was the activities using the virtual microscopes (see Section 6.6.4, Activity Theme 1).
7.5.4 Group work

In social constructivist learning theory, the importance of collaboration and social interaction is paramount to learning, as it provides students with the opportunity to discuss their knowledge and beliefs with others and to listen to other students’ views, which helps them to construct their own knowledge. Students felt that the laboratory group work was a valuable and essential component of their learning histology and pathology. However, there is scope to improve the laboratory activities to encourage more interaction and verbalisation. Students’ responses to statements about their laboratory group work showed that the group work was well regarded; however, there was a difference in responses between the Optical and the Virtual Group when it came to all students equally contributing in their groups, with the Virtual Group responding more positively than the Optical Group. This could be due to the larger group size and the disengagement of some students in the Optical Groups when they were not driving the microscopes. Students’ reflections from the Attitude Survey showed that more students thought optical microscopes facilitated group work than the virtual microscopes but about half the students also thought that the optical microscopes hindered group work. It is recommended that students complete some pre-laboratory questions and then discuss them in the laboratory groups as this might help some students to engage more with other students during the activities.

7.6 Future Research Directions

This study was a snapshot of a single embedded case, comprising three groups of students studying histology and pathology in the Health Sciences at one university over a single teaching period. Future research could extend this study in the following area.

1. A longitudinal study to determine whether the results of the main study are typical. It would also allow factors such as perception of workload to be monitored and manipulated over time to see whether student could be encouraged to adopt a deeper approach to their learning.
2. As the study focused only on the use of virtual microscopes and the impact on students’ learning in the Health Sciences, future research could be expanded into other disciplines (e.g. Botany) which may benefit from incorporating virtual microscopes into their teaching.

3. Cope and Staehr (2005) found that a critical factor in influencing students to take a deep approach to their learning at a unit level was the adjustment of workload over time, in response to students’ perceptions of workload in the unit. Future researchers could probe the relationship between perceived workload and deep learning.

4. Students working with microscopes in their laboratory classes could be videotaped and analysed later.

5. Students’ activities with microscopes could be altered to include more individual work at an exam pace and noting the effect.

6. Another focus for future study could be to determine whether providing annotated virtual slides for self-study in a unit, while reducing workload elsewhere in the unit would encourage students to engage more with the course and to adopt deep approaches to their learning.

Future technological advances in virtual microscopy may well bring about improvements in both hardware and software to produce better quality slides with a faster access speed. A recently designed educational application, ‘Biovere’s Anatomica 3D’, includes virtual microscopy as part of the anatomy simulation programme and is available from [http://www.virtual-anatomy.com/](http://www.virtual-anatomy.com/). It is envisaged that these types of applications will only improve with time and specific histology and pathology ones may follow.
7.7 Conclusion

In conclusion, this chapter discussed the results that were presented in Chapter 6. The chapter began with a brief overview of the study. The research questions were then reviewed in relation to the outcomes of the study. Next, a model for integrating virtual microscopes into curricula was presented and discussed. Recommendations were made and implications for practice were presented. Finally, suggestions for future research were discussed.
APPENDICES
Appendix A.1 Exploratory Study Consent Form

Project Title: Deep learning, virtual microscopes and health sciences.

The purpose of this study is to establish whether preferred study approaches and diagnostic skills in pathology are affected by incorporating virtual microscope activities into histology and pathology teaching. The study will also determine how preferred study approaches are affected by the components of the learning environment, both face-to-face and online. This study will be undertaken by Diana Jonas-Dwyer, a PhD student at Murdoch University, under the supervision of Dr Fay Sudweeks, Dr Tanya J. McGill and Dr Philip Nicholls. The research aims to identify the critical success factors in effectively implementing virtual microscopes into pathology and histology teaching.

You can help in this study by consenting to: (a) complete the Approaches and Study Skills Inventory for Students (ASSIST); (b) complete a log book of time spent face-to-face and time online; and (c) complete reflections on your learning experiences (it is anticipated that the time to complete each reflection will be no more than 10 minutes each or 40 minutes in total); (d) agree to allow assessment results to be matched to the other information collected in the study. All information given is confidential and no names or other information that might identify you will be used in any publication arising from the research. Participants can decide to withdraw their consent at any time without prejudice. Feedback on the study will be provided in the form of a summary report at the end of the semester.

