The Pedagogy Of The Operating Theatre

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towards the fulfilment of the requirements for the degree Doctor of Philosophy

(PhD)

supervised by

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Declaration of originality:

This thesis is my own work and constitutes original research conducted at Imperial College, London. Other authors and their work referred to in this thesis have been appropriately attributed and referenced.

Thesis abstract

(256 words)

This thesis outlines the findings of a large body of research work undertaken during 3 years of full-time study. The findings have already provided the author with helpful anchors for structuring formative feedback to surgical trainees within a simulation program, as well as helpful insights into her own learning.

This thesis explores the operating theatre as a teaching and learning environment for postgraduate surgical trainees. The work crosses paradigms and uses contrasting methodologies to provide rich insights into surgical pedagogic practice.

The first chapter is an introduction to the subject material, outlining the thesis aims and research questions, making clear why the research is important. The perspectives of the researcher are explained, in the first person, to make explicit her background and epistemological stance. The next chapter presents a narrative review of the literature, providing a background to the subject and a theoretical framework.

Chapters three to six constitute empirical work. The third and fourth chapters use a grounded theory method to explore surgeons' perceptions of the content and process of learning in the operating theatre. Chapter five uses case study methodology to illustrate teaching and learning in the operating theatre with concrete examples of pedagogic practice. The sixth chapter is a quasi-

experimental study of learning which makes comparison between different pedagogic styles.

The final chapter of the thesis draws together the findings from the empirical investigations. The personal development of the researcher is discussed in the first person and the body of research work is critically examined in view of its contribution to the field and its implications for future educational innovation.

Summary of major findings

Previous educational research has identified individual learners to have preferred learning styles. This research looks beyond the individual learner, one of the most striking findings was that different content areas of learning in the operating theatre require different learning processes.

Sensory semiosis (making sense of what the learner sees and feels) was found to be one content area of learning in theatre for the post graduate surgical trainee, not previously extensively investigated, that was made explicit by this research. Sensory semiosis was found to be learned through both experience and a process of co-construction between the trainer and trainee. Co-construction was observed to occur either through verbal exchanges between the two, or through physical-verbal exchanges if the trainee was in control of the surgical instruments.

The implications of these findings - for learners, teachers and the profession are then discussed in the closing chapter.

CONTENTS

List of figures

List of tables

List of still images and video clips

ACKNOWLEDGEMENTS

This thesis is the culmination of three years full-time work, preceded by two years of part-time study whilst undertaking a Masters degree in Surgical Education. During these five years most of my waking hours have been dominated by thoughts of surgical education - whether planning educational activities, devising simulations, conducting research studies, teaching junior surgeons or analysing teaching and learning in the workplace.

My thanks must go to my two supervisors, Professor Roger Kneebone and Professor George Hanna. Over the last 5 years they have encouraged me to think in new ways and to try different approaches to research, whilst providing a stimulating and supportive environment for me to grow as a researcher.

I benefitted hugely from being the recipient of a Royal College of Surgeons of England (RCS) research fellowship and also the RCS Harry Morton travelling fellowship, which enabled me to spend four months in Canada at different higher educational institutions. Particular mention must be made of the Canadian academics, Professor Stan Hamstra, Dr. Carol-Anne Moulton and Professor Lorelei Lingard who influenced my thinking profoundly during this research. I wish to thank them personally, for giving so generously of their time to discuss my data with me and guide me in analysis, as well as for making me feel so at home in their institutions in Canada.

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CHAPTER 1 - Background to this thesis

The operating theatre is a complex work environment that also has to function as an educational environment. Teaching and learning occurs for a number of different professional groups. Junior scrub nurses, anaesthetists and surgeons spend long hours in the operating theatre when training during which time they aim to learn what is required to become competent within their own professional area.

For all of these professional groups, much of the learning occurs during the process of patient care, so that education occurs at the same time as service provision (Lyon 2004). This learning may be implicit and embedded within the clinical activities that are being performed (Svensson, Luff et al. 2009). So, whilst this workplace-based pedagogic activity does follow a curriculum, it is dictated by the activities and tasks going on in that environment. This may be considered to be a learning curriculum, and is characteristic of learning within a community of practice (Lave and Wenger 1991). The attributes that are being learned, may or may not be perceived as being learned by the teachers or the learners. These areas of learning may constitute a '*hidden curriculum',* which is invisible to both the learners and teachers (Snyder 1970) but is absorbed by being within the theatre environment. Meighan describes a hidden curriculum within the school setting, but learning 'how to be a surgeon' occurs in a similar way over the course of many hours spent within the operating theatre environment (Pope, Smith et al. 2003).

> “*The hidden curriculum is taught by the school, not by any teacher...something is coming across to the pupils which may never be spoken in the English lesson or prayed about in assembly. They are picking-up an approach to living and an attitude to learning.”*
>
> (Meighan 1981)

This lengthy period of time spent working under supervision and learning at the same time, may be considered to be an apprenticeship model of training. Learning takes place ‘on-the-job,’ during the course of assisting and performing parts of various different operations (Lave and Wenger 1991). Features of an apprenticeship include membership of a group, construction of identity, developmental cycles during learning and a lengthy period of time working under the supervision of a ‘master’ (Lave and Wenger 1991).

The thrust for this research comes upon the back of recent reforms in surgical training as well as changing public expectations, which have led to a dissolution of the traditional apprenticeship model of training in surgery. Firstly, in 1993 the Calman report put forward a revised structure to surgical training in which the Senior Registrar grade was abolished, and a programme for progression through the tiers of the hierarchy was established (Calman 1993). These reforms limited the total number of years that a learner could spend in surgical training, with a clearly defined end point marked by the Certificate of Completion of Training (CCT) (Calman, Temple et al. 1999).

Secondly, the European Working Time Directive (EWTD) legislation, which was originally intended for manual workers operating machinery, was applied to the medical workforce. Since August 2009 junior doctors have been limited to working an average 48 hour week. It was estimated that pre-Calman reforms and European Working Time Directive that 30,000 hours were spent in surgical training, and that this would reduce to around 8,000 hours (Philip, Fleet et al. 2003) perhaps even to 6,000 hours if the Senior House Officer grade were reformed (Donaldson 2002). In a landmark editorial in the BMJ Chikwe et al. stated that as a consequence of both the Calman reforms and the application of the EWTD legislation, surgical trainees were passing through training programmes with fewer hours of experience (Chikwe, De Souza et al. 2004). The result of these changes means that the apprenticeship model of how learning happens, occurring through many hours spent working under the supervision of one ‘master’, seems no longer applicable to contemporary learners.

Public expectations have also changed with the medical profession needing to be accountable to their patients. Apprenticeship style training does not involve objective assessment of competency - progression is purely at the discretion of the master craftsman or in this case surgical trainer. In an apprenticeship model, progression to full participation as primary surgeon, rather than assistant, is not based upon objective assessment of competency, but on an expert judgement. Progression to higher levels of participation is as the master sees fit, there is no testing in an apprenticeship model, the trainee moves on to the next stage when the master is satisfied with his or her ability.

Opportunities for surgical trainees to obtain hands-on experience have diminished due to concerns about the high-risk nature of the clinical task (Raja and Levin 2003). Issues around the acceptability of trainees 'learning' on real patients have been raised, with government demands for a 'Consultant delivered service'.

There is mounting evidence that clinical tasks, such as operations performed by trainees working under supervision, take a longer time to complete (Crofts, Griffiths et al. 1997) (Coates, Kuehl et al. 2001) leading to decreased efficiency of the theatre. Hospitals are increasingly being run as businesses and maximising output of the theatre complex may lead to curtailment of learning opportunities for trainees (Schwind, Boehler et al. 2004).

The result of these training reforms and changes in public expectations has meant that the traditional apprenticeship model of surgical training is no longer applicable or a good way of understanding how learning happens in the workplace. Surgical training is in a transition period, moving towards a systematic educational program in which progression is based upon competence, as determined by assessed performance, rather than time in service. Post-graduate training programs have already moved to this model of progression in Canada (Alman, Ferguson et al. 2013). It is not currently known to what extent diminished exposure due to the restriction of hours will affect acquisition of end competencies. It has been suggested that in an hours-restricted training system, competencies may be gained through better quality training in the shortened time available (Lyon 2003) (Tooke 2008).

Some authors note that many hours spent by junior trainees and students in the operating theatre are not focussed upon their learning needs, but solely on service provision – holding a retractor for example - and suggest that this learning time could be used more 'effectively' (Schwind, Boehler et al. 2004) (Fernando, McAdam et al. 2007).

One of the difficulties with 'improving the training' is that little is currently known about the content of learning in the operating theatre, and even less about the best educational strategies for learning different content areas. There is an urgent need for systematic and thorough exploration of what is learned in the operating theatre and the processes through which this learning takes place. This information is a pre-requisite for designing competency-based curricula. The aim of this research is to make explicit both the content areas of learning in the operating theatre, or learning curriculum for general surgical postgraduate trainees; then to make inquiry into the processes of learning utilised by surgical trainees in specific content areas.

1.1 Research Questions

- What are the content areas of learning in the operating theatre for post-graduate general surgery trainees?

- What processes of teaching and learning are used in the operating theatre?

- What are the most effective pedagogic strategies for these learners in the operating theatre?

1.2 Thesis aims

This thesis aims to shed light upon what is learned in the operating theatre and what processes of teaching and learning are utilised in the post-apprenticeship era.

By making explicit the content and process of surgical learning in the operating theatre this research will lay out a foundation upon which educational innovations may be built. This broad framework may be used to design effective pedagogic interventions for use in either the workplace or in simulation.

1.3 Perspectives

Prior to commencing writing this thesis, I had been a higher surgical trainee with a deep interest in surgical education. I had been qualified as a doctor for 10 years and was well into my post-graduate surgical training, having worked as a Specialist Registrar in general surgery for five years. I had two years of training left to complete, and imagined myself working as a colorectal surgeon in a District General Hospital with a busy clinical practice. I thought that my involvement in teaching would be solely in the clinical workplace, instructing trainees assigned to me, and teaching the occasional passing medical student upon whom I would impart knowledge. Writing this thesis has completely transformed my views about education, the way in which knowledge is constructed, as well as my own career aspirations and ideas about how I will be involved in surgical education in the future.

I registered for a PhD after completing a Masters degree in Surgical Education. The Masters level study was hugely stimulating and challenging and was instrumental in my decision to undertake a formal period of research beyond my clinical training, as an Out Of Program for Research (OOPR). To put this into context, I was at a point in my career where I was relatively comfortable working as a middle-grade surgical doctor in a clinical setting. Whilst I was still learning more advanced surgical procedures in the operating theatre and some of the more complex decision-making processes around operative management, much of my time was spent fulfilling service requirements of the clinical workplace. After commencing the Masters in

Surgical Education suddenly my enthusiasm was unleashed and my thoughts raced as I heard about surgical policy from the policy makers themselves, I realised that there was e-learning and virtual worlds were being used for surgical education and I had a taster of conducting a piece of educational research. Producing my Masters dissertation encouraged me to reflect upon different qualitative methodologies and how they could be used in educational research. This fuelled my interest in pursuing a formal period of study towards a PhD degree and led me to embarking upon writing this thesis.

I have been heard to say that writing this thesis has been the hardest thing that I have ever done, and whilst this is true, it has been an enjoyable transformative journey. Dr. Carol-Anne Moulton said upon writing her thesis that she set out to 'do surgical education research' but in the process 'became a surgical education researcher'. This strongly resonates with my own feelings about the transformation that occurred in me from a clinician who arranged time out of program to 'do a PhD in surgical education' into a 'surgical educator and researcher', committed to career-long, joint academic and clinical practice.

This transformative journey has been hard, and at times I have felt isolated, misunderstood and ostracised. Some of the greatest challenges have been when the critique has come from within my own community of surgeon researchers, due to differing basic assumptions as a consequence of having differing research paradigms. Critical examination of my own assumptions has been an essential part of developing my own views on the values of research conducted in alternative research traditions.

During this thesis I have deliberately set out to use a range of research approaches. The first empirical investigations use grounded theory method in the context of an interview study to investigate content and process of learning in the operating theatre. The second phase of empirical investigation uses case study method in the context of an observational study of teaching and learning in the operating theatres. The final investigation is of quasi-experimental design using simulation as an experimental laboratory to investigate different teaching methods and the resultant objective change in learner performance during a simulated operation. Use of these differing research methods has been in part, in response to the differing research questions, and in part to make the findings accessible to clinicians for whom there are practical implications. This deliberate ploy to understand and utilise contrasting approaches has allowed me to experience and understand the strengths and limitations of the different research traditions.

1.4 Different research paradigms and epistemology

At the start of the period of full-time study for this PhD, my understanding was that there were two main paradigms of surgical education research – quantitative and qualitative. My supposition was that quantitative research was superior, due to the ability to perform a statistical analysis, generate a p-value and make generalizable conclusions. My initial stance was that it was preferable to have a numeric measure, perhaps one created from qualitative data – for example using a Likert scale to convert subjective opinion into a numeric value (Likert 1932), or alternatively a frequency count of particular themes in interviews being used as a surrogate measure of the importance of the theme to the interviewees.

During the course of writing this thesis I have reflected upon these assumptions, and have increasingly found myself wondering about the value of numeric data derived from qualitative data sources, especially whether steering respondents to select from a pre-formed list of statements constructed by the researcher actually robs any meaning intended by the study participant.

> *"Not everything that can be counted counts, and not everything that counts can be counted."*
>
> attributed to Albert Einstein

The two paradigms of research do tend to correspond to the answering of quite different questions, with each offering specific advantages and limitations. During this research I wanted to use qualitative data in all its richness to inform the reader fully about the phenomenon of interest, but also to present useful generalizable findings that may be beneficial to surgical educators. I decided to conduct mixed method research, as I thought that this would afford both the richness of detailed analysis as well as some generalizable conclusion. I also thought, and others too, that using mixed methods would increase the reliability of the conclusions (Schifferdecker and Reed 2009).

The qualitative aspects of this work were particularly challenging to present to clinical audiences. This was in the main due to the differing assumptions of what constituted methodological rigour, as the expectation was that an *n* number and *p* value were the optimal parameters, to inform the audience of the thoroughness of the investigation. Presenting the findings at surgical meetings also created logistical challenges as presentation slots were very short - I was given a 3 minute presentation slot at the Society of Academic and Research Surgery (SARS) meeting - and it was difficult to present the minute analysis of video data to the audience within such a short time-frame. Successful presentation of the qualitative data required much practice, I am deeply grateful to Carol-Anne Moulton and Lorelei Lingard for their helpful insights into how to make the methodology understandable and accessible to clinical audiences. Through experience at a variety of different academic meetings I found that selecting and presenting a very small sub-segment of the qualitative data assisted the audience in understanding the depth of analysis and in conforming to the tight presentation slots.

The next step in the journey of becoming a surgical education researcher was to develop an understanding of inductive and deductive research, and the merits and suitability of these in answering research questions. Inductive research seemed most suited to my first two research questions where a divergent response was required resulting in a multiplicity of different answers, but which did not show me which was the most powerful or influential. Deductive research, in contrast, might be more appropriate when trying to ascertain relative importance between factors or superiority.

At this point, I still regarded inductive inquiry as preliminary work prior to the main study. During the course of writing this thesis my view of inductive research has altered. Now, I would maintain that it is important in its own right, that the findings are substantial, without the need to go on to investigate the relative influences of the themes that were uncovered, although of course a researcher may choose to do so.

The other perspective with which I have wrestled during the writing of this thesis is the philosophical debate between positivism and interpretivism and where my own epistemological stance is within this spectrum. I should start by making explicit that my background has been a strongly positivist one. Broadly speaking, medicine is regarded as a science, and much of the undergraduate medical curriculum is articulated as if there is absolute knowledge and certain truths with right or wrong answers. Montgomery cautions against regarding medicine as a science and asserts that clinical judgment is essential to medical practice even in a 'highly scientific, technologized era' (Montgomery 2006). The positivist culture of medical schools is further propagated through examination systems for example single best answer questions and pedagogic interactions such as quizzing medical students for the ‘correct’ answer.

Certainly, when embarking upon this research I equated positivism only with quantitative methodology and interpretivism with qualitative methods, which exhibited my deep scepticism of the rigor of qualitative research with its subjective interpretations. During the course of my PhD I have found myself reflecting not just about my research but also upon clinical practice, and wondering how these assumptions about the world and philosophical beliefs may shape surgical work. Take the example of a surgeon dissecting out a structure – a positivist would assert that the structure was always there, waiting to be uncovered and dissected out from the inflammatory tissue by the surgeon; the interpretivist however, would suggest that the surgeon sculpts out, by careful dissection, a structure from a mass of inflammatory tissue, and then he, the surgeon names it. These belief systems have wide implications for the philosophy of clinical practice especially when considering complications and ways of understanding surgical error.

My change in epistemological stance has come about after reflecting on how, in all research paradigms, researchers themselves shape interview schedules, make choices about what to observe, set up experiments in a particular way and so, in the course of collecting their data, they will have made choices which influence the outcomes of the research. The traditional positivistic view, that scientific research is a search for an objective reality, where the researchers themselves are incidental to the research and not influential to the process, did not seem to me to be entirely congruent with my own experiences of conducting research. I have been intimately involved in my own research and certainly have had a part in shaping the findings. I therefore started to think that the researcher could not be regarded as entirely detached from the findings of their research. My response to this has been to take a reflexive stance, to look at the choices critically that I have made as the research progressed and to highlight these to the reader.

I am still unsure of my own exact place along the spectrum between positivism and interpretivism, however think I am most comfortable with my views being described as post-positivist. This is illustrated by my assertion that a surgical education researcher with a similar background to my own would obtain comparable, although not identical findings, if they were to conduct similar research. And, I concede [I am viewing this as a negative] that in conducting this research, I have been intimately linked with the issues and questions, and have made choices that have undoubtedly shaped the findings. These choices and the rationale for them will be discussed and brought to the attention of the reader, throughout this thesis, this may be regarded as taking a ‘reflexive stance’ or the ‘limitations’ of the study depending upon the perspective of the reader.

CHAPTER 2 - Literature review

2.1 Introduction

At the start of this research it was essential to establish what was already known about postgraduate surgical learning in the operating theatre. This was accomplished through a thorough and in-depth review of the literature as it stood at the outset of the period of research. This initial literature review was then supplemented by a number of other key papers that were published within the duration of the research including a couple of papers from associated projects within my own research group.

There are several methods by which the published literature may be reviewed, each review methodology has inherent advantages and disadvantages and some discussion and explanation of the approach chosen for the purpose of this thesis is warranted.

This chapter starts by providing a theoretical framework from the educational literature. This is a brief summary of the works and ideas of some of the major educational theorists whose ideas have relevance for this thesis. This is to provide some background for the reader unfamiliar with the educational literature. This chapter then goes on to outline the rationale for a narrative literature review. This discussion about choice of type of literature review perhaps provides the reader with further insights into the transformational change that occurred in the researcher over the course of writing the thesis.

The narrative review of the literature is then presented in two distinct parts - firstly a summary of what is known about content of learning in the operating theatre and then secondly a summary of what was known about process of learning in the operating theatre.

The overview of relevant articles that is presented is designed to provide the reader with a sound starting context for the original research described in this thesis. The literature has been selected by the author to showcase the diversity of the existing corpus of literature as well as to pinpoint some key papers for the reader.

2.2 Theoretical framework

The literature on educational theory is vast and cannot be comprehensively reviewed as part of this thesis. The authors and works that are presented here are highly selective and have been chosen as holding relevance to adult learning in the workplace. A huge body of literature on child development and school teaching is omitted as not directly appropriate. The aim of this theoretical framework is to provide some key threads for the reader, from a range of different authors, in order to assist the reader's understanding of the theoretical constructs behind the ideas explored in this thesis.

2.2.1 The Constructivists and experiential learning

The constructivist school of learning is underpinned by the assumption that, of necessity, learning is grounded in each learner's personal experience.

"*For the things we have to learn before we can do them, we learn by doing them*"

Aristotle 380 – 322 BC

John Dewey 1859 – 1952

Dewey was primarily a philosopher who believed "*every idea, value and social institution originated in the practical circumstances of human life*" (Palmer 2010). Education was the construction and reorganization of experiences that added meaning. Dewey asserted that truth did not represent an idea waiting to be discovered; it could only be realised in practice. Although much of his writing covered schools and pedagogy within the school system, many of his ideas are relevant to the adult learner as he believed that there was an essential relationship between human knowledge and social experience (Dewey 1916). His ideas hold clear relevance to experiential learning in the workplace.

Lev Vygotsky 1896 – 1934

Vygotsky on the other hand was a psychologist, best known for his inter-disciplinary work between psychology of art, literary theory, neurology and psychiatry. Similarly to Dewey, Vygotsky studied children to obtain a better understanding of adult learning. He observed that when copying, a child was able to perform much better when guided by adults than when working alone. Vygotsky defined ZPD as *"the distance between the child's actual developmental 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."* (Vygotsky 1978) The assistance and guidance provided by the adult has been termed "scaffolding".

Vygotsky also wrote about 'inner speech', which to him was important to link the invisible thoughts of a subject and their speech. According to Vygotsky "*the process of trying to communicate with others results in the development of word meanings, that then form the structure of consciousness*" (Palmer 2010). The behaviourists at that time thought that inner speech was merely overt speech, the same as talking to oneself in terms of content. However Vygotsky thought that inner-speech was closer to the inner-thoughts of the person and these were not necessarily the same in terms of content. Inner-speech, to him, was rudimentary ideas and thoughts of the individual.

Jean Piaget 1896 - 1980

Piaget was one of the most influential constructivists. He defined education as linking:

'on the one hand the growing individual (and) on the other hand the social, intellectual and moral values into which the educator is charged with initiating that individual'. (Piaget 1971)

Piaget's view was that teachers, in one generation, use their intellectual and moral values in the education of learners in the next generation. Piaget also wrote about autonomy in learning – not that learning should be solitary, nor an anarchy where learners do what they want, but that learners should want to do what they do.

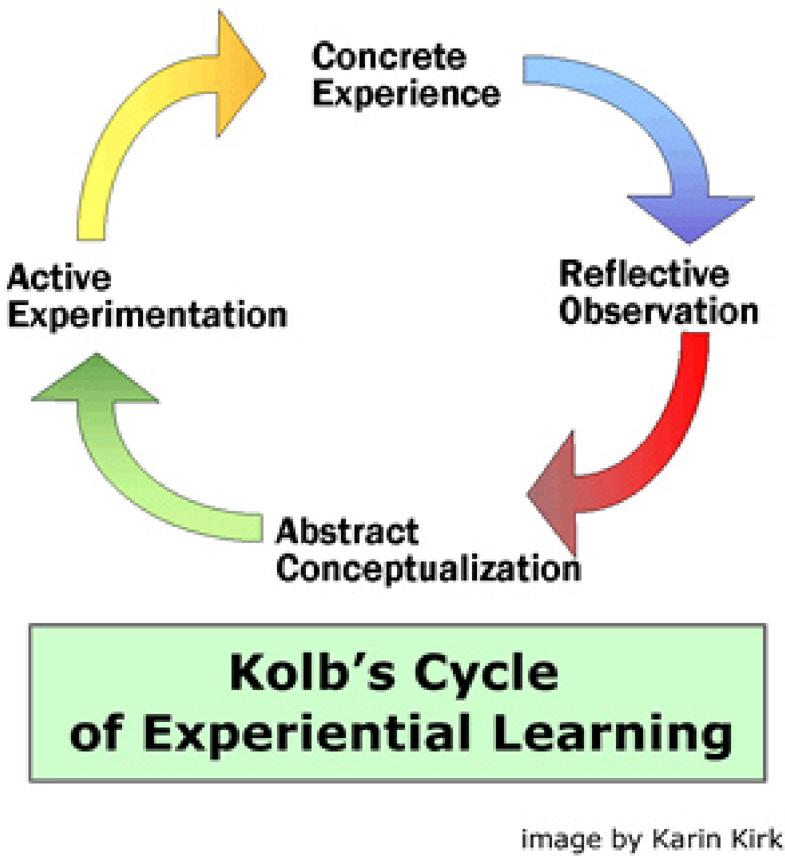
Donald Schön 1930 - 1997

Schön's work has profoundly influenced education within the health professions by highlighting the need for reflection in professional practice to aid learning (Schon 1983). Schön outlines differences between 'reflection-on-action', occurring post-hoc the event and 'reflection-in-action' which takes place contemporaneously. He was interested in ‘thinking on one’s feet’ and the ability to improvise. In his book ‘The reflective practitioner’ he challenges practitioners to reconsider the role of technical knowledge versus artistry suggesting that the ‘expert’ is able to make small alterations to improve the appearance of the whole (Schon 1983).

David Kolb 1939 -

David Kolb is a modern philosopher best known for his learning cycle, which includes Schön’s ideas of reflection but places them within a cycle of concrete experience and abstraction of ideas.

Figure 1: Kolb's experiential learning cycle



Kolb's model is a four-stage learning cycle with:

- Concrete experience
- Reflective observation
- Abstract conceptualization
- Active experimentation

Kolb states that learning is an iterative cycle through these stages - "*knowledge is continuously gained through both personal and environmental experiences*" (Kolb 1984)

He states that in order to gain genuine knowledge from an experience, certain abilities are required:

- The learner must be willing to be actively involved in the experience
- The learner must be able to reflect on the experience
- The learner must possess and use analytical skills to conceptualize the experience
- The learner must possess decision-making and problem solving skills in order to use the new ideas gained from the experience.

Kolb and Fry went on to characterise different learners or learning methods into different "learning styles" – convergent, divergent, assimilative and accommodative (Kolb and Fry 1975). They then situate these learning styles between points of Kolb's learning cycle.

Kolb and Fry argue that identifying the learning styles of the students is essential to best tailor the educational methods to them (Kolb and Fry 1975). The learning styles that they outline are:

- Convergent: Abstract conceptualization and Active experimentation. These learners are good at making practical applications from ideas and using deductive reasoning to solve problems.
- Divergent: Concrete experience and Reflective observation. These learners are good at offering original ideas and seeing things from different perspectives.
- Assimilative: Abstract conceptualization and Reflective observation. These learners are capable of making theoretical models through inductive reasoning.
- Accommodative: Concrete experience and Active experimentation. These learners are good at actively engaging with the world rather than reading and studying it.

Kolb created the 'Learning inventory', which may help classify learners into one of these categories, to assist teachers in formulating best individual educational design.

Jean Lave and Etienne Wenger 1939 - and 1952 -

Lave and Wenger are well known for their work on socially mediated learning. They examined learning within diverse social communities within the context of apprenticeship (Lave and Wenger 1991) looking at five different situations where learning occurs in an apprenticeship style. They created a sociological analytical model that could be used to look broadly at other circumstances.

The book Situated Learning explores the apprenticeship learning of Yucatec midwives, Vai and Gola tailors, butchers, US Navy quartermasters and non – drinking alcoholics. Lave and Wenger reported that all of these groups had similar patterns in the style of their apprenticeship and these features were cardinal of apprenticeship style learning.

Common features of apprenticeship learning identified by Lave and Wenger include:

- Membership and construction of identity
- Location and organisation of mastery in communities
- Problems of power, access and transparency
- Developmental cycles in communities of practice and change
- Contradiction between continuity and displacement

Lave and Wenger purport that apprenticeship learning occurs through a process of ‘legitimate peripheral participation’. They make clear that this term is to be used as a phrase with its own meaning rather than a composite of the individual terms ‘legitimate’ or ‘peripheral participation’. They use it to mean belonging to a ‘community of practice’ within which the learner has his or her own place and role. Lave and Wenger are clear that in their model of legitimate peripheral participation there is no ‘core’ or ‘centre’ but instead peripheral participation leads to full participation. The 'legitimacy' describes the students ‘right’ to be there, the student must be an accepted member of the ‘community of practice’.

Lave and Wenger assert that during these apprenticeship schemes the student changes identity. Perhaps due to the lengthy periods of time the student spens with the master and perhaps due to the student's desire to please the master, they observed that apprentices eventually behaved in a similar way to the 'master' and shared many of their interests, beliefs and attitudes.

'Legitimate peripheral participation gives a sketch in the learners mind as to how the masters themselves talk, walk, work and how they conduct their lives.' (Lave and Wenger 1991)

They concluded that apprenticeship appeared to change the identity of the person undergoing the training.

Miller and Boud 1949 – and 1955 -

Miller and Boud also wrote about experiential learning but provided further insights into how learning was stimulated. They break away from formal hierarchical words such as teacher or trainer and write about an 'animator' (Boud and Miller 1996). They see 'animators' as those who can foster learning through experience – not necessarily in formal teaching roles, but in each learning setting.

"*Animators act with learners, or with other, in situations where learning is an aspect of what is occurring, assist them to work with their experience."*

(Boud and Miller 1996)

Another key concept put forward in this book is that the animator needs to be able to withdraw when their support is no longer required *"animators need to operate in ways in which to make their own interventions increasingly* *redundant, thereby avoiding the use of their own power to create dependency and thus exercising control over learners"* (Boud and Miller 1996)*.* These ideas strongly resonate with Vygotsky's "scaffolding" principles.

K. Anders Ericsson 1955 -

Ericsson's ideas are mentioned both within the narrative review of the literature and also here within an outlining of the theoretical framework. This is because much of his work has been based upon empirical study of musicians, sportsmen and women and chess players. Ericsson's body of work has been substantial and as a result he has been able to theorise broadly about learning, in general, from his empirical findings.

Ericsson's work is centred upon transitioning from a competent performer to an expert, rather than the initial stages of learning. He stated that

> *"the key challenge for aspiring expert performers is to avoid the arrested development associated with automaticity and to acquire cognitive skills to support their continued learning and improvement"* (Ericsson 2004)

Ericsson theorises that 'sustained deliberate practice' is required to re-stimulate the learning curve for further improvement beyond the plateau of competence. He describes how national level chess players do not get better by playing chess games at their local chess club but by studying published games between the very best chess players in the world:

> *"…they play through the games one move at a time to determine if their selected move will match the corresponding move originally selected by the*

master. If the chess master's move differed from their own selection, this would imply that their planning and evaluation must have overlooked some aspect of the position. By more careful and extended analysis, the chess expert is generally able to discover the reasons for the chess master's move" (Ericsson 2004)

Ericsson writes that transitioning from a competent performer to an expert performer requires slow deconstruction of the expert performance and understanding of how it differs from competent performance. Deliberate practice of the isolated segment is required until expert performance is achieved. Ericsson writes that achievement of expert performance in the majority of domains, is as a result of this type of self-critique and sustained deliberate practice, rather than congenital advantages.

2.3 Literature review

There has been a strong trend within clinical medical research to perform systematic literature reviews, rather than a traditional narrative reviews, as a way of summarising research evidence. The systematic review is based upon a clearly formulated question and the review then identifies relevant studies, appraises their quality and summarizes the evidence by use of explicit methodology. It is asserted that the well-defined methodology means that the literature papers collated are less likely to be biased by the perspective of the researcher. Other advantages of a systematic literature review are that it can provide information about the effects of a phenomenon across a wide range of settings and empirical methods, in addition, data from quantitative studies in a systematic review may be combined using meta-analytical techniques, increasing the likelihood of detecting real effects left unexposed in smaller individual studies. These advantages are very laudable and it is understandable why the systematic review has gained such popularity within the scientific community. However, for some research topics the strengths of the systematic review may turn into weaknesses. The narrow focus of the review question and the strictly prescribed methods of data collection may not allow for comprehensive coverage of the subject matter.

Hammersley criticizes the assumptions made by systematic reviewers, as positivist models of research may be more favourably evaluated due to the methodological criteria applied (experiments are more highly valued). He concludes:

"… judging the validity of the findings and conclusions of particular studies, and thinking about how these relate to one another, and how their interrelations can be used to illuminate the field under investigation. This will require the reviewer to draw on his or her tacit knowledge, derived from experience, and to think about the substantive and methodological issues, not just apply replicable procedures."

(Hammersley 2001)

Narrative reviews, allow the reviewer to draw upon his tacit knowledge of the field and allow coverage of a wide range of issues within a given topic; but do not necessarily state or follow rules about the search for evidence. The reader, therefore, trusts that the author has made unbiased choices and has selected items for inclusion based upon their extensive reading and expertise in the field. Information about the author himself, his background, institution and own research work, may become important to the reader when weighing up whether a narrative review holds value.

It was made explicit, in the 'Perspectives' section of this thesis, that the researcher set out on this journey into research as a positivist, and believed that a review of the literature was an objective task, in which she would be incidental to the review process and not influential upon the selection of articles for review. This perspective made the concept of narrative review, with researcher selection of articles, flawed; and despite the broad scope of the research questions, the researcher believed that the most scientifically rigorous means of reviewing the literature was to perform a systematic literature review. The initial systematic review including the search strategy and retrieved articles are presented in Appendix A. Further synthesis and evaluation was not undertaken, as a number of key articles essential for the reader, in order to follow the story of this thesis, were not identified through systematic review, despite multiple iterations and refinements of search strategy.

This then led the researcher to contemplate performing a narrative review. One of the strengths of narrative review is that it can address much broader questions than an empirical study alone and can incorporate relevant material that may be missed by the strict criteria of a systematic review. Narrative literature reviews are said to be vital in bridging the gap in interpretation as certain broad conclusions may lie forever beyond the reach of any single investigation, in particular when single empirical studies include small numbers. A literature review can examine and integrate the results of dozens of studies and by

> *"…focusing on patterns and connections among many empirical findings, a literature review can address theoretical questions that are beyond the scope of any one study."*
>
> (Baumeister and Leary 1997)

Narrative literature review seemed more appropriate in these circumstances to bring together the diversity of the published literature on teaching and learning in the operating theatre. This narrative review of the literature does not aim to mention or reference every relevant published paper on the topic. It instead uses selected key papers to illustrate the types of studies that have been conducted and a broad overview of their findings.

2.4 Narrative review

This narrative review of the literature will be presented in two distinct parts, firstly a review of content that is known to be learned in the operating theatre and then secondly a review of what is known about the process of learning in the operating theatre. The literature has been selected by the author of this thesis to showcase the diversity of the existing corpus of literature as well as to pinpoint some representative papers for the reader.

2.4.1 What is known about content of learning in the operating theatre

The systematic database search pointed to a large body of literature reporting differences between objectively measured skills of fully trained Consultant level surgeons and post-graduate trainees. This seemed a reasonable start point for outlining what was already known about content of learning in the operating theatre. Amongst these studies a multitude of different parameters were used to measure the surgeon's skill. One of the recurrently measured parameters was time to complete a particular defined task (Bermas, Fenoglio et al. 2004) (Oostema, Abdel et al. 2008) (Datta, Mackay et al. 2001) (Dubrowski, Sidhu et al. 2005). These studies and multiple others found Consultant surgeons to be significantly faster than post-graduate surgical trainees at completing a defined surgical task. Yet, instinctively, one realises that post-graduate surgical training is not solely about making the trainee faster at a procedure that they are already able to perform. Fast surgeons are not generally equated with being good surgeons (Darzi, Smith et al. 1999) and whilst the author supposes that speed may be linked to familiarity with the procedure, she would assert that speed is a secondary end-point of the surgical learning, rather than an object of learning in itself.

Other studies used motion analysis, recording hand path-length and number of movements as well as time taken (Datta, Mackay et al. 2001) (Oostema, Abdel et al. 2008) (Woodrum, Andreatta et al. 2006). These and other studies found differences in these measures of efficiency between Consultants and trainee surgeons. Mason's recent systematic review of studies that used motion tracking for assessing laparoscopic skill concluded that these measures of efficiency or economy of movement could reliably differentiate between experienced and novice surgeons (Mason, Ansell et al. 2012), perhaps suggesting that economy of movement is learned during postgraduate training.

Other studies have used motion analysis to examine differences in the **quality** of the movements for example the smoothness of hand movements (Dubrowski, Sidhu et al. 2005) (Oostema, Abdel et al. 2008) and force-torque signatures (Rosen, MacFarlane et al. 1999). These studies showed that Consultant surgeons had different hand movement characteristics to trainees. The amount of force required to distract the tissues without causing unnecessary tissue trauma may be plausibly a primary content area of learning during post-graduate surgical training. However, the smoothness of the hand movements seems unlikely to be primary content area of surgical learning, but rather a secondary end-point as a result of experience.

There is a large body of literature that examines patient outcomes when trainees operate, and compares these with fully trained surgeons (Akingba, Deniseiko-Sanses et al. 2008) (Bakaeen, Dhaliwal et al. 2009) (Baskett, Kalavrouziotis et al. 1236; Baskett, Buth et al. 2002) (Borowski, Ratcliffe et al. 2008) (Caputo, Chamberlain et al. 2001) (Gulbins, Pritisanac et al. 2007) (Gundevia, Whalley et al. 2008) (Hassan, Koller et al. 2006) (Moorthy, Asopa et al. 2004). These studies found that patient outcomes were no different when the trainee was in charge of the operating instruments, provided they were operating under supervision.

One of the challenges of interpreting studies looking at patient outcomes are that they are often retrospective and non-randomized leading to selection bias (consultants doing the more complex cases) which may explain why no differences in outcomes were found between post-graduate surgical trainees and Consultants' operating. However, the large number of published papers cannot be ignored. A handful of studies have attempted to tackle this question in a more scientifically rigorous way by either adjusting for patient factors (Sethi, Hammermeister et al. 1991), or prospectively randomising patients to being operated on by a surgeon or a trainee under supervision (Acun, Cihan et al. 1001) (Rijbroek, Wisselink et al. 2003). These studies also found no difference in patient outcomes when a trainee was the primary operating surgeon. This may be because patient outcomes are multi-factorial and so it may not be possible to find a statistical difference between fully trained and trainee surgeons amongst the large number of other variables. However, these studies suggest that the level of experience of the surgeon handling the surgical instruments did not affect patient outcome. This provides some evidence that hand skills are perhaps not the only important content area of learning in the operating theatre.

There are a handful of papers in the published literature that have found that expert and novice surgeons look at the operative field in different ways. Law et al. used eye gaze tracking during computer based surgical simulations and found that eye movements differed between experts and novice surgeons (Law, Atkins et al. 2004) these findings were confirmed by Kocak who recorded eye movements during laparoscopic tasks in a box trainer (Kocak, Ober et al. 2005). Richstone then examined eye metrics in both simulated and live operating theatres and found that eye tracking could reliably distinguish between expert and novice surgeons in both of these environments (Richstone, Schwartz et al. 2010). These papers found that expert and novice surgeons move their eyes differently during operations, however eye movements themselves are clearly not an important content area of learning in the operating theatre. Like hand metrics, the differences in eye-movements would appear to be secondary end-points as a result of learning something else.

There are a large number of papers examining construct validity of surgical scoring systems. Validated scoring systems, such as Objective Structured Assessment of Technical Skill (OSATS) (Reznick, Regehr et al. 1997) (Broe, Ridgway et al. 2006) can reliably distinguish between fully trained surgeons and trainees when performing real surgical tasks (Beard, Choksy et al. 2007) (Goff, Nielsen et al. 2002) (Swift and Carter 2006). The OSATS scoring system has been validated both in the workplace and in simulation. The scoring system uses expert raters to make judgements, in seven domains, using descriptors of each attribute to aid matching. The seven-item scale includes the following items:

- Respect for tissue
- Time and motion
- Instrument handling
- Knowledge of instruments
- Use of assistants
- Flow of operation and forward planning
- Knowledge of specific procedure

Whilst items such as 'time and motion' are likely to reflect secondary end-points of learning, other items included in this rating tool such as 'knowledge of specific procedure' and 'respect for tissues' may start to articulate primary content areas of learning in the operating theatre. For example, the OSATS scale item 'respect for tissues' asks for expert judgements to be made about the 'appropriateness of the actions' for the tissues being handled (Datta, Bann et al. 2004).

Other published literature that finds differences between Consultants and trainees in terms of the 'appropriateness of their actions' comes from commercial simulators. The ProMIS and LapMENTOR attempt to give insight into the quality of surgical work through their inbuilt metrics including an error score. The surgeon is penalised by the simulator if they dissect in the incorrect place or cut the incorrect structure. These types of errors are weighted in terms of severity by the in-built simulator software and this generates an error score. These error scores have also been shown to reliably differentiate between fully trained surgeons and trainees (Woodrum, Andreatta et al. 2006) (Kobayashi, Jamshidi et al. 2011) (Francis, Hanna et al. 2002) suggesting that procedure specific content such as the order in which the steps of a procedure should be undertaken and where to dissect next are content areas of postgraduate surgical learning.

An alternative body of literature, speaks about professional judgements of expert surgeons in determining the 'appropriateness of actions', although does not make any comparison with learner surgeons. Moulton writes about "slowing down when you should" (Moulton 2010) which is a marking of the transition from 'automatic' to 'effortful' functioning. Moulton hypothesises that this ability of the surgeon to 'slow down' is an important factor in expert performance. Her data was gathered through iterative interviewing and observational work in the operating theatre and her findings were that expert surgeons were able to transition into a more effortful mode of working when required to do so (Moulton, Regehr et al. 2010).

Moulton describes an expert surgeon as being able to 'remain attentive in automaticity'. This term 'situational awareness' has been used to describe similar heightened awareness in the literature and there is evidence that ‘situational awareness’ is linked to superior operative outcomes (Mishra, Catchpole et al. 2008). This link to operative outcomes suggests that intra-operative ‘situational awareness’ may be clinically relevant and certainly deserves scrutiny as a potential area of content learning in the operating theatre. Whilst Moulton’s work examined only fully trained surgeons she certainly suggests that learning to ‘slow down when you should’ may be an important domain of learning.

The term ‘situational awareness’ has frequently been grouped under the umbrella term non-technical or cognitive skills (Yule, Flin et al. 2006) and has been regarded by some authors as a more global awareness of other activities going on in the operating theatre, for example the surgeon having insights into the activities of the anaesthetist and circulating nurse. The literature certainly tells us that ‘situational awareness’ is a skill perceived by surgeons to be required in their daily practice (Yule, Flin et al. 2006; Yule, Flin et al. 2006). However, it is unclear whether this global ‘situational awareness’ is a primary content area of surgical learning. Cognitive load theory would suggest that novice learners may be over-burdened by the technical task and as a result are not able to pay attention to other aspects in the environment (Miller 1956) (Sweller, Ayres et al. 2011). In the surgical context Kurahashi demonstrated that technical skills training improved the ability to learn new information (Kurahashi, Harvey et al. 2011) and Kassab et al showed that a complex environment with distractors led to a deterioration in technical skills in novice subjects but not in experts (Kassab, Kyaw Tun et al. 2011). These studies raise the question as to whether being able to exhibit ‘situational awareness' is also a secondary end-point measure, seen only when the surgeon has mastered the technical task and has freed up cognitive resources to be able to attend to the rest of the operating theatre. 'Situational awareness' itself may not be a primary content area of surgical learning. It is not known whether 'situational awareness' is learned in the operating theatre or whether exhibiting 'situational awareness' becomes possible due to mastery of other technical aspects of surgery.

Non-technical skills required of Consultant surgeons have been set out by several authors (Baldwin, Paisley et al. 1999) (Carthey, MR et al. 2003) (Healey, Undre et al. 2004) The main non-technical skills categories identified in a literature review performed by Yule and Flin were:

Inter-personal

- Communication
- Leadership
- Teamwork
- Briefing / planning / preparation
- Resource management
- Seeking advice and feedback
- Coping with pressure and fatigue

Cognitive skills

- Situational awareness
- Mental readiness

- Assessing risks
- Anticipating problems
- Decision making
- Adaptive strategies / flexibility
- Work distribution

(Yule, Flin et al. 2006)

It not clear from the existing published literature whether these non-technical skills are learned over the course of post-graduate surgical training, or whether they are inherent attributes possessed by some individuals, that are only displayed when the surgeon has become familiar with the technical aspects of the surgery. There have been moves in recent years to attempt to try to teach non-technical skills to surgeons (Flin, Yule et al. 2007). The participants of such courses were of Consultant grade, and the courses took the format of small group teaching in a classroom setting. The seniority of the course participants and the type of teaching provided on these courses lead the researcher to question whether non-technical skills are learned during the course of post-graduate training in the operating theatre environment.

2.4.2 What is known about the process of learning in the operating theatre

The other research question for consideration in this literature review concerns the process of learning in the operating theatre.

Multiple studies have documented learning curves for a procedure, using number of procedures completed as the denominator (Jaffer and Cameron 2008) (Lau, Patil et al. 2002) (Reichenbach, Tackett et al. 2006) (Rosen, Solazzo et al. 2002). These studies of outcomes from the operating theatre provide evidence that surgical learning is linked to the number of procedures performed, and they point to repetition as a potentially important process of learning.

Price et al. found that trainees who had the opportunity to engage in self-directed practice (repetition of the task) scored significantly higher than those who received expert-guided simulator training alone (Price, Naik et al. 2011). This study provides some further evidence that some surgical learning is achieved through a process of repetition.

Recently, there has been a surge of interest, in the surgical community, in Ericsson's work on expertise and acquisition of skill through sustained deliberate practice (Ericsson, Charness et al. 2006). The self-directed practice that trainees engaged in in Price et al's study (they were instructed to complete 10 further full vascular anastomoses) does not replicate Ericsson's model of sustained deliberate practice in which there should be reflection and practice of a minute sub-section of the task (Price, Naik et al. 2011).

Crochet et al. however, investigated the role of sustained deliberate practice in surgical skill acquisition using Virtual reality simulators and found, perhaps surprisingly, that the deliberate practice group was significantly slower and utilised a greater number of hand movements than the control group. However, OSATS and procedure specific ratings by experts performed on video footage of the study participants' performance showed significantly higher scores for the deliberate practice group. The evidence from this paper suggests that sustained deliberate practice may be beneficial in some of the domains captured by OSATS and procedure specific rating tools, but not necessarily in the 'time and motion' domain.

The literature tells us that there are differences in the preferred learning styles of surgical trainees and Consultant surgeons (Jack, Kenkare et al. 2010). Jack et al. found that surgical trainees preferred active learning whilst fully trained surgeons preferred reflective learning. Whilst these differences may represent generational differences perhaps due to recruitment into the specialty, this study raises the question as to whether surgical trainees' learning style had to change in order to progress within the surgical hierarchy. Jack et al. ascertained trainees' preferred learning style was active learning, however, this learning process may not have been appropriate for the operating theatre as active learning would usually incorporate active experimentation. This paper raises questions as to whether the trainees' preferred learning style had to change during the course of surgical training in response to the learning opportunities afforded.