If you have any questions about this project please feel free to contact either myself, Diana Jonas-Dwyer, on 0411 048 986, Dr Fay Sudweeks on 9360 2364, Dr Tanya McGill on 9360-2798 or Dr Philip Nicholls on 9360 2599. If at any time you do not wish to participate in this study please contact Ms Diana Jonas-Dwyer. My supervisors and I are happy to discuss with you any concerns you may have on how this study has been conducted, or alternatively you can contact Murdoch University’s Human Research Ethics Committee on 9360 6677.

*********************************************************************************************************
I understand that all information that is provided is treated as confidential and will not be released by the investigator unless required to do so by law.

I have read the information above. Any questions I have asked have been answered to my satisfaction. I agree to take part in this study.

I agree that research data gathered for this study may be published provided my name or other information which might identify me is not used.

Participant: ___________________ Date: __________________

Investigators

Diana Jonas-Dwyer 15 February 2006
Dr Fay Sudweeks 15 February 2006
Dr Tanya McGill 15 February 2006
Dr Phillip Nicholls 15 February 2006
Appendix A.2 Main Study Consent Form 1

Project Title:  The impact of microscopes on learning in the health sciences.

The purpose of this study is to establish whether preferred study approaches and diagnostic skills in pathology are affected by incorporating virtual microscope activities into histology and pathology teaching. The study will also determine how preferred study approaches are affected by the components of the learning environment, both face-to-face and online. This study will be undertaken by Diana Jonas-Dwyer, a PhD student at Murdoch University, under the supervision of Dr Fay Sudweeks, Dr Tanya J. McGill and Dr Philip Nicholls. The research aims to identify the critical success factors in effectively implementing virtual microscopes into pathology and histology teaching.

You can help in this study by consenting to PART A (a) complete the Approaches and Study Skills Inventory for Students (ASSIST); (b) complete a log book of time spent face-to-face and time online; and (c) complete reflections on your learning experiences (it is anticipated that the time to complete the reflection will be no more than 30 minutes in total); (d) agree to allow assessment results to be matched to the other information collected in the study. Some students will be selected to take part in PART B which consists of interviews and a focus group. Please indicate if you agree to participate in this part of the study. All information given is confidential and no names or other information that might identify you will be used in any publication arising from the research. Participants can decide to withdraw their consent at any time without prejudice. Feedback on the study will be provided in the form of a summary report at the end of the semester.

If you have any questions about this project please feel free to contact either myself, Diana Jonas-Dwyer, on 0411 048 986, Dr Fay Sudweeks on 9360 2364, Dr Tanya McGill on 9360-2798 or Dr Philip Nicholls on 9360 2599. If at any time you do not wish to participate in this study please contact Diana Jonas-Dwyer. My supervisors and I are happy to discuss with you any concerns you may have on how this study has been conducted, or alternatively you can contact Murdoch University's Human Research Ethics Committee on 9360 6677.

I understand that all information that is provided is treated as confidential and will not be released by the investigator unless required to do so by law. I have read the information above. Any questions I have asked have been answered to my satisfaction.

I agree to take participate in part A of this study. ☐
I agree to take part in Part B of this study, an interview or focus group. ☐

I agree that research data gathered for this study may be published provided my name or other information which might identify me is not used.

Participant: ___________________________________ Date: ______________________

Investigators

Diana Jonas-Dwyer 12 February 2007
Dr Fay Sudweeks 12 February 2007
Dr Tanya McGill 12 February 2007
Dr Philip Nicholls 12 February 2007
Appendix A.3 Main Study Consent Form 2

Focus Groups and Interviews

Project Title: The impact of microscopes on learning in the health sciences.

The purpose of this study is to establish whether preferred study approaches and diagnostic skills in pathology are affected by incorporating virtual microscope activities into histology and pathology teaching. The study will also determine how preferred study approaches are affected by the components of the learning environment, both face-to-face and online. This study will be undertaken by Diana Jonas-Dwyer, a PhD student at Murdoch University, under the supervision of Dr Fay Sudweeks, Dr Tanya J. McGill and Dr Philip Nicholls. The research aims to identify the critical success factors in effectively implementing virtual microscopes into pathology and histology teaching.

You can help in this study by consenting to PART B which consists of interviews and/or a focus group. Please indicate if you agree to participate in this part of the study. All information given is confidential and no names or other information that might identify you will be used in any publication arising from the research. Participants can decide to withdraw their consent at any time without prejudice. Feedback on the study will be provided in the form of a summary report at the end of the semester.

If you have any questions about this project please feel free to contact either myself, Diana Jonas-Dwyer, on 0411 048 986, Dr Fay Sudweeks on 9360 2364, Dr Tanya McGill on 9360-2798 or Dr Philip Nicholls on 9360 2599. If at any time you do not wish to participate in this study please contact Ms Diana Jonas-Dwyer. My supervisors and I are happy to discuss with you any concerns you may have on how this study has been conducted, or alternatively you can contact Murdoch University’s Human Research Ethics Committee on 9360 6677.

*********************************************************************************************************

I understand that all information that is provided is treated as confidential and will not be released by the investigator unless required to do so by law. I have read the information above. Any questions I have asked have been answered to my satisfaction.

I agree to take part in Part B of this study, an interview or focus group

I agree for the interview to be taped.

I agree for the focus group to be taped.

I agree that research data gathered for this study may be published provided my name or other information which might identify me is not used.

Participant: _____________________________________ Date:______________________

Investigators

Diana Jonas-Dwyer
12 February 2007

Dr Fay Sudweeks
12 February 2007

Dr Tanya McGill
12 February 2007

Dr Phillip Nicholls
12 February 2007
Appendix B - Demographics

Background Questions

1. Gender  Male ☐  Female ☐

2. Age ____________

3. Educational Level________________________________________

4. Study Major ____________________________________________

5. Will you use a microscope in your chosen career? Yes/No

6. Please rate your skills using the internet and computers.

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<tr>
<td>Little</td>
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<td>Very Skilled</td>
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<td>Or No Skill</td>
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Appendix C - The ASSIST Survey

ASSIST
Approaches and Study Skills Inventory for Students
(Short version)

This questionnaire has been designed to allow you to describe, in a systematic way, how you go about learning and studying. The technique involves asking you a substantial number of questions which overlap to some extent to provide good overall coverage of different ways of studying. Most of the items are based on comments made by other students. Please respond truthfully, so that your answers will accurately describe your actual ways of studying, and work your way through the questionnaire quite quickly.

Background information

Name or Identifier ........................................... Age ...... years Sex M / F
University or College ....................................... Faculty or School ......................................
Course .............................................................. Year of study .......

A. What is learning?

When you think about the term ‘LEARNING’, what does it mean to you?

Consider each of these statements carefully, and rate them in terms of how close they are to your own way of thinking about it.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Very close</th>
<th>Quite close</th>
<th>Not so close</th>
<th>Rather different</th>
<th>Very different</th>
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<tbody>
<tr>
<td>a. Making sure you remember things well</td>
<td>5</td>
<td>4</td>
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<td>b. Developing as a person.</td>
<td>5</td>
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<tr>
<td>c. Building up knowledge by acquiring facts and information</td>
<td>5</td>
<td>4</td>
<td>3</td>
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<tr>
<td>d. Being able to use the information you’ve acquired</td>
<td>5</td>
<td>4</td>
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<tr>
<td>e. Understanding new material for yourself.</td>
<td>5</td>
<td>4</td>
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<tr>
<td>f. Seeing things in a different and more meaningful way.</td>
<td>5</td>
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© 1997a Centre for Research on Learning and Instruction, University of Edinburgh
Available at http://www.ed.ac.uk/etl/questionnaires/ASSIST.pdf [Accessed 25 August 2005]

Please turn over
B. Approaches to studying

The next part of this questionnaire asks you to indicate your relative agreement or disagreement with comments about studying again made by other students. Please work through the comments, giving your immediate response. In deciding your answers, think in terms of this particular lecture course. It is also very important that you answer all the questions: check you have.