Somewhat contradictory findings are presented by Swanson et al. who examined Myers Briggs Personality Type Indicators of surgeons and trainees (Swanson, Antonoff et al. 2010). She found modern residents to have a more introverted personality type rather than extroverted and she extrapolates that these individuals would *“prefer to communicate through writing, learn through internal reflection and distill their own thoughts independently”* compared with the fully trained surgeons who *“favor spoken over written communication, learn through action and discussion, and are stimulated through interactions with other people”*.

(Swanson, Antonoff et al. 2010)

Both of these studies discussed preferred learning styles of the trainee surgeons based upon their personality types and self report data. These responses may be affected by trainee perceptions of anonynimity of responses and desire to conform to stereotype. This type of data is unable to inform the reader about learning processes that are actually utilised by surgical trainees in the operating theatre.

Different research traditions have used alternative methodologies to inform researchers about actual practices and 'ways of doing things'. Ethnography is a qualitative methodology, using observation as a tool to explore cultural phenomena. The sociological literature contains multiple ethnographic studies of medical education in which the researcher has immersed themself within the culture of the medical school or hospital and produced narrative descriptions of medical learning including postgraduate surgical learning and culture (Bosk 2003) (Katz 1998) (Cassell 1981) (Cassell 1991). The critique of these works is that the description represents a synthesis of multiple different observation episodes - a sort of overall picture, often regarded as a story. Whilst this has some advantages as sampling error for example is eliminated, there are the disadvantages of researcher subjectivity, of what to select and the desire to portray a 'story'.

Other ethnographers have produced microscopic, fine grained descriptions of moment by moment surgical interaction. Collin (Collin, Paloniemi et al. 2010) and Prentice (Prentice 2007) describe a social collaborative way of learning which was frequently inter-professional:

“surgical operations as participatory practices from the perspective of inter-professional learning and cooperation. We ask what kinds of shared practices enable learning and collaboration within the surgical operating team.”

(Collin, Paloniemi et al. 2010)

Svensson (Svensson, Luff et al. 2009), Koshmann (Koshmann, Lebaron et al. 2007) and Hirschauer (Hirschauer 1991) use micro-ethnographic techniques to provide detailed description of teaching and learning interactions between the surgeon and the trainee within an operative case. They described *"how particular phenomena and procedures are made accessible and intelligible to trainees and the ways in which brief episodes of insight and instruction enable complex procedures to be followed and understood."* (Svensson, Luff et al. 2009) Koshmann describes how this may be achieved through gesture and pointing, using adjuncts such as the monitor screen during laparoscopic surgery, and shapes to make explicit for the trainee exactly what the surgeon is paying attention to and why.

Ethnographic work in anaesthesia has provided rich insights into teaching and learning interactions between team members in the anaesthetic room (Hindmarsh 2002) (Hindmarsh 2007) (Pope, Smith et al. 2003) describing non-verbal means of instruction, tying in with Koshmann's descriptions of using gesture. In anaesthesia non-verbal means of instruction were particularly prevalent as the patient in the anaesthetic room was awake, and aware during instruction of anaesthetic trainees.

The critique of this micro-ethnographic literature is that these studies were based upon detailed analyses of short, one-off episodes in the operating room rather than a systematic collection of data. As a result, it was not possible for the authors to extrapolate their findings about how trainees learn in the operating room to other settings, other trainees and other operations. The authors of these papers were social scientists, with no insider knowledge of the operations that they observed. Whilst some analyses involved surgeons the selections of what to observe, and the meanings then attributed to what they found, were shaped in the main by 'outsiders' from the field of surgery who may have missed some of the technical nuances of particular stages of the operation due to lack of insider knowledge.

2.5 Summary

What is apparent from this literature review is that there is a heterogenous wealth of information in the published literature about teaching and learning in the operating theatre. Much of the literature around content of learning in the operating theatre examines secondary outcome measures such as hand metrics and eye movements rather than the primary content areas of learning.

There is strong evidence in the literature that repetition is important in surgical learning, however there is little empirical study of other aspects of the learning processes in the operating theatre. Within the context of shortened hours and diminished opportunity for repetition, understanding the process of how trainees learn in the operating theatre is increasingly important.

The sociological literature provides an alternative lens and some complementary methodologies for describing the process of surgical learning. This literature suggested that surgical operative learning was a social phenomenon associated with elaborate gestural and other non-verbal interactions between trainer and trainee, accompanied by verbal interjections.

What is apparent from this literature review is the diversity of different methodologies that have been used to research teaching and learning in the operating theatre. These studies have come from multiple different research paradigms and traditions, which are arranged as silos, and it is apparent that little work to date has brought together methodologies used in the social sciences with questions that are pertinent to the surgical community.

These methodological areas of intersection hold great promise for shedding light upon teaching and learning practices in the operating theatre. This thesis will examine critically, content and process of learning in the operating theatre from a different angle, using inter-sectional methodologies from both social and physical sciences.

CHAPTER 3 - Surgeons' perceptions of what is learned in the operating theatre

3.1 Abstract

Objective

The objective of this chapter is to make explicit what is learned by general surgical trainees in the operating theatre.

Method

A grounded theory methodology was used. Data was iteratively collected, through semi-structured one-to-one interviews with 22 surgeons (trainers and trainees). Throughout this process the transcripts were thematically analyzed by a four-person data analysis team.

Results

Major themes of learning in the operating room were perceived to be - Factual Knowledge, Motor skills, Interpretation of visual cues, Interpretation of haptic cues, Adaptive strategies, Team-working and Management, Attitude and Behaviours. 314 data points (short paragraphs or groups of sentences conveying meaning) were classified under these major themes by two independent coders with intra-coder reliability of 0.7.

Discussion

Novel themes not previously fully acknowledged in the literature that were found in this study included aesthetic and haptic semiotics – making sense of what the learner is seeing or feeling. There is overlap with learning of medical diagnostics and the interpretation of 'signs' which the sociological literature would describe as 'texts'.

Adaptive strategies were perceived to be learned from the outset of training alongside routine technical skills.

Surgeons also perceived that behaviours and attitudes were learned in the operating theatre resonating with Vygotsky's ideas of an apprenticeship changing the identity of the learners.

3.2 Introduction

Learning may be defined as a process by which a person gains knowledge, skills, behaviours and values. Some content areas of learning are evident to the external observer, but others are internal processes; for example, the acquisition of a set of beliefs or values. Academic study of learning poses challenges as internal cognitive learning is difficult to ‘see’ and may be missed by testing which relies upon four assumptions:

- That one can render the learnt material explicit
- That a standardized setting is appropriate (this may not be the case as behaviours are highly circumstantial and modifiable).
- That the process of testing does not change the display of the learnt attribute.
- That sampling will reliably capture the phenomenon of interest (it is not possible to study the learner constantly to observe what they have learnt); testing relies upon sampling particular content domains at particular time points.

Analysing insights reported by the learners themselves is an alternative way of investigating learning, that may facilitate enquiry into internal cognitive learning.

Using participant reported data has its own inherent advantages and disadvantages for example there are difficulties of re-call bias, where participants are only able to recount particularly memorable episodes or moments in their training. Learners are not always aware of all that they have learned, for example a “hidden curriculum” (Snyder 1970) is implicit and invisible to the learners. Using self-report data relies upon the metacognitive abilities of the study participants to be able to comment insightfully upon their own learning.

Advantages however of examining self-report data are that multiple content areas of learning may be discussed including subtle internal cognitive learning and learned behaviours. The data may also represent a synthesis of multiple learning episodes over a long period of time, providing a rich account of different pedagogic instances. Self-report data may negate the difficulties of content selection and temporal sampling as the choices of what to report are made by the study participants.

3.3 Method

This study used a grounded theory design. Whilst different ways of conducting a grounded theory study have been described, all of them share the central concept that data collection and analysis should occur simultaneously. This is so that further data collection is determined by what has already been discovered during analysis so that analysis is iterative with gradual refinement of findings.

3.3.1 Grounded theory

Grounded theory was initially described by Glaser and Strauss, hereafter referred to as a Glaserian method, to avoid confusion with later developments. The Glaserian method approaches qualitative data collection and analysis through a positivist lens, where the underlying philosophical belief is that objective ‘truth’ exists within the data that requires uncovering by the researcher through a process of systematic collection and analysis of data (Glaser and Strauss 1967).

Glaserian theorists purport that theories emerge solely through the data without researcher bias, consequentially, collection of data must be regarded as an unbiased process. Participants are encouraged to talk about the topics that they feel are relevant and important. Sampling of participants is either through a random process or through sampling of multiple different comparison groups. Theoretical saturation of data occurs when no new or relevant data emerges regarding a category, or when the properties and dimensions of a category can withstand variations in context of the phenomenon. A Glaserian grounded theory study precludes the need for any researcher reflexivity due to the assumed unbiased nature of the data collection.

However, Glaserian grounded theory is not always appropriate when answering specific research questions, as the participants may not address these questions within the interview; so this investigation used an alternative form of grounded theory method, as described by Corbin and Strauss (Corbin and Strauss 2008) hereafter referred to as a pragmatist method. This way of conducting a grounded theory study was chosen as it acknowledged literature search and professional experience of the researcher assists in guiding the data collection and analysis. This method allowed the researcher to focus the interview upon specific areas of enquiry whilst endeavouring to minimize researcher bias.

Reflexivity is an essential component of this method as it enables the researcher to understand their influence on the data and enables them to take steps to minimize bias. Theoretical sampling within a pragmatic grounded theory study is responsive to the data, not pre-established prior to data collection. The sampling strategy is purposive and seeks to further explore concepts derived through the data analysis. Sampling strategy in a pragmatic grounded theory study relies upon concepts not participants.

Other grounded theory methods that were considered for this study are constructivist approaches to grounded theory, described by Charmaz (Charmaz 2006) hereafter referred to as the constructivist approach. In this approach, the researcher acknowledges they have helped to shape the data and are inextricably linked to it. Constructivist researchers acknowledge that they are involved in interpreting the meaning of the participants, as the researcher's insightful interpretations can allow the analysis to extend deeper than the explicit utterances of the interview. Reflexivity is an inherent part of constructivist grounded theory methods but in contrast to a pragmatic method this is not to alert the researcher and reader to potential biases, but to provide insight to the reader as to how the researcher formulated their interpretations.

A pragmatist grounded theory design was used for this study as it allowed the researcher to explore the specific research questions of this thesis, whilst remaining as objective as possible.

The researcher's post-positivist epistemological beliefs were that there were objective findings within the data set. Therefore Glaserian and pragmatic values of minimizing the influences of researcher bias were embraced. The researcher acknowledged that her shared professional background with the research participants allowed for a deep and thorough exploration of the topic, and though an advantage in many respects, it was possible her position within the surgical hierarchy and her own ideas could have influenced the outcomes of the study.

Throughout this investigation these potential biases have been considered and attempts made to minimize them. These objective ideals, yet acknowledgement of researcher biases, concur with the theoretical constructs of a pragmatic grounded theory study as described by Corbin and Strauss (Corbin and Strauss 2008).

3.3.2 Participant report data

This section sets out for the reader the choices the researcher made when considering how to gather participant report data.

The research question was inductive, requiring an in-depth exploratory approach, which was an important consideration when weighing up the most suitable method for data collection. However, the researcher also wanted the results of the study to be generalizable. This led to some debate over suitable method for data collection, as a questionnaire can be distributed to a large number of participants, yet a personal interview can generate detailed, descriptive information.

Questionnaires themselves have different formats, some utilize a Likert scale for participants to record their level of agreement with a statement, and this approach was not thought suitable for an inductive study because the statements themselves needed to be generated, either from literature review, or from prior research work. A list of statements built from limited evidence may have neglected important content areas of learning as a statement list itself is unavoidably selective. A free text questionnaire format, was more congruent with the exploratory aims of the study, but despite the flexibility afforded for the participant's responses, this format required a rigid set of questions to be presented to the participants. Whilst allowing for standardization, the passive administration of such questionnaires does not allow further clarification of responses by the researcher. The researcher thought that on balance, this means of data collection would capture short, discrete statements from the participants such as slogans or buzzwords without allowing the researcher to seek explanation about what was actually meant by each phrase.

Face-to-face dialogue on an individual basis with a researcher from a surgical background was thought to be the best method of data collection. Focus groups were considered as an efficient means of gathering data from a number of participants simultaneously however, the concern was that a more junior trainee might feel uncomfortable expressing their perceptions of teaching and learning in the presence of a trainer, due to issues of hierarchy.
The interviews were therefore conducted on a one-to-one basis in person by the researcher as this allowed for in-depth discussion and clarification of responses rather than formulaic answers.

3.3.3 Type of interview

Semi-structured interviews were used in this investigation where an interview guide was used with particular topics that the researcher wished to cover in the course of the interview. The exact wording of questions and order in which they were asked was left up to the interviewer. This differs from a structured interview where " *... all respondents are asked the same questions with the same wording and in the same sequence"* (Corbetta 2003).

Whilst structured interviews are convenient for amalgamation of responses for analysis and coding, they afford no opportunity for the researcher to follow up responses to derive further explanation or detail. Unstructured or non-directive interviews hold the possibility that the research questions themselves may not be adequately addressed by the interviewees and were not thought to be an efficient means of gathering data to answer the specific research questions.

The semi-structured interview requires skilful probing around the topic of interest, by the researcher, and a criticism of this method is that this probing may lead to biasing of data. In this investigation the interviewer held professional knowledge of the field of study, and was able to formulate relevant follow-up and probe questions during the course of the semi-structured interview, but was aware of the need to remain open to the ideas of the respondents.

With the challenges of non-standardisation of the interview, the researcher acknowledged it was important to reflect upon potential biases, and to strive continuously to minimize these biases where possible.

3.3.4 Design of interview topic guide

The interview topic guide was designed to elicit data that would aid the researcher in answering the question - what is learnt by post graduate surgical trainees in the operating room, i.e. ‘content’ of postgraduate surgical learning. The researcher and primary supervisor formulated the initial topic guide with consideration given to themes arising from the literature review (see Appendix B). Through iterations of data collection and analysis the guide changed considerably as it was informed by the on-going analysis in which emergent themes were drawn from the data.

The latter interviews sought further information about these emergent themes and aimed to clarify their boundaries, so questions were designed to address areas of overlap between categories to understand these watershed areas (see also Appendix B for topic guide used for final interview).

Surgeons, in their day to day practice of writing the names of operations into their logbooks, are used to discussing the named procedure being conducted, for example, a laparoscopic cholecystectomy and their role during the operation, for example surgeon or assistant. The researcher wished to examine in detail the attributes being learnt during the course of each operative procedure, and how teaching and learning interactions occurred during the operative case itself. The researcher formulated questions to guide the interviewee to relate their thoughts to this microscopic level. The questions were carefully formulated so:

"…[*the questions have] dual goals of motivating the respondent to give full and precise replies while avoiding biases stemming from social desirability, conformity or the constructs of disinterest."* (Hoyle, Harris et al. 2002*)*

The majority of questions used during the interviews were open-ended questions; occasionally the interviewer used a close-ended question to clarify a response and ensure she had understood its meaning.

The interview started with an introductory question 'I am interested in teaching and learning in the operating theatre, are you involved in these activities and how?' This was an open-ended question to enable interviewees to engage in the interview and start talking. The response to this question quickly revealed whether the interviewee regarded themself as teacher or learner in the operating theatre, or in the case of senior trainees, the response suggested to what extend they regarded themself as teacher or a learner.

Subsequent questions used language tailored to the role in which the interviewee had placed themselves. For example, if the interviewee had framed themself as a trainer or teacher, the transition question was 'what do you teach in the operating theatre?' which often elicited a response about the types of operative procedures within that surgeon's practice and the appropriateness of these operative procedures for particular levels of learner.

If the interviewee had framed themself as a learner the transition question was ‘what do you learn when you are in the operating theatre?’ For senior trainees who had framed themselves as both teacher and learner both these questions were addressed.

The transition question then led to the key question, for example for a laparoscopic colorectal surgeon who had framed himself as teacher and specified his practice was appropriate for senior learners, the key question was ‘Within one particular case, for example a laparoscopic colectomy, what are you trying to teach the registrar’. This specification of a particular case and level of the learner guided the interviewee to respond in more detail rather than give more general points.

Once the interviewer had posed the key question, there were follow-up probes. It was important these follow-up probes were as open ended and unbiased as possible. Examples of a follow-up probe include “you mentioned learning tissue handling, can you tell me more about that?” In some interviews the transition questions elicited an in-depth response and here probe questions followed on from the transition question.

3.3.5 Piloting the interview

There were several purposes to piloting the interview. The researcher gained experience with conducting semi-structured interviews; ensured the questions in the initial topic guide were clear and elicited the type of response the researcher required; and the practical issues of data capture were ‘test-run’.

The researcher had previous experience of qualitative interviews as she had used focus groups for data capture during her Masters in Surgical Education research dissertation. She had not previously used one-to-one interviews or semi-structured interviews so, the pilot interviews were an introduction to this form of interviewing. Two pilot interviews were conducted with surgeons, the interviews were transcribed by the researcher and the researcher together with the primary supervisor reflected upon the conduct of the interview. In particular attention was paid to any questions that were potentially biased.

For example during pilot interview 1 the researcher used the following probe:

Researcher “*And can I just pick you up on something that you mentioned, do you think therefore that the complexity of the case, or the nature of the clinical case, impacts on the teaching and learning of the more junior surgeon in theatre?*”

Interviewee “*Yes*”

A more appropriate probe question was:

Researcher “*What are your thoughts about junior trainees being involved in highly complex cases?*”

It was found during the pilot exercise that it was important to allow the interviewee sufficient time to think and formulate their response. It was apparent from pilot interview transcripts the researcher had not always waited for the participant to respond, but jumped in with either clarification of the initial question or a slightly tangential question.

For example during pilot 1:

Researcher	*"I'm going to push you a little bit on the subtleties here… this is a really detailed question, you said something about them showing you how to do it…"*
Interviewee	*"Ok."*
Researcher	*"…but they're not doing it. What is it? Do they tell you how to put in a Z stitch? How does the trainer in that circumstance explain to you or teach you what it is that they want you to do?"*
Interviewee	*"Pointing. I think they say "You go in here, you come out there, you go in here, you come out there and once you've done those two you're left with what looks like a Z; but if you tie it off its much quicker and easier than doing a purse-string."*

The pilot interviews were useful to 'try out' the questions to ensure clarity. The other reason to pilot the topic guide was to obtain estimates of how long it took to gather the desired information. Alternative topics were left out of the final guide because they were not relevant to the research question. The following example illustrates both points:

Researcher *"I'd like to ask you what external factors do you think affect learning in theatre?"*

Interviewee *"What do you mean by external?"*

Researcher *"So perhaps, not to do with the teacher or the learner, but the…"*

Interviewee *"Environment."*

Researcher *"Yeah."*

The interviewee did not fully understand what the researcher meant by 'external factors' and factors affecting teaching and learning in theatre represented an entirely new research question that was eventually cut from the latter interviews.

3.3.6 Ethics

It was made clear to all participants that involvement in this study was voluntary and they could withdraw from the study at any time. There were no direct power relations between the researcher and the potential participants so the researcher believed no participants felt coerced to take part in the study.

Potential participants were initially approached by email; access to email addresses was gained through the NHS Trust and University email directory. The recruitment email explained the purpose of the research study, provided a participant information sheet and consent form (see Appendix C) as well as a contact email address and telephone number for questions relating to the study. This information was provided at least 48 hours in advance of any interview taking place, to allow participants time to consider whether to take part in this study and to facilitate informed choices. Once an interview was arranged, informed signed consent was gained prior to the start of the interview. Ethics approval for this study was granted by St. Mary's Research Ethics Committee reference 10/H0712/1 protocol 1.0.

3.3.7 Data management

On commencing the interview the participants completed a demographic information sheet (see Appendix D) with information including age, gender and grade (or seniority), then assigned a participant number which was then used to label all data to ensure anonymity of transcripts. The demographic information sheets were kept in locked filing cabinets in secure offices.

The interviews were audio-recorded using a hand-held digital Dictaphone device. During the interview the interviewer attempted to remain engaged with the participant, but neutral with regard to the content they were expressing.

Eye contact was maintained throughout and the interview proceeded as a natural conversation between the two.

There were times during the interviews where the researcher made notes for example to indicate the tone was sarcastic, so that this information was not lost in transcription. The electronic audio files were stored by participant number in a hierarchical file arrangement on a password protected computer. After transcription these audio files were deleted. For analysis the audio files were transcribed verbatim.

Initially, the researcher transcribed the audio recordings, enabling review of her interview conduct and aiding immersion into the data to draw out emergent themes. As the study progressed, an external transcription agency was used. The researcher checked all transcripts, listening through the initial audio recording, making amendments where necessary. Once the interview had been transcribed and checked by the researcher against the original audio file, the transcript was emailed back to the surgeon participant to ensure they were satisfied this captured what they had said, prior to analysis. Opportunity was provided for the participants to make alterations or additions at this time. No participant chose to do so.

3.3.8 Setting and context of interviews

The researcher wished to gather detailed information representing a synthesis of training experiences to date, not an account of the most recent training episode. It was decided to interview surgeons away from the workplace, in private offices to provide distance and enable abstraction of ideas. The staging of interviews away from the workplace allowed them to be conducted without background noise and interruptions.

The interviews took between twenty-five and ninety minutes. The length was dictated by the surgeon’s verbosity not the interviewer's questions as the interview consisted of response sequences with short prompts from the interviewer.

Arranging a mutually convenient time for the interview to take place did pose problems. After sending two follow-up emails to arrange a time for the interview to take place, if there was no response from the potential participant the researcher inferred they may be unwilling or unable to spare time for the interviews so excluded them from the study and looked for another suitable participant. Two surgeons were excluded from the potential sample for these reasons.

A potential selection bias was that the participants interviewed were prepared to give up approximately an hour of their time on a voluntary basis to discuss teaching and learning in the operating theatre. The researcher acknowledged that these surgeons were likely to represent trainers and trainees who had strong views on training, although these may be either positive or negative.

3.3.9 Sampling strategy and sample size

The researcher wanted to collect in-depth opinions of the content of training in the operating room and broader views about postgraduate training. It was decided to sample trainees - immersed in the day-to-day aspects of training - as well as Consultant surgeons. The researcher thought the trainers might be able to give a different perspective.

With qualitative research, generalizability is not the goal, rather an appropriate sample size that answers the research question. Quantitative sampling strategies aim to draw a representative sample from a population so results may be generalized back to the population. Sample size, in a quantitative paradigm, is defined as the optimum number necessary to enable valid inferences to be made about the population. The larger the sample size in a quantitative study, the smaller the chance that there is a sampling error.

In this research, the desired information was surgeons' views about content of learning in the operating theatre. For random sampling to be appropriate the characteristics under study of the whole population should be known - in this case this meant already knowing the variety of views of all surgeons and then taking a random sample of views as an illustrative sample. In addition, a random sample is only likely to produce a representative sample if the subject of interest is normally distributed in the population. For qualitative studies it seems unlikely ‘values’ ‘beliefs’ or ‘attitudes’ are normally distributed in the population, therefore alternative sampling strategies were used.