5 means agree (√) 4 = agree somewhat (√?) 2 = disagree somewhat (x?) 1 = disagree (x).

Try not to use 3 = unsure (??), unless you really have to, or if it cannot apply to you or your course.

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<tr>
<td>1.</td>
<td>I manage to find conditions for studying which allow me to get on with my work easily.</td>
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<tr>
<td>2.</td>
<td>When working on an assignment, I’m keeping in mind how best to impress the marker</td>
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<td>3.</td>
<td>Often I find myself wondering whether the work I am doing here is really worthwhile</td>
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<td>4.</td>
<td>I usually set out to understand for myself the meaning of what we have to learn.</td>
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<td>5.</td>
<td>I organise my study time carefully to make the best use of it.</td>
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<td>6.</td>
<td>I find I have to concentrate on just memorising a good deal of what I have to learn.</td>
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<td>7.</td>
<td>I go over the work I’ve done carefully to check the reasoning and that it makes sense.</td>
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<td>8.</td>
<td>Often I feel I’m drowning in the sheer amount of material we’re having to cope with.</td>
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<td>9.</td>
<td>I look at the evidence carefully and try to reach my own conclusion about what I’m studying</td>
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<td>10.</td>
<td>It’s important for me to feel that I’m doing as well as I really can on the courses here.</td>
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<td>11.</td>
<td>I try to relate ideas I come across to those in other topics or other courses whenever possible.</td>
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<td>12.</td>
<td>I tend to read very little beyond what is actually required to pass.</td>
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<td>13.</td>
<td>Regularly I find myself thinking about ideas from lectures when I’m doing other things.</td>
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<td>14.</td>
<td>I think I’m quite systematic and organised when it comes to revising for exams.</td>
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<td>15.</td>
<td>I look carefully at tutors’ comments on course work to see how to get higher marks next time.</td>
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<td>16.</td>
<td>There’s not much of the work here that I find interesting or relevant.</td>
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<td>17.</td>
<td>When I read an article or book, I try to find out for myself exactly what the author means.</td>
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<td>18.</td>
<td>I’m pretty good at getting down to work whenever I need to.</td>
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<td>19.</td>
<td>Much of what I’m studying makes little sense: it’s like unrelated bits and pieces.</td>
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<td>20.</td>
<td>I think about what I want to get out of this course to keep my studying well focused.</td>
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<td>21.</td>
<td>When I’m working on a new topic, I try to see in my own mind how all the ideas fit together.</td>
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22. I often worry about whether I’ll ever be able to cope with the work properly.  
23. Often I find myself questioning things I hear in lectures or read in books.  
24. I feel that I’m getting on well, and this helps me put more effort into the work.  
25. I concentrate on learning just those bits of information I have to know to pass  
26. I find that studying academic topics can be quite exciting at times.  
27. I’m good at following up some of the reading suggested by lecturers or tutors.  
28. I keep in mind who is going to mark an assignment and what they’re likely to be looking for.  
29. When I look back, I sometimes wonder why I ever decided to come here.  
30. When I am reading, I stop from time to time to reflect on what I am trying to learn from it.  
31. I work steadily through the term or semester, rather than leave it all until the last minute.  
32. I’m not really sure what’s important in lectures so I try to get down all I can.  
33. Ideas in course books or articles often set me off on long chains of thought of my own.  
34. Before starting work on an assignment or exam question, I think first how best to tackle it.  
35. I often seem to panic if I get behind with my work.  
36. When I read, I examine the details carefully to see how they fit in with what’s being said.  
37. I put a lot of effort into studying because I’m determined to do well.  
38. I gear my studying closely to just what seems to be required for assignments and exams.  
39. Some of the ideas I come across on the course I find really gripping.  
40. I usually plan out my week’s work in advance, either on paper or in my head.  
41. I keep an eye open for what lecturers seem to think is important and concentrate on that.  
42. I’m not really interested in this course, but I have to take it for other reasons.  
43. Before tackling a problem or assignment, I first try to work out what lies behind it.  
44. I generally make good use of my time during the day.  
45. I often have trouble in making sense of the things I have to remember.  
46. I like to play around with ideas of my own even if they don’t get me very far.  
47. When I finish a piece of work, I check it through to see if it really meets the requirements.  
48. Often I lie awake worrying about work I think I won’t be able to do.

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Appendix C – The ASSIST  246
49. It’s important for me to be able to follow the argument, or to see the reason behind things.
50. I don’t find it at all difficult to motivate myself.
51. I like to be told precisely what to do in essays or other assignments.
52. I sometimes get ‘hooked’ on academic topics and feel I would like to keep on studying them.

C. Preferences for different types of course and teaching

Try not to use 3 = unsure ( ? ? ). unless you really have to, or if it cannot apply to you or your course.

<table>
<thead>
<tr>
<th>Preferences</th>
<th>√</th>
<th>√?</th>
<th>??</th>
<th>x?</th>
<th>x</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. lecturers who tell us exactly what to put down in our notes.</td>
<td>5</td>
<td>4</td>
<td>3</td>
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<td>1</td>
</tr>
<tr>
<td>b. lecturers who encourage us to think for ourselves and show us how they themselves think.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>c. exams which allow me to show that I’ve thought about the course material for myself.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>d. exams or tests which need only the material provided in our lecture notes.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>e. courses in which it’s made very clear just which books we have to read.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>f. courses where we’re encouraged to read around the subject a lot for ourselves.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>g. books which challenge you and provide explanations which go beyond the lectures.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>h. books which give you definite facts and information which can easily be learned</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Finally, how well do you think you have been doing in your assessed work overall, so far?

Please rate yourself objectively, based on the grades you have been obtaining

<table>
<thead>
<tr>
<th>Rating</th>
<th>Very well</th>
<th>Quite Well</th>
<th>About average</th>
<th>Not so well</th>
<th>Rather</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

Thank you very much for spending time completing this questionnaire: it is much appreciated.
# Appendix D – Cronbach’s Alpha for Sections A, B and C of the ASSISTS in the Main Study

<table>
<thead>
<tr>
<th>ASSIST 1 and ASSIST 2</th>
<th>ASSIST1</th>
<th>ASSIST2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cronbach’s Alpha</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part A - What is Learning</td>
<td>0.58</td>
<td>0.66</td>
</tr>
<tr>
<td>Conceptions of Learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part B - Approaches to Studying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DA - Seeking Meaning</td>
<td>0.604</td>
<td>0.580</td>
</tr>
<tr>
<td>DA – Relating Ideas</td>
<td>0.499</td>
<td>0.641</td>
</tr>
<tr>
<td>DA – Use of Evidence</td>
<td>0.393</td>
<td>0.534</td>
</tr>
<tr>
<td>DA – Interest in Ideas</td>
<td>0.635</td>
<td>0.716</td>
</tr>
<tr>
<td>Deep Approach (DA)</td>
<td><strong>0.773</strong></td>
<td><strong>0.830</strong></td>
</tr>
<tr>
<td>STA – Organised Studying</td>
<td>0.383</td>
<td>0.621</td>
</tr>
<tr>
<td>STA – Time Management</td>
<td>0.724</td>
<td>0.774</td>
</tr>
<tr>
<td>STA – Alertness to Assessment Demands</td>
<td>0.470</td>
<td>0.648</td>
</tr>
<tr>
<td>STA – Achieving</td>
<td>0.572</td>
<td>0.701</td>
</tr>
<tr>
<td>STA – Monitoring Effectiveness</td>
<td>0.474</td>
<td>0.466</td>
</tr>
<tr>
<td>Strategic Approach (STA)</td>
<td><strong>0.823</strong></td>
<td><strong>0.860</strong></td>
</tr>
<tr>
<td>SA – Lack of Purpose</td>
<td>0.588</td>
<td>0.695</td>
</tr>
<tr>
<td>SA – Unrelated Memorising</td>
<td>0.512</td>
<td>0.636</td>
</tr>
<tr>
<td>SA – Syllabus Boundness</td>
<td>0.624</td>
<td>0.705</td>
</tr>
<tr>
<td>SA – Fear of Failure</td>
<td>0.732</td>
<td>0.747</td>
</tr>
<tr>
<td>Surface Approach (SA)</td>
<td><strong>0.779</strong></td>
<td><strong>0.839</strong></td>
</tr>
<tr>
<td>Part C – Preference for different types of course and teaching</td>
<td><strong>0.277</strong></td>
<td><strong>0.425</strong></td>
</tr>
</tbody>
</table>
Appendix E – The Log Book