Qualitative researchers acknowledge study participants are not equally good at observing, understanding and interpreting their own and others’ behaviour, and sociology has recognized some informants are ‘richer’ than others and these participants are likelier to provide insight and understanding. Qualitative research seeks to accomplish answering the research question by selecting ‘information rich’ cases.

Miles and Huberman state 3 types of case have greatest payoff (Miles and Huberman 1994)

1) Typical cases, where the views expressed are ‘normal’ or ‘average’ for those being studied.

2) ‘Deviant’ or extreme cases

3) ’Negative’ or disconfirming cases i.e. Exceptions to the rule.

Marshall described three approaches to selecting a sample for qualitative study (Marshall 1996).

- Convenience sampling - a sampling technique where the most accessible participants are chosen to take part in the study. Though this was an easy way to secure participants, this method could potentially lead to biases in the data and results.

- Purposive sampling is used by researchers to select potential participants likely to be able to provide information that will answer the research question.

Purposive sampling may be through a judgment sample where a *“framework of variables that might influence an individual’s contribution [are sampled] and [these] will be based on a combination of the researcher’s practical knowledge of the subject area, the available literature and evidence from the study itself.”*

(Marshall 1996)

A judgment sample is based upon the researcher’s insights about what factors influence the views expressed. An alternative form of purposive sampling is theoretically informed purposive sampling where the participants are chosen when likely to inform the emerging theory. These two forms of purposive sampling may be combined.

To begin, the researcher sampled both established Consultants and junior trainees to provide a broad range of opinion and data - this is a judgment sampling technique. Six interviews were conducted and analyzed and emergent themes appeared. The researcher used theoretically informed sampling to provide information about the emergent theory and a further sixteen interviews were conducted. Trainers and trainees described different content, in terms of what they were learning in the operating theatre. To gather further data relevant to emerging content areas, the researcher purposively engaged trainers or trainees who were anticipated to express views about these aspects. For example a major theme arising in the early part of this investigation was learning of visual cue interpretation. With this in mind, the researcher sampled a trainer with whom she had operated twice, who discussed during those operations, the different colours of intra-abdominal fat, and how to differentiate between mesenteric, retroperitoneal and colonic epiploic fat from visual appearance. This purposive sampling was guided by the researcher's prior professional experience with the participants, as well as by inviting nominations from other trainees or trainers who specifically describe subtle visual aspects during operations.

3.3.10 Participants

All participants were working within the NHS at the time of the study, with the majority of participants entirely trained in the UK postgraduate system. Twenty two surgeons were interviewed, seven were female. All the female surgeons were trainees although some were very senior trainees. Ten surgeons were working at a University teaching hospital and twelve surgeons were working in District General Hospitals. Twelve surgeons were trainees and ten surgeons were Consultant level surgeons. The trainees in the study represented a large spectrum of seniority with both CT1 level and ST8 level trainees included in the sample.

3.3.11 Data Analysis

The interview transcripts were used rather than the original audio recordings. This was primarily to protect the anonymity of the research participants - allowing the data to be viewed by a diverse analysis team without breach of confidentiality.

Content analysis was chosen as it involves scrutiny of transcripts for overarching themes. It is regarded by Holsti to be *"…an objective, systematic, and general description of the manifest content of a text."* (Holsti 1969)
Holsti indicates the process aims for generality, so the results of analysis have theoretical relevance and content analysis deals with manifest content, not hidden or symbolic meanings. However, there are different ways of conducting a content analysis, depending upon the epistemological stance of the researcher. Holsti states the analysis is "carried out on the basis of explicitly formulated rules and procedures", however this suggests the rules are formulated *a priori* before full analysis of data, which contravenes the iterative approach of a grounded theory study.

Some researchers count the frequency of occurrence of themes in the data to suggest the importance of a particular theme. Many regard this type of content analysis as a quasi-quantitative technique. Guba and Lincoln indicate:
"…The frequency of assertion is not necessarily related to the importance of that assertion…" (Lincoln and Guba 1985)

It is clear that the importance of a particular theme to one participant will differ from that of another participant, and this is highly subjective. Some topic matter is more difficult to discuss and requires a higher level of participant reflection meaning this theme would not arise in every interview. The researcher felt these themes should be attended to and quantifying the occurrence of the theme was not an appropriate analysis technique.

The constant comparative method as per Glaser and Strauss is an alternative way to perform content analysis. The constant comparative method does not require explicitly formulated rules and procedures *a priori* as Holsti advocates but uses a "continuously developing process" where data is compared with …*"previous incidents in the same and different groups coding in the same category…"* (Glaser and Strauss 1967)

The constant comparative method does not require explicit rules to be made about what goes into a particular category at the start of analysis, just the investigator compares the new data with that already in the category and checks whether the new data 'fits'.

'This constant comparison of the incidents very soon starts to generate theoretical properties of the category' (Glaser and Strauss 1967) so by the end of analysis formal 'rules' about what 'belongs' in that category can be made after reviewing what was placed in the category.

Discourse analysis, involving analysis of language, was considered as an alternative analytical method as it is widely used by sociologists, anthropologists, psychologists and philosophers. It looks at the language used with relation to social, political and cultural attitudes. It is used as a method for investigating identity constructs, as analysis takes into account the choice of words and the sentiment of what is being said. In a discourse analysis the researcher pays attention to chosen vocabulary, and may analyse the way the responses are delivered, for example in a Foucauldian discourse analysis the researcher pays attention to pauses and inflections of voice, and what is not voiced.

In this study, the researcher assumed the participant's verbal expressions were insightful into their thoughts and perceptions. Her assumption was that the participants had no reason to lie, and that their words should be taken as true representations of what they thought. Researchers who use discourse analysis do not share this view of language. They argue when participants state a belief or express opinion they do so with regard to whom they are addressing and in which circumstances. To make sense of what people say it becomes necessary to take into account the social context in which they speak.

In this investigation, the researcher was interested in exploring the perceived content of learning in the operating theatre. There was no reason to suppose the participants had cause to lie, as the researcher had no direct hierarchical relationship with the participants in terms of clinical supervision or career progression, and there was no reason to suppose pauses in the interview had hidden meanings. The researcher was not specifically interested in the language and word choices made by the participants, rather the overall meaning conveyed by the interviewee. Content analysis seemed the most appropriate analytical method for data analysis in this investigation.

Multiple analysts were used to ensure nothing was ‘missed’ in the data, allowing alternative perspectives to be considered. A team of four analysts was used. These were from differing academic backgrounds and had prior experience of working with qualitative data. The data analysis team was made up of a Professor of Surgical Education who was a fully trained surgeon, qualified as a general practitioner and working full-time in medical education research (RK); a post-doctoral level educational psychologist whose research interests were evaluating learning during surgical simulation training (SM); a post-doctoral level social scientist with an interest in learning in workplace settings (JB) and the primary researcher - a senior surgical trainee with a Masters in Surgical Education (AC).

This diverse team meant that the transcripts were considered from four different viewpoints, ensuring broad oversight and that the primary researcher did not bias the analysis. Each member of the analysis team was given a copy of the interview transcript for individual reading and consideration of themes. The primary researcher met with members of the analysis team on an individual basis, fortnightly, during data collection and analysis, to discuss the data and emergent themes, in addition there were two half day data analysis sessions, where all four members of the analysis team met face to face to discuss the data. At these meetings, troublesome data was used as examples and the analysis team considered how the quotation should be categorized under the existing structure or whether it could potentially constitute a new category.

3.3.12 Coding framework and use of NVivo 9

The first six interviews were considered by the analysis team to generate the initial speculative coding framework. After generating early theoretical categories purposive sampling was used across these initial categories. Sixteen further interviews were conducted creating new categories and there was refinement of initial themes. When new themes emerged from the dataset during the latter interviews (sixteen) the previous interviews were then reviewed and re-coded using this new category. This coding was then cross-checked with other team members to ensure agreement. If disagreement existed, further discussion took place between the analysis team members, as to whether this represented a new theme or a sub-theme within an existing category.

The widely used qualitative software tool NVivo 9.0 QSR International was used for handling the data. No analytical functions of NVivo were used, as the analysis team performed the coding. The software provided a repository for the data. One advantage of using a software package for the storage of this data was that when a new theme was created, it was straightforward to review previously coded data and re-consider it in the light of the new theme. It allowed merging of sub-themes when it became apparent that the participants were referring to the same concept. Two analysts installed NVivo 9.0 onto their personal computers (AC and SM) and although intellectual decisions regarding coding categories were made by all four, the re-coding of data when new themes emerged was performed by these two researchers. Sub-themes were developed from the data in a hierarchical arrangement under the major themes.

To ensure nothing was overlooked in the data, every transcript was coded in full, this is called open coding. This was an intense process, as every phrase was considered for meaning. A large number of data points were generated. A data point was defined as “any phrase, sentence or paragraph conveying meaning”; so the data points were of variable length, sometimes three or four words, sometimes an entire paragraph. These data points could be viewed in NVivo within the theme or sub-theme in which they had been classified as well as the researcher being able to see both the interview in which this had occurred and context within the transcript of the data point.

Some data points were classified under more than one category. Once the data had been coded, all these areas of overlap were considered to identify causal relationships between categories. This may be considered using a ‘coding paradigm model’ as the researcher aimed to make explicit relationships between the themes and subthemes. A ‘coding paradigm’ was used to understand teaching and learning in the operating theatre by making clear the exact relationships between the different categories - this was particularly relevant when considering boundaries between different content areas of learning.

Once all data had been coded by the primary researcher (AC) another team member (SM) then re-coded all of the data in NVivo 9.0 using the agreed themes and sub-themes. The transcripts were coded 'whole' by the secondary researcher - and so there were differences in the data point count coded by the two researchers. This secondary analysis was conducted to ensure durability of the themes. The inter-coder reliability was calculated from the proportion of the second coder's data points that were identically selected and coded by the primary researcher.

3.3.13 Member checking

Member checking involves reporting the emergent findings of the study back to the sample population, to ensure the findings 'ring true' with the participants. Throughout the data collection and analysis the primary researcher discussed her findings with participants in the study (post interview), she presented preliminary findings at departmental meetings and later in the analysis presented the study findings at International surgical and educational meetings ('Association of Surgeons of Great Britain and Ireland' and 'Ottawa Conference on Assessment in the Health Professions').

These meetings provided a forum for discussion of the emergent themes and allowed for further refinements. Generally, the response to the initial analysis was very positive with many surgeons voicing strong agreement with the findings. Many commented that the findings of the study helped explain their scepticism about current simulation practice, as details of what was learnt in the operating theatre were made explicit and this led to reflection about what was currently recreated in simulation practice.

3.4 Results

Twenty-two surgeons (10 consultant surgeons and 12 surgical trainees; 15 males) participated in this study. This included trainees ranging from Core Training Year 1 (CT1) through to Specialty Training Year 8 (ST8). Trainers sampled ranged from 15 and 32 years post initial medical qualification. All surgeons were working in the NHS and the sample included Consultants and trainees working at University Teaching Hospitals and at District General Hospitals.

In total, 566 data points (short paragraphs or phrases conveying meaning) were coded during the analysis. 277 were coded by the primary researcher as relating to content of learning in the operating theatre, 93 data points were coded as content areas by the secondary coder. Table 1 outlines the major themes that emerged from the interview analyses and the inter-coder agreement. The inter-coder agreement was calculated as the proportion of the second coder's items which were identically coded by the primary researcher.

It should be noted that in the context of a grounded theory study, that an inter-rater agreement indicates to the reader how the thoughts of the two independent coders had become aligned over the course of multiple discussions during coding sessions. The inter-coder agreement is presented in this thesis as is the convention in the surgical literature where a high level of inter-rater agreement would be desirable, and cited as a measure of reliability of the data. In a qualitative paradigm the inter-rater agreement is neither important nor valuable as the qualitative researcher's desire is for the full richness and diversity of themes (seen by different analysis team members) to be drawn from the data without necessarily there being any agreement between the analysis team members.

Table 1: Number of data points coded and coding agreement across content categories between two members of the analysis team

	AC	SM	Coding agreement
Factual knowledge	**46**	**22**	**0.6**
Motor skills	**50**	**13**	**0.9**
Interpretation of visual cues	**45**	**17**	**0.7**
Interpretation of haptic cues	**12**	**6**	**0.7**
Adaptive competence	**78**	**22**	**0.8**
Team-working and management	**24**	**8**	**0.7**
Attitudes and behaviours	**22**	**5**	**0.4**
Overall	277	93	0.7

Quotations have been selected to illustrate the themes and subthemes that emerged from the data itself. The quotations presented here cannot be exhaustive, and those that have been selected, are representative of all data coded under that themes and subtheme. Quotations presented here, have been selected on the basis of clarity and brevity.

3.4.1 Factual knowledge

This referred to knowledge that was held by surgeons and was regarded as factual and un-contestable. This content area was frequently considered pre-requisite knowledge; subject matter that ought to be known and mastered prior to learning to operate. The participants frequently framed this content area as suitable for the junior learner.

"…and it's a good opportunity to buff up the junior surgical trainees, and the middle grades, on the aspects surrounding it, particularly the anatomy, the embryology..."

Trainer 6_District General Hospital_01.06.11

Sub-themes within the theme 'factual knowledge' included knowledge of:

- Anatomy
- Equipment names and requirements
- Clinical indications for the surgery
- Recognized complications of the surgery
- Steps of the operation
- Routine post-operative care of a patient undergoing a specific operation

3.4.1.1 Knowledge of anatomy

Data points coded here referred to learning anatomy as abstract ‘text-book’ anatomy instead of how it visibly unfolds within an operation. This factual knowledge would include the names of specific structures in a ‘typical’ human encountered during a specific operation, and the ‘typical’ anatomical course that these structures would follow.

“…I think it also helps to reinforce to people where their anatomical knowledge may be lacking…”

Trainer 10_District General Hospital_25.07.11

3.4.1.2 Knowledge of instruments

The names of the surgical instruments and which instruments were going to be needed within a ‘typical’ case.

“…what the instruments are, though often I have to ask or keep my ears open for what people ask for.”

Trainee 6_Teaching Hospital_CT1_28.03.11

3.4.1.3 Clinical indications for the operations

This would include the signs and symptoms, or investigative findings, that would cause a surgeon to decide definitively that the operation was necessary.

“…so we talk around it, we talk about the indications, we talk about carotid disease…”

Trainer 6_District General Hospital_01.06.11

Whilst in clinical practice there are grey areas or uncertainties about the benefits of the operation outweighing the risks of surgery, this theme related only to the knowledge of the absolute indication for the surgery without acknowledgement of patient or circumstantial factors. When the surgeons were talking abstractly about teaching and learning in theatre they appeared to regard knowledge of the indications for surgery as absolute and factual.

3.4.1.4 Recognized complications of the operation

Similarly to the indications for the surgery, the surgeons referred to recognized complications of the operation as abstract factual knowledge.

“…[I’m learning about] intra-operative complications… immediate and late complications specific for that procedure or generalized for the patient.”

Trainee 11_Teaching hospital_ST6_15.06.11

3.4.1.5 Steps of the operation

The participants referred to a step-wise approach to the operation, where the trainer broke down the task to be accomplished into small steps. The knowledge of what these steps constituted was related as factual un-contestable knowledge.

"…[I am] learning how to perform a whole operation skin to skin and giving you the steps…"

Trainee 10_District General Hospital_CT2_08.06.11

"…we can actually convey to people reasonably quickly and easily the constituent steps of a procedure…"

Trainer 2_Teaching Hospital_13.10.10

3.4.1.6 Routine post-operative care after a specific operation

The final subtheme referred to within this category was knowledge of the usual post-operative care of the patient. Whilst this can, in reality, be variable upon patient factors, the surgeons referred to the 'typical' post operative care as factual knowledge.

"…[I teach] how to manage patients before and afterwards."

Trainer 6_District General Hospital_01.06.11

"…[They learn] what kind of follow up they need and which, is (sic) there any dos or don'ts post op that they need to know."

Trainee 6_Teaching Hospital_CT1_28.03.11

All items coded here were expressed by the surgeons as abstract factual knowledge. The surgeons acknowledged that in surgery there were many exceptions and circumstances where these facts may not hold true. The ‘typical anatomy’ or ‘usual steps of the operation’ were considered pre-requisite factual knowledge for the learner.

3.4.2 Motor skills

This area related to teaching and learning hand skills, which involved dexterity and accurate execution of movements, frequently referred to by the surgeons as ‘surgical handicraft’.

“ …one of the things I think is poorly taught in surgery is basic surgical handicraft.”

Trainer 6_District General Hospital_01.06.11

Sub-themes that emerged from this category included:

- Basic manoeuvres e.g. one-handed surgical knot tying
- Accuracy and fine motor skill
- Economy and efficiency of movement
- Depth perception with respect to laparoscopic work

3.4.2.1 Basic manoeuvres

Surgeons referred to the initial learning of surgical manoeuvres such as the one handed knot and being able to engage and release the ratchet on a haemostat. These were regarded, by them, as basic skills that should be acquired early on in training.

"…you do need a certain basic level of manual dexterity and there are certain core building blocks, such as knot tying which, as I always say to trainees, you can learn that away from the patient…"

Trainer 7_District General Hospital_15.06.11

"There are certain baseline skills which I expect people to know. So you know, a junior trainee should be able to suture and tie knots, and take clips on and off, and hold instruments properly like retractors."

Trainer 4_Teaching hospital_11.11.10

"…I've got one SHO that just needs at the moment to technically learn how to tie knots and things like that."

Trainee 9_District General Hospital_ST5_02.06.11

3.4.2.2 Accuracy and fine motor skill

Surgeons discussed learning fine motor control requiring absolute precision, this was perceived to happen after the learner had mastered the basic manoeuvres, so was considered a more advanced skill.

"…once you go beyond the basic skill set, where I'm mostly focused on [is] making sure that my suture technique is meticulous."

Trainee 10_District General Hospital_CT2_08.06.11

The surgeons related, that the challenge posed by laparoscopic surgery was that the length of the instruments meant that small hand movements were amplified, requiring additional precision hand skill, which in turn necessitated careful control and concentration. In relation to laparoscopic surgery:

[I] know exactly what I should be doing and where I should be looking and where I should be cutting and whether I should be taking a bit more out here or a bit more out there, the difficulty is that… there are times where I find it difficult and I find it tiring."

Trainee 5_Teaching Hospital_ST4_28.03.11

3.4.2.3 Economy and efficiency of movements

Another skill, perceived as higher level learning than the basic manoeuvres, was efficiency and economy of movement, so that the task was completed in a timely fashion and that additional corrective movements did not exhaust the operator.

"…and so that's the thing that I learned the most, is to make my movements most efficient…"

Trainee10_District General Hospital_CT2_08.06.11

"It's learning to, how to improve the skills they've got at the moment to make them more economical in their hand movements…"

Trainee 9_District General Hospital_ST5_02.06.11

"…and instrument handling and the way you move with an economy of movements. Because when I first started operating I was getting terrible hand cramps because you put yourself in terrible positions and you end up really

tense because you're really worried about the operation and that is only something that (sic) you get less over time."

Trainee 10_District General Hospital_CT2_08.06.11

3.4.2.4 Hand-eye co-ordination

The surgeons referred to motor skills learning occurring in both open and laparoscopic surgery. They related that the challenge of laparoscopic surgery from a purely motor skill aspect, was that the learner's gaze was directed at a video monitor requiring the hand movements to be executed in a different directional orientation from the gaze of the learner. This was frequently referred to as learning hand-eye co-ordination.

"…there's a little bit about the hand eye coordination, or not the hand eye coordination, but the instrument eye coordination within, within the screen, on the screen in the operating theatre…"

Trainee 5_Teaching Hospital_ST4_28.03.11

All items coded here referred to learning and execution of movements, particular to surgery, with precision and efficiency. This domain was frequently cited as being basic level, as it did not pertain to the higher cognitive capabilities of where to dissect next, or how to deal with anomalies in patient anatomy, but only the physical capabilities of the learner. Within this motor skills theme the surgeons expressed some hierarchical views about the sub-themes noting that initial learning was of the basic manoeuvres, followed by precision and accuracy, followed finally, by economy and efficiency of movements.

3.4.3 Interpretation of visual cues

This was defined as the ability of the learner to make meaning of what he or she was seeing. For example, the learner may have possessed knowledge of the abstract factual anatomy of the inguinal canal, as learnt from an anatomy textbook, however, the learner may not have been able to visually identify the correct dissection planes or structures when in vivo. The surgeons described learning to interpret visual cues as learning how to *translate* what they were seeing into the 'known' anatomy of the textbook. No sub-themes were apparent within this theme.

"…but it's the appreciation for just slight variations in colour, texture, change of your tissues when you'll start understanding what structure is going to suddenly spring up behind a little fatty pad. You just have a, you just have to be, if you've looked at enough of whatever operation it might be, you can see where your vein or your artery or that little tiny nerve is going to be appearing just a couple of cells away."

Trainee 9_District General Hospital_ST5_02.06.11

"…you get an appreciation of your tissues. So you, and obviously when you dissect down, particularly in things like carotids or thyroids or something like that, you're taking literally single layer cells just very slowly. And you'll start seeing veins or arteries, but particularly nerves. You'll see pulsations. You'll see, it's an appreciation of your tissues…"

Trainee 9_District General Hospital_ST5_02.06.11

Part of the difficulty related by the surgeons was that anatomy textbooks frequently portrayed anatomy in diagrammatic form, over-simplified and that much of what was being learnt in the operating theatre was what the structures really look like in vivo in a human.

“As much as you can read in a textbook, what you see in actual life is more difficult to correlate, like the vessels aren’t as obvious to me, that this is the inferior epigastric versus seeing it in a book and it’s painted in red…”

Trainee 6_Teaching Hospital_CT1_28.03.11

Visual cue interpretation was a content area regarded by the surgeons as more challenging in operative cases where there was infection or inflammation. They discussed how in these cases it was more difficult to find the plane or see where they were going. These sort of cases were said to be more suitable for a senior learner as interpretation of the visual cues was more complex.

“…it’s a question of getting into the right planes, recognizing when you’re in the right plane and if not how to get in it. And recognizing when you’re getting out of it. And then when you get a bit more grown up, recognizing how to make the plane, when you’ve got a degree of inflammation or previous surgery, or something that means that the plane that God or Darwin made is not there any more.”

Trainer 6_District General Hospital_01.06.11

The surgeons referred to visual cue interpretation as: a content area of learning that was relevant for all levels of surgical learner; whether it was identifying the hernia sac or whether it was identifying the ureter in a mass of inflammatory tissue. The surgeons related that a more difficult case was one in which the visual cues were more complex to interpret, and structures were not clearly discernable.

3.4.4 Interpretation of haptic cues

This was defined as the ability of the surgical learner to interpret what they are feeling by touch, both in terms of structure and pathology. There were only a small number of data points classified here, and in earlier iterations of the analysis visual cue and haptic cue interpretation were initially considered together. However, as the analysis proceeded individual themes evolved and so these sensory modalities of learning were separated. There were no sub-themes found within this theme.

"…you need to be able to put your fingers into a small incision and know what you are feeling – like to be able to find the appendix through a tiny incision and more than that, you should be able to tell whether or not it is inflamed just by the feel…"

Trainee 2_Teaching hospital_ST7_04.09.10

Surgeons described 'learning the feel', for example knowing how hard to press, in order to cut the skin with the knife.

"…, the sensations you get from holding a knife, cutting skin… What it should feel like."

Trainer 7_District General Hospital_15.06.11

All content here related to learning haptic perception – the surgeons learning to make sense of what they were feeling with their fingers or surgical instruments.

3.4.5 Adaptive strategies

The surgeons in this study discussed learning adaptive strategies in the operating theatre to deal with anatomical variants or complications. The adaptive strategies were likened to a toolbox of potential solutions for dealing with unexpected findings. There were no sub-themes.

"And you're teaching them how they can react to differences in anatomy and other complications that arise during the operation."

Trainer 9_District General Hospital_20.07.11

The surgeons described adaptive strategies as high-level skills, junior trainees described this as an area with which they had difficulty.

"…because most procedures I've seen, and I've done parts of, but the part that I need the most supervision for is dealing with complications or variations."

Trainee 4_Teaching hospital_CT2_25.03.11

"…and I suppose the other difficulty is variation, well every patient is different. So I think it's dealing with the variation in anatomy or in pathology that is the main difficulty."

Trainee 7_Teaching hospital_CT2_31.05.11

It was expressed that having an extensive resource of strategies, marked the difference between a trainee and a consultant surgeon.

"…dealing with changes that occur in the operating theatre, a bleeding vessel, for example, is what changes a registrar from a registrar to a consultant – I suppose."

Trainer 8_District General Hospital_23.06.11

Adaptive strategies described by the surgeons included items describing contingency (what to do when things went wrong).

"…when things go wrong that, you know, having the backup skills of how to deal with that, so get bleeding say during an appendicectomy, how do you control that."

Trainee 8_District General Hospital_02.06.11

It was thought, by the participants of this study, that trainees were learning multiple adaptive or contingency strategies during the course of their training. When they encountered something difficult, unexpected or a complication occurred intra-operatively, they had a tool-box of cognitive resources to be able to deal effectively with the difficulty. This was clearly perceived to be essential for consultant level practice.

3.4.6 Team working and managerial skills

This data related to learning to be part of a team, organization or hospital system. Some examples were in relation to the immediate team and how to get the best out of colleagues:

"…about the way that a theatre is run and the way that you extract the best out of a group of people and out of a scrub nurse, to try to help along the way with an operation."

Trainee 5_Teaching hospital_ST4_28.03.11

Other quotations were about how to keep the theatre running efficiently in order for it to be a functional part of the larger hospital structure.

"…learning more about the way that a theatre is run, about the coordination of different teams within a theatre and their interplay…"

Trainee 5_Teaching Hospital_ST4_28.03.11

Part of the data coded here involved activities that could be described as communication skills and situational awareness. The surgeons described staying alert to what else was going on in the theatre. This enabled them to work collaboratively with other professionals, and to anticipate surgical difficulties before they arose, allowing the operation to continue without interruption.

"…or, if I hear the sats probe noise, you know as it gets lower the sats, the probe makes a different noise, I will then interact with the anaesthetist. You need to keep an eye on what they are doing with the patient because it does make a difference, you notice a difference in the abdominal feel or a difference on the monitor, or if it's laparoscopy I will see a difference on my gas pressures. You need to look at the environment you're in and all the monitoring you have because that gives you a clue about a potential issue which is going to impair your ability to do that operation. And you can predict it actually rather than waiting for them to eviscerate because all the relaxant has disappeared."

Trainer 4_Teaching hospital_11.11.10

This theme contained data that related to trainee surgeons learning to work as part of a team, to facilitate best patient care, and to make efficient use of the theatre as a resource. The constituent skills being learnt included communication skills, macroscopic situational awareness and an understanding of other professional roles.

3.4.7 Attitudes and behaviours

The surgeons also described learning personal values or attitudes that were regarded a part of ‘becoming a surgeon’. These attitudes were manifest within the operating theatre; however they also referred to beliefs and ways of doing things that had wider implications and were pervasive to all areas of professional practice. The surgeons described learning to deal with pressure and stress, learning to cope with time pressure and the responsibility for patient care.

“And pressure and stress… can have an impact on your performance.”

Trainee 4_Teaching Hospital_CT2_25.03.11

They discussed learning to deal with chronic as well as acute stress, relating that the surgical trainee needed to learn resilience and a sense of responsibility for any complications.

“…[They need to learn] resilience, taking responsibility for complications at that stage, both intraoperative that can be fixed, and also in the postoperative period…”

Trainer 10_District General Hospital_25.07.11

Surgeons also discussed learning a perfectionist attitude to their work.

"…and thirdly I think the attitude 'no short cuts' 'do things correctly', and 'do things nicely'. This is something it takes a long time to learn. Because you are nearly changing the personality, you are changing the culture of the people, but this is very important, 'no short cuts', everything 'done nicely' and 'done quietly' this is an attitude."

Trainer 1_Teaching hospital_28.09.10

"but seeing someone develop…attention to detail, is important."

Trainer 10_District General Hospital_25.07.11

This theme related to the personal attributes that the surgeons thought were being learnt in the operating theatre. These were internally held attributes or beliefs that shaped surgeons' behaviours. Despite these personal attributes and attitudes having more global implications than just in the operating theatre, the surgeons described them as being learnt in the operating theatre itself. They included learning how to deal with pressure and stress, resilience and becoming a perfectionist.

3.5 Discussion

3.5.1 General discussion of findings

This investigation aimed to explore surgeons' perceptions of the content of learning in the operating theatre. The results of this study have outlined the seven posited major domains of learning in the operating theatre for the post graduate trainee - factual knowledge, motor skills, visual cue interpretation, haptic cue interpretation, adaptive strategies, team working and managerial skills, attitudes and behaviours. Some of the content areas, made explicit by this investigation, are already well recognized in the surgical literature.

The motor skills domain has been extensively investigated (Mackay, Datta et al. 2002) (Rosser, Rosser et al. 1997) using secondary endpoints to measure time taken to complete a task, path length, number of hand movements and force-torque signatures.

Another content area of learning made explicit by this study, that is already widely assumed to be important, although it has not been empirically studied, is factual knowledge acquisition. This study shows that surgeons perceive factual knowledge to be an area of content learning in the operating theatre, however, there is little evidence in the literature that fully qualified surgeons perform better than trainees in this domain (Yeung, Cope et al. 2008). Yet, it is this type of abstract knowledge that is tested in written multiple choice examinations and viva voce exams as part of the MRCS (Membership of the

Royal College of Surgeons) and FRCS (Fellowship of the Royal College of Surgeons) examinations with questions such as ‘what are the indications for X procedure?’. Despite there being minimal evidence, there appears to be a widely held assumption, by members of the profession, that fully qualified surgeons perform better on factual knowledge tests that trainees.

Themes such as team working and managerial skills are discussed in the literature under the umbrella term of non-technical skills; whilst the literature is not clear as to whether these attributes are learned in the operating theatre or through general professional experience, they are not new domains of learning made explicit by this study.

These established domains of learning are not further explored in this discussion section. The focus will be upon novel findings - visual and haptic cue perception, adaptive strategies and learning of attitudes and behaviours as these are areas that have not been previously fully acknowledged in the published literature.

This discussion section will place these findings within the broader literature, considering current knowledge not only in the health sciences but also in sociology and cognitive psychology.

3.5.2 Making meaning from sensory perceptions – sensory semiotics

Whilst it is known that gaze patterns differ between novice and expert surgeons, in both simulated and real surgical environments, it is not known why the gaze patterns differ and what draws experts to focus on specific aspects of the operative field (Law, Atkins et al. 2004; Richstone, Schwartz et al. 2010).

Interpreting visual cues is not exclusive to surgery, in many clinical disciplines making sense of visual information is an essential part of becoming a good diagnostician (Goldacre, Laxton et al. 2010). Clinicians examine patients looking for abnormal findings in the hands, face and skin that give pointers to the underlying diagnosis, the experienced clinician has learnt what ‘normal’ and ‘abnormal’ look like. Bleakley refers to an aesthetic domain where visual images are the source material and learners are expected to ‘make sense’ of what they are seeing (Wilson 1996). The science of ‘meaning making’ is called semiotics. Bleakley refers to pathologists looking at specimen slides, radiologists looking at X-ray images and dermatologists looking at skin rashes all as examples of medical semiotics in the aesthetic domain. Sociologists have examined ‘meaning making’ from visual images (Kress and van Leeuwen 2006) but little reference has been made to ‘meaning making’ from contemporaneous technical images such as the operative field.

There are also a number of papers in the published surgical literature that point towards haptic cue interpretation being an important domain of learning for the surgical trainee. Dunnington et al found that ‘allowing the learners to feel the pathology’ was considered a marker of a good teacher (Dunnington 1993). A study from the veterinary literature found that qualified vets had a better ability to distinguish different levels of stiffness compared with vet students, suggesting that haptic perception may be a learned skill (Forrest, Baillie et al. 2010). A large number of papers in the surgical literature have examined haptic feedback in the context of virtual reality simulation (Playter and Raibert 1997) (Panait, Akkary et al. 2009) (Strom, Hedman et al. 2006) – and this attention to haptics suggests that this is an important sensory modality to make ‘realistic’ in simulation, for the learner.

During operations, surgeons use their hands or surgical tools to gain information about structures lying inside the body. This can be through enveloping the structure in the hand to gain 3-dimensional information about its shape, or by interpreting fine touch sensations transmitted through the surgical instruments to determine normal from abnormal. It is thought that lateral motion may be used to discern texture, pressure may be used to determine hardness and contour-following may be used to determine global shape (Lederman and Klatzky 2009). What has not previously been made explicit in the surgical literature is that development of haptic perception may be an important area of surgical learning. Surgeons may need to attribute specific meanings from input sensations, for example whether the palpated structure is malignant, inflamed or normal, this may be termed haptic semiotics.

Semiotics refers to the study of ‘meaning making’ from signs. Academic work in this field speaks of ‘social semiotics’ - this phraseology “*draws attention to the fact that meanings always relate to specific societies and their cultures*” (Kress 2010). In this context the appearance of the operative field and the ‘feel’ of the tissues holds particular meanings for the cultural group – surgeons.

The ‘signs’ convey messages to individuals within this particular cultural group, and are referred to by sociologists as ‘texts,’ although the material may be lexical, graphical, haptic etc. There are therefore a variety of modalities in which ‘texts’ are presented. The surgeons in this study describe learning to interpret visual and haptic ‘texts’. There are different physical domains and sensual domains in which the surgical ‘texts’ are being presented, this may be termed ‘multi-modal’ presentation (Kress 2010).

Haptic and visual cue interpretation are thought to be linked, with cues in one sensory domain either supporting or refuting interpretations of cues in the other sensory domain.

Keehner and Lowe, in a review article presented at the Association for the Advancement of Artificial Intelligence, consider both visual and haptic cue interpretation and state that:

“*…in traditional open surgery, it would be difficult to identify anatomical structures using vision alone. Blood vessels can be hard to distinguish from other tubular structures by sight. Adhesions (scar tissue) from previous* *procedures can change the shape and appearance of structures. During surgery, bleeding at the operative site often hampers visual information about shape, size, and color. Basic research in perception shows that sensory inputs are weighted according to the quality of information they provide*."

(Keehner and Lowe 2010)

The wider scientific literature suggests that when visual cues are ambiguous, they may carry less weight, and haptic cues may dominate (Ernst and Banks 2002) (Atkins, Fiser et al. 2001). This research suggests that surgeons may afford some flexibility and judgement in the way in which they combine information from visual and haptic cues, weighting them accordingly depending on the context, and the quality of the cues available to them.

Bholat (Bholat, Haluk et al. 1999) found that direct palpation provided the greatest degree of haptic feedback, with diminishing quality of the haptic cues when either conventional surgical instruments or laparoscopic instruments were used. Compared with conventional surgical instruments, laparoscopic instruments led to a significant decrease in the ability of the surgeon to differentiate consistency of objects presented to them; however the laparoscopic instruments did not detract from the surgeon's ability to discriminate shape or surface texture (Bholat, Haluk et al. 1999).

These findings are of significance to the general surgical community where laparoscopic approaches now predominate surgical techniques. It is possible that haptic cues, transmitted through long instruments, as well as the friction of the instrument in the port, may be dampened, meaning that visual cues become relatively more important for semiosis.

"Because of the physical disconnection between the surgeon and the operative site, the quality of the sensory feedback is substantially degraded. Direct touch with the hands is not possible, and distal feedback from the instrument tips is distorted by friction in the cannulae (where the instruments enter the body). The haptic cues that surgeons say are so important for recognizing anatomical shapes are substantially diminished under these conditions."

(Keehner and Lowe 2010)

These insights suggest that learning visual cue interpretation may have assumed even greater importance, due to recent technological progress in terms of access techniques for surgical operations.

3.5.3 Learning adaptive strategies

This investigation also made explicit that adaptive strategies were an important content area of learning in the operating theatre. Hatano and Inagaki were the first authors to coin the terms 'routine technical expertise' and 'adaptive expertise', they used the example of two Sushi chefs - one working to produce perfectly and identically executed pieces every time under controlled restaurant conditions as a 'routine technical expert' and an 'adaptive expert' as a chef who had trained in these controlled and strictly regulated conditions but was now designing new pieces using the materials and ingredients available, through a process of innovation. Hatano and

Inagaki suggested that in order to become an adaptive expert, first you must become a routine technical expert, then with further experience the ability to innovate may or may not be acquired (Hatano and Inagaki 1986).

Adaptive expertise is required in circumstances where there are no strictly controlled or regulated environmental conditions, where individual differences or variations may be encountered. One of the content areas discussed by surgeons in this study was termed ‘adaptive strategies’ - a portfolio of ideas of recourse that could be utilized when complications or individual variations were encountered. There is no suggestion that adaptive strategies were learnt **after** becoming a routine technical expert, but that the acquisition of adaptive strategies occurred throughout training to enable the surgical trainee to work with the anatomical and pathological variability encountered.

This study set out to investigate learning in the operating theatre and therefore the term ‘adaptive strategies’ rather than ‘adaptive expertise’ was used. Participants were not describing fully trained surgeons learning how to innovate, instead they were discussing learning adaptive strategies alongside skills applicable for routine technical expertise.

Hatano and Inagaki stated that adaptive experts were able to comprehend why procedures they knew worked, then they were able to modify those procedures, flexibly, when required and thus invent new procedures when none of the known procedures were effective. Little is known about what triggers individuals to innovate and in what contexts the learning of adaptive expertise is fostered. Hatano and Inagaki suggest four conditions as important for triggering the development of adaptive expertise:

- Encountering, fairly often, a novel problem to which prior knowledge is not readily applicable
- Engaging in frequent dialogic interaction such as discussion, controversy and reciprocal teaching
- Being free from urgent external need e.g. Material rewards or positive evaluations, and thus able to pursue comprehension even if it is time-consuming
- Being surrounded by reference group members who value understanding.

(Hatano and Inagaki 1986)

In terms of the surgical educational environment, the first condition for fostering adaptive expertise is frequently present, due to patient anatomical and pathological variability. Condition three is often constrained by the work demands of the operating list or clinical urgency. Conditions two and four are linked to the teacher themself, their teaching style and the attitudes of others working within the theatre environment. Further investigation is required as to how trainees learn adaptive strategies in the theatre environment.

3.5.4 Learning attitudes and behaviours

Personal attitudes and behaviours have not previously been discussed in the literature as ‘content areas of learning’ in the operating theatre. Lave and Wenger thought that apprenticeship style learning changed the identity of the learner. The surgeons interviewed in this study perceived that attitudes and behaviours, attributes that may constitute the identity of the individual, were being learned in the operating theatre. There are many features of surgical training that mirror an apprenticeship style of learning. Lave and Wenger believed that the change in identity was due to long periods of time spent with the master, and a desire of the student to please the master by mirroring his or her behaviours (Lave and Wenger 1991).

Swanson and Jack found that preferred learning styles and personality types, as per Myers-Briggs indicators, were different between fully trained and trainee surgeons (Swanson, Antonoff et al. 2010) (Jack, Kenkare et al. 2010); their conclusions were that these represented different generations and changes in selection and recruitment into surgery. The suggestion that attitudes and behaviours are learned within the operating theatre, is a novel finding. It prompts consideration of an alternative explanation of Swanson and Jack’s findings, which is that junior surgeons undergo transformative change during the process of post-graduate training. This resonates with Lave and Wenger’s assertions that apprenticeship learning leads to a change in learner identity (Lave and Wenger 1991). An exploration of what constitutes identity change and how this is linked with personality and preferred learning style is beyond the scope of this thesis. It is however, interesting to note that surgeons perceived that their attitudes and behaviours changed during their post-graduate training and for the reader to note that this may represent a change in identity of the learners.

3.6 Conclusions

Some of the domains of learning made explicit by this study have already been extensively investigated, for example motor skills acquisition. Other domains of learning have been previously mentioned in the surgical literature, for example team-working and managerial skills under the over-arching term non-technical skills, but gaps remain in our knowledge of how and where these complex attributes are acquired. Yet other domains of learning - factual knowledge - have brief mention within the surgical literature, yet appear to be widely accepted by the surgical community as being appropriate domains for high-stakes examination purposes and career progression.

Domains of learning, highlighted by this investigation, that have not had prior extensive coverage in the surgical literature include:

- Visual semiotics – the learning of visual cue interpretation
- Haptic semiotics – the learning of haptic cue interpretation
- Adaptive strategies
- Personal attitudes and beliefs

Sensory semiotics holds particular interest to the general surgical community as the wider scientific literature suggests that cues are weighed up, depending upon context and quality of the information. So that if one set of cues are ambiguous, the surgeons' decisions may be dominated by judgements based upon an alternative set of cues. This may be significant in laparoscopic surgery where the long instruments and friction in the ports may diminish the quality of the haptic cues and lead to a higher reliance upon visual inputs.

3.6.1 Reflexivity

This was an interview study, and reports the perceptions of surgeons and is therefore subjective. Although direct evidence of clinical practice can only be gained through observation in the operating room, the views and opinions of trainers and trainees can offer a different kind of insight. When captured in an interview setting, such responses can identify principles or themes of particular importance. This perspective (grounded, of course, in each participant's personal experience but modulated through reflection and abstraction) frames general issues such as 'What are the important aspects to be learned in the operating room?' rather than specific ones such as 'What did I (or my trainee) learn from this particular case at this time?'

It has already been acknowledged that during probing in a semi-structured interview it is possible for the researcher to potentially bias the data. There has been discussion for several centuries amongst philosophers and sociologists regarding the extent the interview itself can in fact be unbiased as many authors would argue that the interview data is shaped by the interactions between the interviewer and the interviewee (Kant 1963; Silverman 2010).

An interview is "*…an interchange of views between two or more people on a topic of mutual interest, [and] sees the centrality of human interaction for* *knowledge production and emphasizes the social situatedness of research data."* (Kvale 2009)

Some authors would go further and argue that the interview itself represents a 'creative conversation' as each utterance by the interviewee is interpreted by the interviewer and therefore the data does not belong solely to the interviewee but has been jointly constructed between the pairing(Scheurich 1995).

Whilst the researcher acknowledged the potential for bias when conducting semi-structured interviews, she sought to minimize these effects by piloting the interview topic guide, prior to commencing data collection and by staying mindful of the need to be non-judgmental and open to new ideas throughout the data collection and analysis. This was in accordance with Hoyle, Harris and Hudd who state that:

"…*proper training and proper interviewer behaviour can help greatly in achieving the goals [of minimizing bias during interviews]"* (Hoyle, Harris et al. 2002)

The interviewer was a senior surgical trainee in the UK training system. She was neither the trainee of, nor the trainer of, any of the participants recruited to the study, although, had previously worked in the same hospital setting as some of the participants. This was to try to ensure that the views expressed by the participants were genuinely their own views rather than an attempt on behalf of the interviewee to express concordance with the views of the researcher. Additionally, the researcher had not discussed her emergent research findings with any of the interviewees prior to the research interviews taking place. The researcher therefore concludes that the views expressed by the interviewees were their own views.

No incentives were offered to the participants to take part in the study however, their motivations to take part in the study should be considered. Whilst the absence of pecuniary reward or honorarium meant that participants took part in the study purely out of good will, this inevitably may have biased the results.

The researcher supposed that all the surgeons who took part in the study were likely to have had a particular interest in surgical education as they gave their time freely. The reasons for their interest in taking part in the study were not explored, however the researcher supposed that this may have been because of experiences of poor training and a philanthropic desire to assist with research that could contribute knowledge that may lead to better training for future generations, or conversely they may have experienced excellent training and wished to ‘give something back’ to the healthcare system through participation in the research project.

Whilst the researcher was neither trainer nor the trainee of any of the participants in the study, the surgical community is small, and most of the participants in the study had had previous professional contact with the researcher. Whilst this previous professional contact was helpful in terms of recruitment to the study, as potential participants did not regard the researcher with suspicion but rather appeared to regard her as ‘one of them’, the previous professional contact was a potential for bias. Motivation to take part in the study should be considered - trainers potentially may have been motivated to take part in the study due to previous positive contacts within the professional setting, and trainees may have been motivated to take part in the study either because they felt indebted to the researcher due to positive training experiences or even the hope that they would benefit from training from the researcher in their future careers.

To conclude this chapter, the content of postgraduate learning in surgery has been found to be complex, spanning social, cognitive, psychological and motor domains. Further research is needed to determine whether this self-report data is an accurate representation of content of learning in the operating theatre.

CHAPTER 4 - Surgeons’ perceptions of how learning happens in the operating theatre

4.1 Abstract

Objective

The objective of this chapter was to explore surgeons’ perceptions of how learning happens in the operating theatre - the processes of teaching and learning.

Method

Grounded theory methodology was used. Data was iteratively collected through semi-structured one-to-one interviews with 22 surgeons (trainers and trainees). Throughout this process, the transcripts were thematically analysed by a four-person data analysis team.

Results

5 processes of learning were identified by the surgeons.

- ‘Learning by doing the case in the absence of explicit teaching activity’
- ‘Learning by doing the case with explicit teaching activity’
- ‘Learning by observing the case with explicit teaching activity’
- ‘Learning by observing the case in the absence of explicit teaching activity’
- ‘Learning by teaching others’

These process categories broadly related to the learner's level of participation in the operation (operating surgeon or assistant) and whether explicit teaching was being given. Content of learning appeared linked to process. This investigation found that higher motor skills were perceived to be learned through repetition, that team-working, managerial skills, attitudes and behaviours were perceived to be learned through modelling and that factual knowledge was perceived to be learned through quizzing and telling. Sensory semiotics and adaptive strategies were perceived to be learned through multiple processes, in both participatory roles (surgeon or assistant) and both with and without explicit teaching activity.

Discussion

This investigation found that different content areas of learning in the operating theatre required different learning processes. This somewhat contradicts current ideas of educational design in which attempts are made to tailor the learning processes to the preferred styles of the students. Educational design in this way may not be desirable or possible in the operating theatre which functions first and foremost as a work environment, where patient operations are performed, and only secondarily as a learning environment.

Different educational theories become particularly relevant to different content areas of learning. For example social learning theories appear important in learning team-working, managerial skills, attitudes and behaviours. Learning of sensory semiotics and adaptive strategies appears particularly complex, with surgeons describing “scaffolding” as well as reflection-in-action.