The Exploratory Study Log Book

**Processes in Human Disease - Log Book**

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Semester 1 2006**

The purpose of this log is to record the amount of time spent studying both online and face-to-face (e.g. time spent using optical or virtual microscopes, time spent attending lectures, time spent attending labs, etc).

<table>
<thead>
<tr>
<th>Date</th>
<th>Time began</th>
<th>Time</th>
<th>Total time (minutes)</th>
<th>Type and description of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g 1/01/2006</td>
<td>9:00:00 AM</td>
<td>10:10:00 AM</td>
<td>70 lab – using optical microscope</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9:00:00 AM</td>
<td>10:00:00 AM</td>
<td>60 home – using virtual microscope</td>
<td></td>
</tr>
</tbody>
</table>

The Main Study Log Book

**Research Project Log Book - Semester 1 2007**

<table>
<thead>
<tr>
<th>Name:</th>
<th>Student No:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Do Not Edit This Master Sheet - It automatically calculates the figures from the other tab sheets! Click on a tab to edit. Once this log is complete submit via the Assignments tool in WebCT. Save this file, name it Log and your student no. e.g. Log_0000000.xls and submit the file as an attachment to the Log Assignment.</td>
</tr>
</tbody>
</table>

The purpose of this log is for you to record the amount of time spent studying both online and face-to-face (e.g. time spent using optical or virtual microscopes outside of labs and lectures, time spent on WebCT). Enter the time on the appropriate worksheet. This master sheet will calculate the time for each type of activity.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using optical microscope</td>
<td>2.67</td>
</tr>
<tr>
<td>Using virtual microscope</td>
<td>2.00</td>
</tr>
<tr>
<td>Reviewing Lecture</td>
<td>1.00</td>
</tr>
<tr>
<td>Study using a textbook or notes</td>
<td>1.00</td>
</tr>
<tr>
<td>Using WebCT</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Total** 7.67
Appendix F – Reflections Form (Attitude Survey)

Information

<table>
<thead>
<tr>
<th>Education Level Achieved prior to undertaking current study:</th>
<th>Choose from the list</th>
<th>If you chose Other please give further details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td></td>
<td>Student No:</td>
</tr>
</tbody>
</table>

Reflections

Please complete your reflections using this form and use the Save As menu item to save your file with your Student No. at the end of the file name, e.g. reflections_0000000.doc to your computer. Submit the Reflections assignment by attaching your file to the Reflections assignment in your WebCT unit.

Please answer the following questions to provide your reflections about learning in the unit

Which microscope did you use for your lab?
- Optical
- Virtual

During the semester which microscope did you use most of the time?
- Optical
- Virtual

What did you like most about the optical microscope?

What did you like least about the optical microscope?

What did you like most about the virtual microscope?

What did you like least about the virtual microscope?

When you were doing activities with the microscope, were you mostly:
- on campus
- at home
- elsewhere

(please specify)

When you were doing activities with the microscope, were you mostly:
- working alone
- working with a group

Please specify approximately how many in the group

Describe how the activities with the microscope helped you to understand the course material more.

If you read more than the required texts, please specify where you found most of your resources, Please choose only one of the following?
- web
- library
- lecturers
- WebCT supplementary materials
- other people
- other, please specify

The following questions relate to your laboratory work.