4.2 Introduction

Understanding how individuals learn particular skills and attributes is important for planning effective learning strategies. There needs to be an understanding of the mechanisms that learners employ, so that stimuli and circumstances, to afford pedagogic advantage, may be provided. Participant reported data may provide valuable insights into the strategies used by individuals for teaching and learning in the operating theatre. The disadvantage of using participant reported data, is that it relies upon the meta-cognitive abilities of the participants of the study being able to relate how they learn (Flavell 1976).

The data presented in this chapter was collected concurrently with data exploring content of learning in the operating theatre. Processes of learning are presented in this separate chapter; this was done to aid the reader, as although initially abstract processes of learning are presented, the content themes outlined in the previous chapter are then used as a basis for further analysis.

4.3 Method

This investigation used a grounded theory methodology using one-to-one interviews to gather data from surgical trainers and trainees. The method and choices made about study design, participant selection and analysis methods are fully explained in the preceding chapter.

During the interviews, questions of process were more challenging to respondents, than questions about content. Participants' responses about content of learning in the operating theatre provided an anchor for questions about process. Content was always addressed before moving on to questions about process. For example, once the interviewer had reached the key question and had probed the answer she would revert either to a transition question or a key question to explore process. For example, 'how do you teach in the operating theatre?' Or, if the key question about content had elicited answers in very specific areas, then questions about process would use this as a stem. For example, 'During a laparoscopic colectomy with a registrar you were talking about teaching them to identify tissues planes; how do you go about teaching this?'

Whilst there was considerable overlap between data discussing the content of what was being learnt and how learning happens, very few of the actual data points were identical (exactly matching groups of words). A compound query was run in NVivo 9.0 in which Boolean operators were used to search all identical phrases coded under ‘Content’ AND ‘Process’. This found that only twenty-six data points had been coded in both of these areas. However a number of data points, although not an exact match, linked content and process. This formed the basis of a further analysis, entitled axial coding of content and process.

4.4 Results

289 data points (short paragraphs or phrases conveying meaning) were coded as process of teaching and learning by the primary researcher and 85 by the secondary coder. Table 2 outlines the major themes that emerged from the interview analyses and the inter-coder agreement. The inter-coder agreement was calculated as the proportion of the second coder’s items that were selected and identically coded by the primary researcher. The emergent themes from this analysis are presented using illustrative quotations and then further analysis was undertaken using axial coding; this examined areas of overlap and provided insights into the relationships between content of learning and processes utilised.

The process of learning in the operating theatre was widely regarded by study participants to be linked to two different participatory roles - that of ‘surgeon’ or ‘assistant’. Surgeons broadly equated these roles with ‘doing the case’ or ‘observing the case’.

The major categories arising were:

- Trainee doing the case in the absence of explicit teaching activity
- Trainee doing the case, with explicit teaching activity
- Trainee observing the case with explicit teaching activity
- Trainee observing the case in the absence of explicit teaching activity
- Learning by teaching others

Table 2: Number of data points coded and coding agreement across process categories between two members of the analysis team

	AC	**SM**	**Coding agreement**
'Doing the case in the absence of explicit teaching activity'	21	5	0.7
'Doing the case with explicit teaching activity'	132	46	0.8
'Observing the case with explicit teaching activity'	46	7	0.7
'Observing the case in the absence of explicit teaching activity'	85	25	0.5
Learning 'by teaching'	5	2	0.6
Overall	**289**	**85**	**0.7**

Quotations have been selected to illustrate the themes and subthemes that emerged from the data itself. The quotations presented are representative of that theme and subthemes.

4.4.1 ‘Doing the case’ with no explicit teaching activity

This was learning from being the operating surgeon in the absence of explicit teaching activity. Participants discussed the benefits of repetition and gaining motor skills by practising the moves over and over again until they became automated. This repetitive practice from initial hesitancy of movements to automation did not always appear to require faculty input or ‘teaching’ activity.

“And I think the motor skills are learned by repetition, by mileage, by spending sadly long hours in theatre with a pair of scissors and a pair of McIndoes in one hand and a pair of DeBakeys in the other and doing things over and over again. And that hardwires certain skills into your spinal cord.”

Trainer 6_District General Hospital_01.06.11

‘Doing cases in the absence of explicit teaching activity’ was thought to require reflection on the part of the trainee, as there was no explicit feedback from the trainer, instead the trainee needed to respond to the living tissues. This was termed learning by ‘trial and error’ by the surgeons interviewed.

“ I … learn by trial and error in certain situations, so it, within a certain operation if I find that when I make a skin incision, that it bleeds too much, then I learn next time I do the same operation, I try to modify it slightly or I take more care on the way to the operation, on the way into the first incision…”

Trainee 5_Teaching Hospital_ST4_28.03.11

This reflection was in response to ‘intrinsic’ feedback from the tissues, however it required the trainee to be able to recognize and interpret ‘intrinsic tissue feedback’.

“…there is a bizarre gratification in surgery, when you hit the right plane and it just opens up…”

Trainer 4_Teaching Hospital_11.11.10

“…just seeing planes open beautifully and then seeing anatomy which is familiar makes us all feel very comfortable. And it makes you feel happy.”

Trainer 4_Teaching Hospital_11.11.10

4.4.2 'Doing the case with explicit teaching activity'

This theme featured prominently throughout all of the interviews, however there was considerable variation in what 'doing' constituted. It may have been a very minor and low-risk small section of the operation or may have been the entire case skin to skin. In some interviews trainees described the trainer 'giving them little bits of the operation to do' if they were not capable of the high risk or difficult parts of the operation.

"…he's been very good at fairly quickly letting you get on and do bits of the operation as he's been supervising you and taking you through it, talking you through, giving you the tips as you go."

Trainee 2_Teaching Hospital_ST7_24.09.10

The explicit teaching activity when the trainee was 'doing' a part of the case could be broadly divided into two sub-themes which related temporally to trainee actions:

- Instruction – explicit teaching activity preceding a trainee action
- Feedback – explicit teaching activity proceeding a trainee action

4.4.2.1 Instruction

Instruction came before a trainee action and involved the trainer indicating to the trainee what he would like the trainee to do next. It could be verbal:

"He'll just say there's the line or you can see the areolar tissue or you can see the translucency and go through there…"

Trainee 7_London_CT2_31.05.11

Instruction could also be non-verbal:

"…by pointing their laparoscope in the direction they want you to go, or occasionally they may come in and put their hands onto yours to redirect your instrument to where it actually wants to be."

Trainee 2_District General Hospital_SpR_24.03.11

Sometimes instruction was direct, when the trainee was told exactly what to do, at other times it was more of a suggestion of what might work well in the circumstances.

"…without doing the … a 'cut here' approach, but making sure that if someone is drifting into the wrong plane, you help them drift back into the right plane, without necessarily saying, 'Oi, over there,'…"

Trainer 10_District General Hospital_25.07.11

Authoritarian, direct form of instruction was not perceived to have high value, as the surgeons thought that the decision-making was being carried out by the trainer, even if it was the trainee whose hands were on the operating instruments.

"…there's no point for me to say to the registrar 'do this, do this, do this' as you completely control, because this is not really the main way of learning."

Trainer 1_Teaching Hospital_24.09.10

There was some preference expressed by trainees for verbal rather than non-verbal teaching activity when they were in the role of operating surgeon.

“He might retract for you the first time round and say this is the plane. But he won't actually point to it either. He'll just say there's the line or you can see the areolar tissue or you can see the translucency and go through there. But he won't touch it. I think that's, at my stage, that's really important because I need to see it, I don't want to be actually physically shown it, I want to interpret it myself. That's really important.”

Trainee 7_Teaching Hospital_CT2_31.05.11

4.4.2.2 Feedback

Feedback was an evaluation of the learner’s action after execution of a small move and could be positive or negative.

“…making encouraging remarks in that I'm doing something well…”

Trainee 11_District General Hospital_ST6_15.06.11

“I would say it’s from, sort of, well, negative and positive feedback. If they do something well, I say, ‘Yes, that was good,’ you know, ‘I like the way you do that, keep doing it,’ and me observing them. So, if they’re not doing something, which I feel happy with, then I will say, ‘No, you perhaps need to try it this way.’”

Trainer 8_District General Hospital_23.06.11

If the trainee was progressing well, the trainer might say very little, allowing the trainee to continue, as it was tacitly understood that the trainee’s approach was satisfactory.

Feedback and instruction were viewed as necessary for the junior learner, with intra-operative feedback only required for a senior learner when the operation was not progressing as the trainer wanted.

“When I've got a junior surgeon doing a laparoscopic cholecystectomy it's difficult to shut me up. But the closer the trainee comes to reproducing what I want to see, the less I have the need to talk.”

Trainer 7_District General Hospital_15.06.11

“I think they will articulate when… when you do something wrong.”

Trainee 12_District General Hospital_ST3_23.06.11

4.4.3 Observing the case with explicit teaching activity

Surgeons described the learner being an assistant, with the trainer explicitly describing, explaining or showing what they were doing. Sub-themes were explaining, demonstrating and quizzing.

4.4.3.1 Explaining

Some surgeons described a ‘think aloud’ process so that the trainee was party to the cognitive processes that were going on in the mind of the trainer.

“I’ve often found myself talking through options as to how you could deal with something operatively, and I think that helps, hopefully helps people to understand the sort of thought processes going on.“

Trainer 9_District General Hosptial_20.07.11

Trainees related that there was less of this ‘think aloud’ activity when the operation was complex or difficult, perhaps indicating the increased cognitive load that this placed upon the trainer.

“…the consultants, when they’re in teaching mode, then they will probably be more aware that they would, they need to articulate their ideas, like, ‘This is,’ you know, ‘what needs to be done, and this is why I’m doing it, and this is how it’s done,’ but when it’s, as I say, in an emergency operation, when things aren’t going very well, then perhaps it’s just a natural response, and perhaps

they just, they need to concentrate on what they need to do and they don't necessarily articulate exactly what they're thinking to the trainee."

Trainee 12_District General Hospital_ST3_23.06.11

The 'think aloud' was regarded as a useful means of shedding light upon the trainer's cognitive processes and seemed relevant to all levels of trainee. This teaching activity was frequently termed 'explaining' when it was verbally conveyed. 'Explaining' involved the trainer using language to make the decision making process explicit.

4.4.3.2 Demonstrating

Teaching activity when the learner was the assistant was also related to occur through non-verbal mechanisms. In these cases the surgeons described the trainer using gestures to make the plane for dissection more explicit to the trainee. This was often termed 'demonstration' to the trainee.

"When I've got a junior trainee I will help demonstrate the plane, so I might point it out or I might elevate it for them."

Trainer 4_Teaching Hospital_11.11.10

The trainers also described using demonstration to show the trainee how they should proceed, they regarded this as giving the trainee an exemplar - a perfect display of what they would like the trainee to do.

"…sometimes shown, you know, say for the start of the, of a graft anastomosis, shown how to start, by the consultant or the trainer doing the first part of the anastomosis so that I got the hang of it."

Trainee 5_Teaching Hospital_ST4_28.03.11

Demonstration was described as occurring just prior to the trainee getting a chance to 'do' part of the operation. Demonstration was also described as being used as part of feedback or correction. If the trainee had been 'doing' the operation but the particular move had not been to the trainer's satisfaction, he may temporarily relegate the learner into the role of observer, and 'demonstrate' what he had wanted.

"…when they get to the bit, the crucial bit or the main bit of the operation then if they're not doing it the way I want I'll then demonstrate it and show them how to do it and then hopefully let them carry on…"

Trainee 5_Teaching Hospital_ST4_28.03.11

Demonstration was a useful means of showing the trainee what it should look like, providing an exemplar for comparison when the trainee performed the action. Demonstration was described as occurring at a transition stage when the trainee was transitioning into the role of primary surgeon.

4.4.3.3 Quizzing

Another explicit teaching behaviour, described as occurring when the learner was observing the operation, was 'quizzing'; this involved the trainer questioning the learner to establish his level of knowledge and then providing further qualification or explanation of the given answer.

"To increase your learning, if they ask you questions, and not a lot of trainers do always ask questions when they're operating…"

Trainee 4_Teaching Hospital_CT2_25.03.11

There was expression by participants in this study that 'teaching activity' was able to progress learners out of the sphere of unconscious observation and that this was a desirable outcome of the 'teaching activity'.

"…if you aren't structured enough and if you aren't focused enough on what you actually want your trainee to learn, that in actual fact you will go back to the old model which used to be learn by osmosis, watch me young man, and eventually one day you will do what I do."

Trainer 7_District General Hospital_15.06.11

4.4.4 Observing the case in the absence of explicit teaching activity

There were multiple descriptions in the interview transcripts of learning by watching or observing what the trainer was doing. This was described as happening without explicit teaching activity; only through observation of the trainer by the trainee.

"…a lot of what is learnt in the initial stages is learnt by observing…"

Trainer 3_Teaching Hospital_20.10.10

This learning was not described as passive observation (learning by osmosis), but rather as a process where the trainee was constantly reflecting on what they saw and why the trainer was tackling things in that way. This required trainee effort to remain focused on what could be learnt.

"…I think you have to just be proactive when you're assisting because otherwise I think you could easily not take in much…"

Trainee 6_Teaching hospital_CT1_28.03.11

Learning by observation in the absence of explicit teaching activity was particularly challenging for the very junior learner, as the trainee was unaware of what they should be paying attention to.

"I lacked the knowledge to even watch it properly. And I think that the biggest challenge for very junior surgeons, is to learn how to watch effectively and to learn from watching."

Trainer 7_District General Hospital_15.06.11

"I think that as you become more senior you can almost get as much out of watching as you can out of doing. Providing that you've already done the operation enough and that spectrum runs right back to the more junior levels whereby if you watch you will get almost nothing out of it. All you will really do is to see what happens."

Trainer 7_District General Hospital_15.06.11

Learning by observing was clearly a key process of learning in the operating theatre, however this was not described as 'learning by osmosis' or the 'tea steeping method'. The surgeons in this study described learning, when observing, as an active process. This required trainee effort to focus and reflect upon what they were seeing. Learning by observing was particularly challenging for the junior trainee if they were not familiar with the procedure.

4.4.5 Learning by teaching others

This theme featured in the interviews of senior trainees who were operating without direct supervision and newly taking on trainer roles.

Having to teach technical skills to a more junior surgeon could highlight for them their own short-comings, and allow them to reflect upon their own areas for development.

"But actually I'm finding that coming back to basics and teaching is making me realize that I've got a lot to learn in terms of economy of hand movement."

Trainee 9_District General Hospital_ST5_02.06.11

The process of making things explicit for a more junior trainee was described as helping crystallize some of the things that they knew implicitly and it highlighted gaps in their own knowledge or skills.

"And you can ask them to teach somebody else, which is quite a good way of focusing their mind on what knowledge they have and have not got."

Trainer 9_District General Hospital_20.07.11

Teaching others appeared to stimulate reflection by the senior trainee about their own skill set, and was thought to assist with learning. This was through highlighting areas of weakness and encouraging reflection upon their own practice, the trainee would then still need to address these gaps in knowledge and skills. Teaching others therefore provided stimulus and motivation for further learning.

4.4.6 Axial coding relationships between content and process

Whilst only 26 identical data points were coded as both content and process, surgeons referred to particular processes being important for learning in some specific content areas. Insufficient evidence was gathered in this study to formulate robust theories about process of learning across all content areas, however, in some content areas, data emerged to suggest that particular processes of learning were important.

4.4.6.1 Learning by 'doing the case' in the absence of explicit teaching activity

Motor skills learning

The surgeons described motor skills learning in theatre occurring whilst 'doing' the procedure, as a result of being the primary surgeon. Explicit teaching activity was seldom mentioned except when the surgeons described initial learning of basic manoeuvres such as knot-tying, which was generally described as occurring outside the operating theatre – during Basic Surgical Skills courses.

Repetition and numbers of cases were thought to be important in the learning of motor skills in the operating theatre.

"We spent a lot of time with a pair of scissors in our hand just operating…And I did veins and hernias after the first week unsupervised. I'm sure the first 100

didn't do terribly well, but it taught you reliance and it gave you mileage…And one of the things about surgery is that you build up the pathways in your spinal cord with your McIndoes and you develop dissecting skills through doing a lot of dissecting, and I don't think modern trainees get as much mileage as they used to do. They get a hell of a lot of supervised operating, they don't get to develop their skills by doing lots and lots of relatively low grade, relatively low stress operating, which is what we did…I did develop a lot of motor skills in dissection just by doing, repeating relatively low stress operations."

Trainer 6_District General Hospital_01.06.11

"The other thing is just volume I think because trainees aren't exposed nearly enough to volume of work these days. And I think that a lot of the time they can pick up good skills for dealing with particular parts of an operation, but there's no substitute, you may be able to do it brilliantly, but there's no substitute for having done it a 100 times."

Trainer 7_District General Hospital_15.06.11

"They know how to do it, they just haven't practised it, they need to take some suture and go practise it."

Trainer 4_Teaching Hospital_11.11.10

The surgeons interviewed in this study described motor skills learning through being the primary surgeon and having hands on the operating instruments. Motor skills were acquired in the operating theatre through repeated practice and the automation of actions. Learning of motor skills in theatre was not described as being related to explicit teaching activity.

4.4.6.2 Learning by observing the case in the absence of explicit teaching activity

Team working, managerial skills, attitudes and behaviours

These attributes were quite clearly described by the surgeons as being learned through observation of the trainer and modelling. These could be learned when the learner was in the role of assistant. There were very few references to explicit teaching.

"…non-technical skills, decision making, how you communicate with the staff, how do you plan for the operation, how do you try to prevent major disasters in the operating theatre. I think a lot of this is just learnt by observing seniors."

Trainer 3_Teaching Hospital_20.10.10

"They need to be learning and looking at what I am doing to make that list turn over…"

Trainer 4_Teaching Hospital_11.11.10

This was also the case when surgeons described learning attitudes and behaviours. No explicit teaching activity was described.

“You learn to a large extent who and how and what you want to grow up to be like but you also occasionally, you learn what you don’t want to grow up to be like.”

Trainer 6_District General Hospital_01.06.11

These attributes were learnt through trainee observation of the trainer during day-to-day interactions with other members of staff, with the trainee and with patients.

“I’m learning communication with the theatre staff and the way that...just from an observation point of view, from the way my consultant behaves with the theatre staff and interacts with them, I learn about what is appropriate, what isn't appropriate, what you can expect.”

Trainee 10_District General Hospital_CT2_08.06.11

The teacher is clearly an integral part of learning team-working, managerial skills, attitudes and behaviours, however, this was not as a result of explicit teaching, but due to active observation and modelling of their actions by the trainee.

4.4.6.3 Learning when observing a case with explicit teaching activity

Factual Knowledge

This was described as being learned mainly when the learner was in the role of assistant. Factual knowledge content taught explicitly was described as ‘quizzing’ and ‘telling’.

"To increase your learning, if they ask you questions, and not a lot of trainers do always ask questions when they're operating because they think, oh you should know all your basic anatomy, which the majority of us do. But, if you're in an… unfamiliar anatomical region, sometimes it's nice just to refresh your, to start from the basics, refresh your anatomy, think about the complications."

Trainee 4_Teaching Hospital_CT2_25.03.11

"…So we discussed the steps in advance. And then he will show me a step and then talk me through the other steps..."

Trainee 7_Teaching Hospital_CT2_31.05.11

4.4.6.3 Content areas in which several different processes appear to be utilised

<u>Haptic cue interpretation</u>

This was described as being learned when the learner was in the role of primary surgeon as learning to interpret 'the feel' required a hands-on approach.

"I would say particularly emergency surgery probably, where the most important thing is the actual feel of the tissue directly under your fingers"

Trainer 7_District General Hospital_15.06.11

The surgeons described only being able to learn haptic cue interpretation by 'doing', through feeling and cutting living tissues. It was unclear whether explicit teaching was an important part of the process of learning haptic cue interpretation skills.

<u>Visual Cue Interpretation</u>

Surgeons described learning visual cue interpretation both when the learner was assistant and when the learner was primary surgeon. In both of these participation categories the trainee was assumed to have access to the visual stimulus of the operative field.

Learning was sometimes described as being associated with explicit teaching activity:

"…that can be done either by, just either using pair of interfering forceps or whatever, and just opening up a plane and saying 'Look can you see the difference? If you stay in that plane it's not going to be bloody, compared to the plane that you're in.' But then letting them have the instruments back again so that they can continue so far until they start drifting out. "

Trainee 9_District General Hospital_ST5_02.06.11

Sometimes in the absence of explicit teaching activity:

"I think if you do enough cases in theatre on real people you start just having appreciation, you start expecting in what plane you're going to start seeing things."

Trainee 9_ District General Hospital_ST5_02.06.11

Adaptive strategies

Adaptive strategies were also described as being learned both when the trainee was assistant and when they were the primary surgeon.

"Unexpected findings during an operation, what do you do. And often you can, you only know what to do if you've seen it before, either by someone else doing it or by you doing it."

Trainee 8_District General Hospital_ST5_02.06.11

Learning adaptive strategies was sometimes described as happening by observing how a more senior surgeon dealt with difficulties, in the absence of explicit teaching activity, then storing these strategies for future reference.

"…they observe and can absorb what goes on and how to manage other situations. So, if a case is going wrong, that's what happens with some cases – that still is educational, but it's not direct…"

Trainer 4_Teaching Hospital_11.11.10

However, explicit teaching was also used to assist with learning adaptive strategies, sometimes in an abstract way - not directly stimulated by an actual difficulty occurring:

"You can ask them, …what they would do if particular scenario happened. What if I made a hole in the inferior vena cava now, what would we do?"

Trainer 9_District General Hospital_20.07.11

"…he'll say, so what if this had happened, how would you have corrected that, to try and get you to think of future steps."

Trainee 4_Teaching Hospital_CT2_25.03.11

Some participants in this study related that experiencing difficulties for themselves, and trying to solve them, was an important mechanism for learning adaptive strategies. Some expressed that they thought that these skills could not be learnt from observing alone.

"I think that without doing it, although I think you can learn, you know, for instance what to do in unexpected situation or how someone does that certain operation, I do think that unless you're actually doing it, you're not getting that full learning experience."

Trainee 8_District General Hospital_ST5_02.06.11

Learning of adaptive strategies was described as occurring through observation and through experiences of 'doing the case' themselves. The process of learning was sometimes described as associated with explicit teaching - as an abstract exploration of how the trainee would react in certain circumstances, and sometimes without explicit teaching.

4.5 Discussion

The surgeons suggested that there were five different processes of learning and that these were related to the learner's role (primary operating surgeon or assistant), and whether there was any explicit teaching from the trainer. Further axial coding suggested that there were links between content and the processes of learning. This is of interest to the educator as conventional educational teaching has been to tailor the process of learning to the learning preferences of the students for best pedagogic effect (Kolb 1984) (Jack, Kenkare et al. 2010). It is possible that using particular processes would assist learning in particular content areas. This discussion section will place the processes of learning, identified by the surgeons, within the broader literature with reference to educational theory.

4.5.1 Repetition

After learning the basic surgical manoeuvres, which were said to involve explicit teaching activity, it was thought that higher motor skills such as fine movement, accuracy, efficiency and economy of movement were learnt through repetition leading to automation.