Please put a cross in the appropriate box

The degree of interaction in my laboratory group was very high
- SA
- A
- NA
- D
- SD
- Or D

All members of my laboratory group worked equally well
- SA
- A
- NA
- D
- SD

Reaching consensus in the group was easy
- SA
- A
- NA
- D
- SD

I enjoyed working with this group
- SA
- A
- NA
- D
- SD

I found the laboratory group work to be an effective learning experience.
- SA
- A
- NA
- D
- SD

I was able to understand many of the theoretical concepts taught in this unit by doing the group lab activities
- SA
- A
- NA
- D
- SD

The WebCT unit provides an environment that encourages active learning (i.e. being responsible for my own learning).
- SA
- A
- NA
- D
- SD

How could your learning experience in the unit be improved?
Appendix G - Focus Group Questions

** Question for individual answer sheets only.

**Q1. What do you think your learning approach is?**
Q2. In your lab group did you use optical or virtual microscopes?
Q3. Would you prefer to use optical or virtual microscopes in the future? Give your reason(s) why.
Q4. In your lab group work, did you find the guidelines were clear?
Q5. Was it clear to you what your role was in the lab group activities?
Q6. Did you feel you had sufficient opportunity to contribute to the lab group activities? Give examples.
Q7. In what ways were you able to express your opinion in the lab group activities? Give examples.
Q8. In what ways were you able to influence your group to your way of thinking? Give examples.
Q9. What did you find most useful in the group work?
Q10. What did you find least useful in the group work?
Q11. What would you like to do more of in labs?
Q12. What would you like to do less of in labs?
**Q13. If there was a difference between your identified study approach and your own perception of what you thought it was can you explain why that might be?**
Appendix H – Interview Questions

Interview: Student ID _____________________________

1. At the beginning of semester you completed the Approaches and Study Skills Inventory for Students, what approach do you think you identified?
   Deep/Strategic/Surface

_________________________________________________________________________

2. How did you learn about histology/pathology in this unit? (What strategies did you use)?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

3. When using the microscope and identifying something on the slide that you didn’t expect to see how did you find out more about it?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

4. How did you find the workload influenced your studying in the unit?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

5. How did other units impact the workload in this unit?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
7. Did you change your approach to studying during the semester? Can you describe how?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

8. Is there anything else that you would like to add?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

Thank you for taking part in this study. I would like to send you a copy of the interview notes so that you can verify the contents. Can you give me an email address to send them to?
## Appendix I – Focus Group – Snippet of Coding

<table>
<thead>
<tr>
<th>No of St</th>
<th>Q3 Would you prefer to use O or V microscopes in optical - virtual are great for revision, but I like the finer control of light, focus of the optical scopes. The optical revision optical more real picture more easily</th>
<th>Prefer</th>
<th>Virtual</th>
<th>Optical</th>
<th>Optical/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Q3 Would you prefer to use O or V microscopes in optical - virtual are great for revision, but I like the finer control of light, focus of the optical scopes. The optical revision optical more real picture more easily</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
<tr>
<td>2</td>
<td>Optical - it becomes more real when the slide is a physical thing, you can picture move easily when the Optical - it becomes more real when the slide is a physical thing, you can picture move easily when the</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
<tr>
<td>3</td>
<td>Optical - I would like to have the skills to use the optical microscopes so that I can use them in my future career</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
<tr>
<td>4</td>
<td>Optical, I have played with the virtual and I didn’t feel like I had as much control over the viewing of the</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
<tr>
<td>5</td>
<td>Optical - get a better visual effect</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
<tr>
<td>6</td>
<td>Virtual - remove the nausea associated with extended periods of looking down the microscope</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
<tr>
<td>7</td>
<td>Both virtual is good for initial conceptualisation, optical is good for higher resolution and identifying</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
<tr>
<td>8</td>
<td>Virtual is much easier; you don’t have to deal with an optical machine (focusing, lighting, etc) and there is Virtual is much easier; you don’t have to deal with an optical machine (focusing, lighting, etc) and there is</td>
<td>Prefer</td>
<td>Virtual</td>
<td>Optical</td>
<td>Optical/2</td>
</tr>
</tbody>
</table>
REFERENCES


Tickle, S. (2001). What have we learnt about student learning? A review of the research on study approach and style Kybernetes, 30(7&8), 955-969.