Automation of movements had been thought of as arising from the slow formation of a "beaten trail" in the neuronal pathways. Repetition had been considered important in establishing the "beaten trail" where a single performance would only produce a weak trace, however the summation effect of multiple repetitions caused fixation of the pathway and for the movement to become automated. However, in the 1960's, Bernstein, a neurophysiologist, who studied Soviet manual labourers chiselling metal, argued that the resulting automation of movements was not due to the establishment of fixed neuronal pathways, but instead that multiple repetitions allowed the subject to acquire highly developed feedback loops and control strategies; these ensured that the overall movement appeared smooth and identical even in unexpectedly changing external circumstances, due to subtle modifications (Bernstein 1967). Bernstein suggested that motor skill acquisition started with formation of the neuronal equivalent of the motor task, and that the apparent automation of the skill occurred due to elimination of the redundant degrees of freedom. The learner would become able to master or overcome, unexpectedly changing, external or reactive forces through organization of multi-level feed-forward and feedback loops. Repetition was still considered important in this learning process, however, the mechanism was through building experience of dealing with subtle changes and yet maintaining a reproducible and identical movement.

K. Anders Ericsson's work on acquisition of expertise suggests that the repetitions of an individual who will go on to become an expert are different from the repetitions of an individual who will become merely proficient (Ericsson, Charness et al. 2006). Ericsson discusses the importance of 'sustained deliberate practice' of particular components of the task as being necessary in order to become an '*expert*' rather than a proficient performer. This sustained deliberate practice is a focused and de-contextualized repetition of specifically chosen challenging aspects of the overall task, rather than a global repetition of the entire exercise.

In the context of learning in the operating theatre, specific challenging aspects of the overall task cannot be extracted and repeated for learning purposes, as the primary focus of the operating theatre episode is patient care rather than the needs of the learner. Sustained deliberate practice as described by Ericsson does not appear involved in learning motor skills in the operating room itself, although it may have a place in surgical learning in simulation.

4.5.2 Modelling

Learning non-technical skills through observation of the trainer was a key theme that emerged from the data. Bandura’s social learning theory includes three core concepts - that people can learn through observation, that mental states are an essential part of this process, and that although learning through observation may lead to behaviour change, sustained change in behaviour is dependent upon external and internal learner motivators (Bandura 1977).

Learning through observation of the trainer may be termed modelling. Bandura stated that the necessary conditions for modelling to be effective are: attention, retention, reproduction and motivation. Attention and motivation relate to the mental state of the learner. The teacher’s role is to capture learner attention, increase motivation to learn and continue to provide external motivators to encourage sustained behaviour change (Bandura and Walters 1963).

Other social learning theories, important in understanding modelling, are those of Lave and Wenger who argue that learning occurs as a consequence of legitimate peripheral participation in a social group (Lave and Wenger 1991). Immersion in a social environment in which the learner has a role to play, fosters attention and motivation. In the context of surgical training this resonates with descriptions of how a junior learner may progress through the participatory roles becoming assistant then working under supervision, before finally taking the role of lead surgeon. Lave and Wenger assert that the lengthy period of time the learner spends with the master, and the student's desire to please the master, are factors that lead the learner to behave in a similar way as the 'master'.

'Legitimate peripheral participation gives a sketch in the learners mind as to how the masters themselves talk, walk, work and how they conduct their lives.'

(Lave and Wenger 1991)

This process of learning may be threatened through diminishing work-hours as a result of the European Working time Directive (Benes 2006) (Marron 2005) and also the erosion of the 'firm structure' due to junior surgeons out-of-hours rota cover arrangements.

4.5.3 Quizzing and Telling

Quizzing and telling were phenomena that occurred when the learner was in the assistant (observer) role with explicit teaching activity. The trainer would ask questions of the learner who in turn would supply an answer: this then stimulated further ‘explanation’ from the teacher. This construct ‘Initiation’, ‘Response’, ‘Evaluation’ or IRE sequence is well recognised within mainstream education literature (Wells 1993). This style of teaching has been described in the educational literature, as a ‘transmission of knowledge’ from the teacher to the student, rather than the development of skill. Karl Popper (Popper 1934 (English 1959)) refers to this as the “bucket theory of the mind” in which the teacher pours knowledge into the student. The teacher is viewed as a font of knowledge and controller of the learning process.

Transmission style teaching may be considered ‘teacher centred’ as “the informational input occurs largely through the activity of the teacher, whose main skills are directed towards the encouragement of pupil interest and the conceptually coherent and lucid presentation of knowledge” (Swann 1998). The teacher is very important for this style of learning to be effective as they must be able to motivate the learners, maintain and direct the learners’ attention and be able to communicate their content clearly. This style of teaching is reported by the surgeons in this study to be utilised for the transmission of factual knowledge content.

4.5.4 Other learning processes described

The processes for learning sensory semiotics (visual and haptic cue interpretation) and adaptive strategies appeared more complex.

Haptic cue interpretation did require the learner to be ‘doing the case’ in order to obtain ‘hands on’ sensations, however the role of explicit teaching was unclear. Visual cue interpretation and adaptive strategies were described as being learned both through ‘doing the case’ and ‘observing the case’ in both the presence and absence of explicit teaching activity.

4.5.4.1 “Scaffolding”

The explicit teaching described by the surgeons when referring to these content domains was different from the ‘transmission style’ teaching. Surgeons described the trainer helping the learner to take on the higher participatory role of primary surgeon. This assisted performance links closely with Vygotsky’s ideas of “scaffolding” in which the teacher provides support to enable learning within the Zone of Proximal Development (ZPD) (Vygotsky 1978). The ZPD would include tasks that the learner is not yet capable of completing independently however, is able to do so, with assistance. Operating under supervision frequently illustrates learning within the zone of proximal development. The surgical trainee may not yet be capable of performing the procedure independently, however, under the watchful guidance of the trainer, the learner is able to take on the role of ‘lead surgeon’ for the operation this constitutes ‘assisted performance’ (Dunphy and Dunphy 2003).

The surgeons also described explicit teaching activity facilitating learning when the learner was in the assistant role. This was described as a ‘think aloud’ so that the learner had access to the thought processes of the trainer and was therefore able to gain insights into aspects of the operation that impacted the trainer’s decision-making process. This links with Vygotsky’s ideas about ‘inner-speech’ being a way of accessing the thought processes behind actions. The surgeons noted the ‘think aloud’ commentary from the trainer disappearing when the operation became more stressful or when complications were encountered, often related to a high degree of uncertainty about the anatomy or pathology. The ‘think aloud’ commentary was re-instated once the trainer himself had ‘worked out’ what it was that they were dealing with, as though the trainer did not wish the learner to perceive their uncertainty. This resonates with Vygotsky’s idea that ‘inner speech’ was not necessarily a precursor to verbal speech, it was responsive to social relations (Palmer 2010) (Vygotsky 1978).

4.5.4.2 Reflection-in-action

Surgeons, who took part in this study, also clearly described learning visual cue interpretation when ‘doing a case with no explicit teaching activity’. Trainees described learning to find the correct plane for dissection from interpreting positive and negative feedback coming from the living tissues. This learning required the trainee to use the appearances of the living tissues rather than explicit feedback from a trainer as a stimulus to reflect upon their progress intra-operatively. This appears to be a description of reflection-in-action (Schon 1983) stimulated by intrinsic tissue feedback.

Donald Schon (Schon 1983) described both reflection-in-action as well as reflection-on-action. Reflection-on-action is though to occur post-hoc i.e. after the event as a macroscopic review of the overall task. Debriefings after operative cases and formal Procedure Based Assessments (PBAs) represent examples in surgery where reflection-on-action is used. Reflection-in-action, as described by Schon, is intra-task reflection. This is described as the regulation that occurs on a moment-by-moment basis during the unfolding of the procedure itself (Schon 1983). In this investigation two different stimuli were reported by the surgeons to lead to reflection-in-action - inherent tissue feedback and extrinsic teacher-led feedback.

The concept of inherent tissue feedback, leading to reflection-in-action, may be better understood by examining parallels to the kinesthesiology literature. A basketball player may receive inherent feedback from seeing the basketball drop through the hoop, extrinsic feedback from the trainer is not always necessary as the basketball player ‘knows’ he has executed a good shot, without needing to be ‘told’ by the coach. In surgery, a trainee may receive inherent feedback from the tissues, for example during the dissection phase of an operation a learner may start to stray out of the correct tissue plane, the response from the living material may be the tiniest blush of bleeding signifying the cut of tiny capillaries within a filmy cell-thick layer, the learner surgeon may see the blush and adjust their line of dissection. This reflection-in-action and adjustment are carried out seamlessly in a matter of milliseconds, the stimulus for the reflection-in-action has ben the inherent tissue feedback, no extrinsic feedback was necessary. The difference between the basketball player and the trainee surgeon, is that in the initial stages, the surgeon may not recognize the inherent feedback given by the tissues. Initially, the surgical trainee may need to *learn to evaluate* the inherent feedback from the living tissues. The basketball player on the other hand does not need to learn how to interpret subtle inherent feedback, as the ball dropping through the hoop does not require much interpretation. For the trainee to learn how to interpret the inherent feedback from tissues it is thought that what they see or feel is compared with a learned reference of ‘correctness’ and without such a reference of correctness many forms of inherent feedback cannot be used to detect errors (Schmidt and Lee 1999). It is therefore suggested that it is important for the learner to observe many expert dissections to then serve as a reference for ‘correctness’.

The role of the teacher in learning visual cue interpretation may be to provide an expert example, to serve as a reference model, and also to provide extrinsic feedback in the initial stages of learning to prompt reflection-in-action. Inherent tissue feedback can be supplemented by the extrinsic trainer feedback in cases when the learner misreads or ignores subtle tissue cues. As the trainee becomes more skilled at interpreting the visual and haptic cues the requirement for the trainer to provide extrinsic feedback may diminish.

Evidence collected suggested that the trainer was required to interject less frequently when the trainee came closer to replicating what the trainer wanted to see.

4.5.4.3 Dual processing theory

Dual processing is thought to be a key mechanism by which medical professional make decisions. This has been investigated with reference to diagnostics amongst General Practitioners (GPs) (Balla, Heneghan et al. 2012) (Balla, Heneghan et al. 2012). How individuals learn, to match new visual material against a reference in order to make a diagnosis, has been investigated by cognitive psychologists using dermatology and radiology as examples (Law, Atkins et al. 2004) (Bleakley, Farrow et al. 2003). ‘Dual processing theory’ points to two methods of cognitive processing being utilized for visual images – automatic processing, which is fast, instinctive and does not involve working memory (System 1) or analytic processing, which employs a series of rules by which one can ‘work out’ what they are looking at (System 2) (Francis, Hanna et al. 2002; Law, Atkins et al. 2004).

- Automatic, system 1 processing relies upon a rich bank of previous visual exemplars acquired during experiential practice.
- Analytic, system 2 processing requires a deductive rule based schema.

The cognitive psychology literature suggests that both of these systems are used by novices and experts, but experienced professionals have increased diagnostic accuracy when ‘going fast’ and using automatic cognitive processing (Law, Atkins et al. 2004). This is suggested to be due to their more extensive visual library to match against.

Recognition of objects by touch can also be both fast and accurate (Klatzky, Lederman et al. 1985). In terms of ‘learning the feel’, the fast and accurate description of haptic cue interpretation by Klatzky et al is similar to the automatic processing described for visual cue interpretation. The author of this thesis postulates whether learning haptic cue interpretation is also reliant upon having experienced the ‘feel’ of many cases, and that automatic processing in this domain may rely upon a rich memory bank of haptic cues.

Explicit teaching activity appeared to have relevance to learning where analytical processing (System 2) was required and the ‘teaching’ was passing on to the trainee the ‘rules’ that the trainer was using in order to identify anatomical structures and pathology. Explicit ‘teaching’ seems important for System 2 cognitive processing, but it was not clear whether it contributed to the automatic recognition and System 1 thinking.

In this study, surgeons described learning sensory semiotics and adaptive strategies through several different processes. This work suggests that experience and explicit teaching may both be important for learning in these domains. This investigation raises questions as to whether improved teaching in the operating theatre could ever compensate for diminished clinical exposure, as acquisition of a rich library of exemplars seems important to enable accurate matching of sensory cues. If we acknowledge that sensory semiotics and adaptive strategies are important domains of learning in the operating theatre, then one can understand why trainee surgeons need to see and feel large numbers of cases over the course of their training, regardless of improved quality of intra-operative teaching.

4.6 Conclusions

The processes of learning described as being utilised by teachers and learners varied depending upon the content area. This is of interest to the surgical educator as educational practices have suggested tailoring teaching style to the learning preferences of the students for best pedagogic effect (Kolb 1984) (Jack, Kenkare et al. 2010). This research raises questions as to whether and to what extent it may be possible to facilitate learning in particular content areas by promotion of particular pedagogic practices.

Table 3: Emerging relations between content and process of learning in theatre and the corresponding theoretical frameworks

Content domain	Process	Theoretical framework
Factual Knowledge	Quizzing / Telling	Transmission learning
Motor Skills	Repetition	Automation theory
Sensory Semiotics	Instruction Extrinsic feedback Intrinsic feedback Case experience	Scaffolding Reflection-in-action Reflection-in-action Dual processing theory
Adaptive strategies	Instruction Extrinsic feedback Intrinsic feedback Case experience	Scaffolding Reflection-in-action Reflection-in-action Dual processing theory
Team-Working, Managerial Skills,	Observation and modelling	Social learning theory
Attitudes and behaviours	Observation and modelling	Social learning theory

Some content areas were perceived to be reliant upon the learner having hands on experience ‘doing’ for example, motor skills. Other content areas, for example team working and managerial skills, are perceived as being learned primarily through a process of observation. These processes of learning resonated with several different educational theories.

Sensory semiotics and adaptive strategies appeared as particularly complex content areas where multiple different processes of learning were utilised. Vygotskian principles of “scaffolding” and learning within the ZPD were clearly described in these content areas.

Learning without explicit teaching was described as requiring reflection-in-action. One of the stimuli identified in this study, that surgeons use to prompt reflection-in-action, was inherent tissue feedback. For learners to be able to recognise and interpret intrinsic tissue feedback, either a rich library of exemplars, amassed through experience was required, or a set of specific ‘rules’ was used. The broader literature would suggest that learning in these content domains requires both of these aspects - multiple case experiences as well as explicit teaching.

4.6.1 Reflexivity

The limitations of a grounded theory interview study were discussed at the end of the previous chapter. Participants had more difficulty discussing processes of learning than content of learning. The researcher notes that self-report data about processes of learning relies upon the meta-cognitive abilities of the participants of the study (Flavell 1976) (Weinert and Kluwe 1987) and that this type of data may not provide a totally comprehensive picture.

CHAPTER 5 - An illustration of pedagogic practices in the operating theatre

5.1 Abstract

Objectives

The objective of this chapter was to illustrate for the reader how pedagogic practices were actually 'played out' across different content areas in the operating theatre, and to provide detailed insights into how these processes were conducted.

Methods

A case study methodology was used to illustrate the processes of teaching and learning across different content areas. This investigation was a descriptive single-case study with embedded sub-units. The sub-units were operations that were audio and video recorded; these recordings were synchronized as media files, and the audio record was transcribed, in full, to allow detailed analysis on a cross-case basis.

122 operations were observed over 2 years. This represented around 500 hours of field work. 18 operations were audio and video recorded for in-depth, cross-case analysis. The themes that emerged from the preceding interview investigations provided sensitizing concepts for the data analysis. The embedded sub-unit cases were analysed as multiple short clips lasting between a few seconds and a few minutes, and these were coded in NVivo 9, with reference to the themes that had emerged in the interview studies.

Results

Pedagogic activity pertaining to all content areas, described by surgeons during interviews, were observed in the naturalistic setting of the operating theatre.

Three major process themes of pedagogic activities were observed – firstly teacher-led practices, for example ‘quizzing’ and ‘telling’; secondly learner-led practices, for example ‘trial and error’; thirdly collaborative practices between teacher and learner, termed ‘co-construction’.

Different pedagogic practices were observed to be more prevalent across particular content areas. Teacher-led practices were almost exclusively used for transmission of factual knowledge. Learner-led practices were more often used for acquiring motor skills, adaptive strategies, team-working skills and managerial skills, and surgical behaviours and attitudes. A phenomenon called co-construction was found to be utilised for learning sensory semiosis.

Conclusions

This investigation has shown that sensory semiosis was an important content area of postgraduate learning in the operating theatre and that the prominent pedagogic practice in this domain was co-construction.

The phenomenon of co-construction was a dialogic form of teaching, which could involve ‘Socratic exploring’ or ‘authentic exploring’. Co-construction was shown to take place through both verbal-verbal interactions between trainer and trainee as well as through physical-verbal interactions. This novel finding provides some explanation as to why trainees and trainers place so much emphasis upon being the primary operating surgeon, as they are able to practise motor skills, to learn recognition of haptic cues and are afforded an alternative mode of communication by which to contribute to dialogic pedagogic processes.

5.2 Introduction

Previous chapters have revealed what surgeons can tell us about teaching and learning in the operating theatre; however, there are limitations as to how much information can be gained from what people say – as what people say they do, and what people actually do, may be different. To understand the complexities of post-graduate surgical teaching and learning in the operating theatre, observation can provide complementary evidence, and give insights into the context in which these practices are conducted.

One of the rationales for observational research is that the phenomenon of interest can be examined as it occurs, in contrast to controlled experimental studies. Lincoln and Guba, when writing about controlled experimental studies, state that "*attempts by humans to learn about nature were intermittent and unnatural, and so distorted what was learned*", they assert that efforts to control all of the other variables can make the study itself of limited use, as the phenomenon of interest can be distorted by the controlled conditions (Lincoln and Guba 1985). This critique - of positivist ideals of controlling variables - led to ideas of 'naturalistic inquiry', which seeks to describe, understand or interpret daily life experiences and structures based on field observations rather than in experimental conditions. Becker and Geer purport that participant observation is one of the most meaningful research strategies as:

"*observation of some social event, the events which precede and follow it, and explanations of its meaning by participants and spectators, before, during, and after its occurrence…gives us more information about the event under study than data gathered by any other sociological method*."

Becker and Geer (1970)

The nature of observational data is that it must be "*sufficiently descriptive that the reader can understand what occurred and how it occurred…[and yet] must be factual, accurate and thorough without being cluttered by irrelevant minutiae and trivia"*

(Patton 2002).

Whilst the potential benefits of observational research have been acknowledged, observed practices may be altered when the subjects are aware that they are being observed. This phenomenon is known as the Hawthorne effect, and it refers to situations in which the subjects' behaviour is altered by the observation itself (Franke 1978). The Hawthorne effect has been described in many different healthcare settings and is characterised by a temporary positive change in a behaviour where the observer had no intention of changing the subjects' behaviour (Campbell, Moxey et al. 1995) (Leung, Lam et al. 2003) (Verstappen, van der Weijden et al. 2004). It should be differentiated from the 'incentive effect', which is when clinicians alter their behaviour, because they suspect they may be penalized or rewarded. The Hawthorne effect diminishes over time as the population being observed become accustomed to the presence of the researchers when, in contrast, the 'incentive effect' is sustained.

Another difficulty with observational research is that human perception is known to be highly selective and that observations are known be shaped by the observer's interests, biases and background (Katzer, Cook et al. 1978). Variations in perspective may be related to being an insider or outsider, in relation to the culture being studied. Anthropological tradition has used the terms etic and emic to differentiate between these different viewpoints, with 'emic' being a term for categories and language used by the people in the culture studied, and 'etic' describing categories created by researchers based upon their analysis of important cultural distinctions. An emic approach to observational research will likely have findings that resonate with the population being studied; however, an insider researcher may not notice important practices that have become implicit, as they are part of the cultural group and no longer notice phenomena that are so intrinsically part of daily practice.

One of the major factors differentiating observational research traditions is the extent to which the observer becomes involved as a participant. Full participant observation involves the researcher becoming part of the social culture studied; becoming involved with their activities and social practices. This method utilises information from casual descriptions and *ad hoc* interviews and is the basis of an anthropological study of a culture. In contrast, data collection in an onlooker observational study will be much more formalised with detached observations and formal interviews performed away from the contextual environment.

Observational fieldwork can vary considerably in its duration of data gathering. Long term observational studies are useful for understanding "*the interwoven complexities and fundamental patterns of social life*" (Patton 2002) whereas, short term studies are useful for generating information for action; as decision makers cannot wait years for the researchers to gather sufficient data. Patton states that "*fieldwork should last long enough to get the job done - to answer the research questions being asked and fulfil the purpose of the study*" (Patton 2002).

Ethnographies, which are primarily concerned with documenting social interactions and behaviours within a culture, have been referred to in the literature review section (Katz 1998) (Bosk 1979) (Fox 1992). Whilst these present a detailed description of a synthesis of observational episodes through the eyes of an outsider, the researcher wished to perform a more systematic analysis with concrete examples from individual cases with the aim of making generalizations.

This investigation was a type of naturalistic inquiry, seeking to illuminate teaching and learning as it occurred in the native environment of the operating theatre. Careful consideration was given to the research tradition best suited to collection and analysis of this data and how this could be presented in a way that was informative, accessible and helpful to the surgical community who constitute the end-users of this research.

5.3 Method

5.3.1 Study design

Case-study method, in comparison with ethnography, describes an individual 'case' rather than a synthesis of observations (Montgomery 2006). Case-study research may include both quantitative and qualitative data. A 'case' may constitute a phenomenon, an individual or an institution. One of the critiques of case study research is that individual cases are unable to provide a robust platform for extrapolation and scientific generalization. This argument supposes that the 'case' is a sample from which an analyst may attempt to extrapolate findings. However the goal of a case study is to expand and generalize theories - an "analytic generalisation" rather than a "statistical generalisation" (Montgomery 2006). Multiple cases instead represent multiple experiments, with comparison between the experiments, rather than an amalgamation of the cases together and the features of an 'average' case presented.

A two-person research team was used to gather observational data - a post-doctoral sociologist (JB) who provided an etic perspective and the author of this thesis who was a higher surgical trainee and held an emic perspective. This relationship was highly unusual and uniquely powerful as it enriched understanding from both viewpoints. The sociologist used the surgeon researcher as a primary informant and produced ethnographic articles describing teaching and learning in the operating theatre, which have been published in the sociology literature (Bezemer, Cope et al. 2011; Bezemer 2013) (Bezemer, Murtagh et al. 2011) as well as the surgical literature (Bezemer, Cope et al. 2012) . The surgeon researcher used the sociologist to provide a different perspective upon some of the day-to-day activities conducted by surgeons that had become implicit to the surgeon observer. Both took independent field notes, and after each observation episode interesting pedagogic moments were discussed in detail. The relationship between the ethnographer and surgeon was uncomfortable at times; tensions between the two researchers became obvious when planning and organising observation episodes - it became clear that the surgeon observer had implicit knowledge, not shared by the ethnographer, of which order the cases were likely to be operated in, despite the printed ordering of the list, and which cases were likely to be cancelled. Frustrations for the surgeon researcher included this lack of understanding of clinical and organisational priorities (for example day-cases first) and the lack of flexibility and urgency to 'get a good case'. Despite the differences in mind-set, the benefit of having an alternative perspective, and another researcher also deeply involved and embedded within the data, was hugely beneficial.

The researchers were presented with the opportunity to conduct observational data in the operating theatres, a venue usually with limited access to social science investigators. The ethics approval for this study was restrictive and limited the sampling frame. The study design needed to allow for convenience sampling. A single case-study design, with multiple embedded sub-units to act as illustrative concrete examples, was chosen on the basis that this was a *revelatory case,* an opportunity to study a prevalent phenomenon that had been previously inaccessible to social scientists (Stake 1995).

The single-case study method negated difficulties of theoretically-informed, purposive sampling associated with multiple-case studies, yet provided the opportunity to include data from multiple different operations as embedded sub-units. This single-case study defined the 'case' as 'the host institution's operating theatres'; the multiple embedded sub-units were 'operations'. The case study included elective and emergency operations in general surgery. The 'case' did not include other surgical specialties, or hospitals other than the host institution. This was a descriptive case study that set out to describe a natural phenomenon, occurring within the operating theatres of the host institution (Montgomery 2006).

5.3.2 Data collection

The paired researchers attended the operating theatre together; however, they made their own independent field-notes. They then discussed the cases in-depth in weekly meetings throughout the data collection and analysis. In this way both emic and etic perspectives were captured.

Full participant observation was not possible for the sociologist due as he was not a member of the professional group. The surgeon researcher also positioned herself as an onlooker researcher, as taking part in the work of the operating theatre requires full concentration, rather than being a secondary activity during research data gathering.

Whilst acknowledgment of the diversity of different viewpoints appears synonymous with interpretivism, in this investigation the contrasting lenses of the two researchers have been used for rigor to ensure as little as possible was missed in the data. Where there was agreement between the two researchers, this was taken to suggest that findings in the data were visible to both the insider and outsider adding objectivity to the findings.

The differing observational foci were immediately apparent from where the researchers positioned themselves in the operating theatre. The sociologist stood against the wall of theatre so as to afford a wide-angled view of the intra and inter-professional social interactions around the operating table, between anaesthetist, surgeons and nursing staff. The surgeon researcher, in contrast, stood where she was able to obtain a good view of the operative field, for an open operation this was behind the shoulder of the primary surgeon, for a laparoscopic (keyhole surgery) case this was with an easy view of the video screen projecting the laparoscopic camera view.

Full disclosure of the purpose of the researchers' attendance in the operating theatre and the subject matter of their study was provided to all subjects being observed. Detailed notes were made of episodes where clinicians may have altered their practice as a result of being aware of being observed for example "*we'd better not talk about that as we're being recorded…*"

The observational data was collected over two years of sustained on-going research activity. Over this time frame 122 operations were observed ranging from simple skin lesion excisions, under local anaesthetic, to complex major surgery such as open oesophagectomy. Whilst all 122 were not included as sub-units with detailed case analysis, these field notes provided materials that gave background information, the researcher would also suggest that the large number of operations that were observed largely negated the Hawthorne effect.

The observation episodes were dictated by the length of individual operations and ranged from 30 minutes in duration to eight hours. The time and resources available, in relation to the duration of the employment of the primary researcher as a clinical research fellow, dictated the overall duration of the observational research presented in this thesis.

5.3.3 Issues of Access, Ethics and consent

The operating theatre is a site of restricted access due to the need for patient confidentiality and the necessity for privacy for intimate investigations and procedures. The institution hosting the research held a strong record of research in the department of Surgery and Cancer, with previous observational work being carried out by surgeons and psychologists in the operating theatres at this site (Undre, Healey et al. 2006; Sevdalis, Healey et al. 2007). Permission was given by the department of surgery for this study to be undertaken and ethical approval for conduct in the NHS was given by [Institution name] Research Ethics Committee (Ref nr 10/H0712/1). Ethics approval was conditional upon every individual working in the operating theatre giving informed signed consent. All consultant and junior surgeons working within the department were notified about the study via email (Appendix E - study information sheet and consent form) in advance of the proposed start date of data collection. This was to ensure that sufficient time was given to consider whether they would consent to take part. The investigators' contact details were supplied to answer any questions. Signed consent was obtained from the theatre staff prior to observations and recordings commencing. The consent form explicitly requested consent to be observed and / or filmed and / or audio recorded whilst working in the operating theatre (Appendix E). In this way, although a staff member may not have given consent for recordings to take place, the researchers were still able to gather valuable observational data in the format of field notes.

The researchers spent an initial three months, in the operating theatres making field notes before seeking consent from participants to audio or video record them during their work. The time spent in the initial observations was invaluable in terms of researcher training and also in developing a trusting relationship with the theatre staff, who became accustomed to the researchers' presence. This long lead in time ensured a negation of Hawthorne effect. When video and audio-recordings were made this required written consent from every individual working within that operating theatre, the practical implications of this meant that a relatively small number of operations were recorded.

Some of the operations observed were in excess of eight hours in length. The researchers were unable to sustain detailed and informative field notes on every teaching interaction throughout this time period. In addition, these lengthy operations posed difficulties for audio and video data capture. Whilst observations made during these longer operations have contributed to data collection, none of these operations have been analysed in full detail as an embedded unit. One particular operation - laparoscopic cholecystectomy - was frequently performed at this institution, by the subjects being studied, and this operation was usually of a suitable length for the researchers to obtain full field notes, audio and video recordings. Selections of what operations to observe and attempts to obtain field notes, audio and video recordings were made with reference to Yin's ideas of a replication design (Montgomery 2006). Having performed a detailed analysis on an embedded sub-unit that was taken from a laparoscopic cholecystectomy, and having uncovered interesting findings "*the ensuing priority was to conduct a second, third and even more experiments. Some of the replications might attempt to duplicate the exact conditions of the original experiment. Other replications might alter one or two experimental conditions considered unimportant to the original finding, to see whether that finding could still be duplicated. Only with such replications would the original finding be considered robust"* (Montgomery 2006).

A number of the embedded sub-units within this single-case study therefore come from laparoscopic cholecystectomies; the research team then selectively sampled other laparoscopic operations and open operations. These embedded sub-units are analysed on a cross-case basis.

5.3.4 Data capture

Ethical approval for this study stated that video images were to be restricted to the view of the operative field. This was recorded from an overhead camera situated in the light handle of the operating lamp in one theatre in the main theatre complex. This restricted data capture of open operations to this particular theatre. However, for keyhole surgery operations, the laparoscopic view (an internal view) from an internal camera was used, this allowed gathering of video data in other operating theatres and the Day Surgery Unit.
The restriction of only being able to video-record open operations in one specific theatre significantly restricted the range of operations from which the researchers were able to gather data. For example the breast surgeons only performed open operations and were never allocated to work in Theatre 3, so could never be video recorded. Video recording in the day surgery unit was restricted to keyhole cases only, as there was no over-head light handle camera. These practical restrictions have determined the selection of cases examined as embedded units within the case study.

The audio recordings were obtained from a wireless audio-microphone (Revo mic XTag) worn on the collar of the surgeon or trainee’s scrubs. The microphone was worn underneath the sterile surgical gown, which led to interference from contact with the material and some loss of data. The audio microphone recorded and transmitted the data wirelessly to a laptop computer situated within the operating theatre. The range of the audio microphone was only one metre, this ensured that all background conversation was excluded including that of any members of staff who unwittingly entered the operating theatre, and had not given prior consent to take part in the study.

The field notes were taken by the two un-scrubbed researchers – surgeon and sociologist. Neither used a pro-forma or scoring sheet, but independently and naturalistically made observational notes of what they saw.

5.3.5 Data Management

The audio and video data were synchronised together using the first activation of the diathermy as a syncing place-marker. This was performed in Windows Media player and both audio and video files were combined into a WMV (Windows Media Video) file prior to analysis.

The audio files were transcribed in full, and verbatim by the primary researcher. The transcriptions did not attempt to document pauses or rising / falling tonality of the voice - as is the custom in conversational analysis as these transcripts were intended to be used in conjunction with the media files. The transcripts were checked for accuracy by both the sociology researcher and the primary investigator. Where the audio recording was unclear, the primary investigator sought clarification from the subjects involved in the episode.

The transcript was time stamped to break the media file into small clips. The time stamps were placed at natural break points in the operation, at an instrument change, or at a natural break in conversation. The resulting clips were between 10 seconds and 4 minutes duration.

NVivo 9 was used to code the media file, the transcript and field notes. This allowed viewing of the progress of the operation, as visualised on the video whilst hearing the pauses and intonations in the speech contemporaneously. This also allowed analysis of the detailed language of teaching and learning within the transcript. The data capture and method of analysis is considered multi-modal and this had important implications for the findings of this investigation (Kress 2010). Selected media clip examples are included on DVD at the back of this thesis to illustrate the results.

The multi-modal data could not be de-identified although it was anonymised. This was due to individual choices of language and vocabulary, which were still apparent after voice alteration. Only named members of the research team were allowed access to the data. Media files were stored on a biometric access encrypted portable hard drive. Express permission from the participants of this research was sought if raw data was to be presented at departmental or external meetings.

5.3.6 Data Analysis

A naturalistic stance was taken, to afford the opportunity to observe what there was to see, without prior hypotheses, however, some way of organizing the complexity of the experience was required. Sensitizing concepts can be useful to orientate researchers and guide their observations (Blumer 1978). The interview data reported previously in this thesis was gathered at this and other institutions and many of the same subjects were included in both studies. The use of emergent themes from the interview study as “sensitizing concepts” therefore seemed appropriate.

Open coding of the data was performed, in which every moment of the media file, every utterance or word on the transcript, was considered for meaning, with no material omitted. This procedure of examining and coding every part of the data collected adds to the systemic nature of the investigation and diminishes subjective investigator bias.

The analytical approach in this study was a cross-case analysis of embedded sub-units within a single-case study. Each content area was considered separately and in detail, attending specifically to pedagogic processes utilised. Tools from linguistics, including relative modality of language (indicating the degree of tentativeness of the speaker) used by the trainer and trainee, were used to analyse the transcripts of teaching exchanges objectively. Hand or laparoscopic instrument movements of trainer and trainee captured on the video were also considered for meaning.

5.4 Results

During the two years of data collection around 500 hours were spent collecting this observational data. This was a vast amount of work. The case study presented in this chapter reports observational data from the 122 operations as an initial overview description of context, with specific embedded examples from 18 operations. The 18 operations that have been subjected to detailed linguistic analysis have been selected upon basis of completeness of the data-set (field notes, audio and video recordings) as well as their ability to inform on-going theory building.

5.4.1 Descriptive overview of the context

The institution studied was a 495-bed teaching hospital located in West London. The hospital formed part of a larger University group of hospitals and provided both elective and emergency surgical services. One of the other functions of the hospital was to provide post-graduate training to junior doctors.

After passing University finals exams, junior doctors in the UK spend 2 years in a Foundation program. This serves as an introduction to different specialties, with junior doctors usually spending 4 months in contrasting posts. During completion of the Foundation program junior doctors apply for specialty training posts. Different specialties have different arrangements in place with some, such as radiology, offering run-through training. In the majority of surgical disciplines, however, there are two time points at which there is competitive entry. Firstly from the Foundation program into Core Surgical Training (CT1). The core-training program lasts for two years and gives the junior doctor a taster of different surgical specialties. Some Core Training programs in the UK are ‘themed’ so that the posts are relevant to the junior doctor’s career aspirations; other core programs are still very generalised. Secondly, after CT1 and CT2 there is a selection point into Higher Surgical Training at Specialty Trainee 3 (ST3) in their chosen field; this may be in orthopaedics, urology, general surgery and others. This is frequently termed “getting a number”, meaning a numbered training post that will take the junior doctor through from ST3 to CCT.

Table 4: Surgical career grades, nomenclature and years qualified in the NHS system in the UK

Grade	**Number of years qualified**	**Trainee Level**	**Doctor Level**
F1 & F2	1 - 2	Foundation Programme	Junior Doctor
CT1 & CT2	3 - 5	Core Trainees	
ST3 – ST8	5 - 12	Higher Surgical Trainees (Speciality Trainee)	
Consultant	> 10 years		Consultant

The term ‘junior doctor’ is used for all non-Consultant grade medical staff - regardless of whether they are actually junior or not. There were Core Trainees and Higher Surgical Trainees working within the general surgery department at the institution studied. These junior doctors were part of a training rotation spending up to one year at the institution under study as part of their training program and also rotating to other hospitals in North West London. At any one time there were around 10 post-graduate surgical trainees enrolled in Core or Specialty training working full-time within the general surgical department. These trainees ranged in seniority from Core Training Year 2 (CT2) through to Specialty Training Year 8 (ST8) - there were no Core Training Year 1 (CT1) trainees working in general surgery at this institution during the study.

The general surgical department was divided into two units, with junior doctors working under the supervision of Consultant surgeons aligned to either one or other of these sub-units. One of the units was called the Academic Surgical Unit (ASU) the other unit was called the General Surgical Unit (GSU). The division of the department into these sub-units has historically been based solely upon funding source (University or NHS) rather than clinical sub-specialty. At the time of this study the General Surgical Unit was staffed by two Breast / Endocrine surgeons both of whom were Honorary Senior Lecturers of the University. The Academic Surgical Unit was staffed by four Lower GI and three Upper GI surgeons, all of whom were employed as Senior Lecturers, Readers or Professors of the University with Honorary NHS Consultant titles.

The GSU had one Core Trainee, and for part of this study one Specialty Trainee. Other middle grade work on the GSU was taken by ‘Staff Grade’ doctors - fully trained surgeons, all of whom in this case-study were trained abroad and not part of any training rotation.

The ASU had two Core Trainees and six Specialty Trainees, at times also having a ‘Staff Grade’ doctor. The GSU and ASU teams shared between them the emergency work; with all of the Consultants, except the Head of Department, taking part in the on-call rota. The junior doctors were rota’d to take part in the on-call work, sometimes being on-call with their ‘usual’ team but often working with other Consultants.

Out of hours on-call cover at the institution was provided by a cohort of clinical research fellows who worked at middle grade level on the rota. None of the Specialty Trainees worked night shifts. The Core Trainees however, took turns covering the night shifts, usually working 3 or 4 consecutive nights and cross-covering other specialties on a shared rota of trainees working in general surgery, orthopaedics and urology.

At the time of this study, the operating theatres at the institution were located in two buildings. There was the main theatre suite, with 9 operating theatres, which was located on level 4 of a purpose built 10-storey facility opened in 1988, housing Accident and Emergency on Level 1, and the surgical wards on Level 8. During the course of the study the operating theatre reception area, admission lounge and recovery area all underwent an extensive re-fit. A new vascular operating theatre and a new trauma theatre were opened.

The other operating theatres at the institution were known as the ‘Day Surgery Unit’ and located in a part of the hospital that was built in the 1930s.

Image 1 ASU team performing a laparoscopic cholecystectomy in the day surgery theatres

These DSU theatres were accessible from the main hospital building via a bridge crossing. In the Day Surgery Unit there were two operating theatres and a recovery room (where patients wake up after their anaesthetic) on Level 5, and an admission suite (where patients can be seen by the doctors before their operation, examined and consent taken) on Level 4.

The GSU surgeons in this study performed only open operations. They worked in Theatre 1 and Theatre 7 within the main theatre complex and also ran two evening surgical lists each week in the Day Surgery Unit. The ASU surgeons performed both open and laparoscopic procedures and worked in Theatres 3 and 5 within the main theatre complex three days per week and also utilised the Day Surgery Unit one day per week. Theatre 3, in the main theatre complex, was a designated ‘laparoscopic theatre’ with multiple viewing screens situated around the room and green lighting to improve contrast for the surgeons, it was used exclusively by the general surgeons. Theatre 5 and 7 were general theatres with no special adaptations and were also used for urological cases. Theatre 1 was designated as an orthopaedic theatre as it had a laminar air flow system with an overhead canopy to improve sterility by prevention of recirculation of air.

Table 5: Operating theatres, surgical teams and types of operations observed during the study

Theatre	Surgical Teams Observed	Building	Operations in Study
Theatre 1	General Surgery Unit	Main Complex	Open
Theatre 3	Academic Surgery Unit	Main Complex	Open & laparoscopic
Theatre 5	Academic Surgery Unit	Main Complex	Open & laparoscopic
Theatre 7	General Surgery Unit	Main Complex	Open
DSU Theatres	General Surgery Unit	Day Surgery Unit	Open
	Academic Surgery Unit	Day Surgery Unit	Open & laparoscopic

Image 2 ASU team performing an open gastrectomy in the main theatre complex

The patient was positioned on an operating table in the centre of the room, underneath bright, overhead lamps suspended from the ceiling. Sterile paper sheets, called drapes, were placed over the body of the patient, so that every part of the body was covered in green sterile sheets apart from the operative site itself.

For operations performed under general anaesthetic an anaesthetist was always present. Sometimes this was a Consultant anaesthetist, sometimes this was a trainee anaesthetist working without direct supervision but able to call for a Consultant for assistance, if the occasion arose. If a Consultant anaesthetist gave the anaesthetic, there was often a junior anaesthetic trainee with them. This anaesthetic pair would situate themselves at the head of the operating table behind the drapes, occasionally walking out of the operating theatre into the anaesthetic room. The anaesthetist and their trainee would be 'un-scrubbed' and free to walk around the operating theatre; however they spent much of the operation adjacent to an anaesthetic machine at the head of the table, out of gaze of the surgical team, where they would engage in teaching talk - about the case, the type of anaesthetic and what to do if things went wrong. For general anaesthetic cases an operating department practitioner (ODP) would also be un-scrubbed and in the operating theatre. These are highly skilled, non-medical assistants to the anaesthetist whose role it was to assist with peri-operative care. The ODP was most prominent at the start and end of cases, when their role was to co-ordinate the flow of patients through the theatre and the set-up for the operation – i.e. patient positioning and preparing non-surgical equipment that might be needed.

For all cases there was an operating surgeon scrubbed at the table. 'Scrubbed-up' meant wearing a sterile gown and gloves over the top of the scrub suit, as well as the theatre shoes and hat worn by all theatre staff. Most surgeons also wore a facemask; however this was absent for some laparoscopic cases. The operating surgeon at this institution was usually a Consultant surgeon, but at times was a Specialty Trainee. The operating surgeon would have a surgical assistant, frequently a Specialty trainee doctor who would also be 'scrubbed'; although if the operating surgeon were a trainee, the Consultant surgeon would usually take the role of first surgical assistant. In complex operations there was a second surgical assistant, this was usually a core surgical trainee and they would also need to be 'scrubbed' to take on this role. In some cases other surgeons or Specialty trainees would enter the operating theatre and watch the case un-scrubbed for a period of time; sometimes they would comment or engage in conversation with the operating surgeon, and then leave.

The other group in the operating theatre was the nursing staff. Firstly, the scrub nurse, whose job was to assist the operating surgeon by handing him instruments as per his request and to keep guard over 'sharps' (scalpel blades and needles) and swabs to ensure that they were not left inside the patient. The scrub nurse also wore a sterile gown and gloves, allowing her access to the sterile operating field at the operating table. She stood close to the operating surgeon, usually at his right side where she could see the operative field, hear the surgeon's commands and pass the instruments into his hand at the appropriate moment. There were also one or two circulating nurses whose job was to fetch things for the scrub nurse, who, by nature of the sterility of her gown and gloves, was unable to fetch things without 'desterilising herself'.

All of the local anaesthetic cases observed as part of this case study were performed in the Day Surgery Unit. Operations performed under local anaesthetic required no anaesthetist or operating department practitioner, just an operating surgeon, and in addition, at times a surgical assistant, a scrub nurse and circulating nurse.

In the background of all operations was the persistent “beep-beep” sound produced by the anaesthetic machine, which communicated an auditory representation of the heart rate, by the frequency of the noise, and also the blood saturation of oxygen by the pitch of the sound. In some operations this sound was prominent, in others the volume was muted. It was not apparent to the researcher, whether this was a conscious decision on behalf of the surgeon or the anaesthetist. Some surgeons liked to play music from their iPod during the operation, or asked the anaesthetist to play music from their respective iPod, other surgeons preferred silence.

For some of the operations medical students or work experience students were present. It was customary for them to attend the operating theatre in twos or threes. They were immediately identifiable by their apparel - their poorly fitting theatre shoes borrowed from the communal stack in the changing room, the theatre hat not adequately tied tightly under the hairline so that hair was spilling out from underneath, and the red lanyard of the University, marking them out as a student. The medical students usually positioned themselves near to the exit of the operating theatre, standing well away from the operating table and out of direct gaze of the surgeon. On occasions, one of the students was invited to scrub-up by the Consultant surgeon, this appeared to be offered as a ‘reward for attendance’ and was directed at the group of students. The students appeared keen to embrace this opportunity, however there was a lack of confidence about how to scrub, the most confident student would put him or herself forward, but needed help from one of the circulating nurses or the researcher in order to gown and glove without desterilising himself on the way to the operating table.

5.4.2 Operations observed and level of participation of post-graduate surgical trainees.

122 operations were observed over a period of 2 years, 99 of these were elective (planned) operations and 23 of these were emergency operations. All of the emergency operations were performed in the main operating theatres.

5.4.2.1 Emergency operations observed

Table 6: Numbers and types of emergency operations observed during the study

Operation	Count
Incision and drainage (I &D) of skin lesion	5
Examination under anaesthetic (EUA) of the rectum +/- drainage of abscess +/- lay open fistula or seton	3
Scrotal exploration	1
Appendicectomy	7
Acute cholecystectomy	1
Adhesiolysis / washout	2
Defunctioning colostomy	1
Perforated duodenal ulcer	3
Total	**23**

14 emergency operations were performed through an open approach from the outset, 9 were performed laparoscopically. No emergency operations were started laparoscopically then converted to open. 6 of the 7 appendicectomies were performed laparoscopically as well as one perforated duodenal ulcer, one cholecystectomy and one defunctioning loop colostomy.

A post-graduate surgical trainee was present at 10 of the 23 emergency operations observed during this study, the remaining 13 were attended by staff grade surgeons or clinical research fellows taking part in the night-time on-call rota. In terms of participation, 9 were performed by Consultant surgeons as the primary surgeon, these were the 3 perforated duodenal ulcers, 2 adhesiolysis / washout procedures, 1 defunctioning colostomy, 1 cholecystectomy and 2 EUAs. All appendicectomies were performed by junior surgeons; 4 of these by full-time post-graduate trainees and the remaining 3 by staff grade or clinical research fellows.

5.4.2.2 Elective operations observed

Table 7: Numbers and types of elective operations observed during the study

Sub-specialty	Operations	Count
Upper GI	Gastrectomy	3
	Oesophagectomy	1
	Fundoplication	3
	Cardiomyotomy	1
Breast	Excision lesion plus axillary procedure	8
	Microdochectomy	3
	Punch biopsy	3
	Implant / cosmesis	4
Colorectal	Left sided resection	11
	Right sided resection	3
	Small bowel	2
	Anal lesions	11
General	Hernias	10
	Cholecystectomies	20
	Other general	16
Total elective		**99**

For upper GI surgical operations, the gastrectomies and oesophagectomies were open procedures. Full-time post-graduate surgical trainees were present at all four operations; one was performed by an ST7 level trainee under supervision with the trainer scrubbed. The fundoplications and cardiomyotomy were performed laparoscopically and there was a postgraduate trainee present at three out of the four cases, the remaining case was assisted by a staff grade surgeon. In all of these cases the Consultant surgeon was the primary operating surgeon.

There was a post-graduate surgical trainee “scrubbed in” for only 2 of the 18 breast cases, for the other 16 cases there was a staff grade at the operating table. The only operations that were not performed by a Consultant surgeon as the primary operator were the punch biopsies and one of the microdochectomies, which were performed by a staff grade doctor. It was observed that for all of the presumed malignant cases - frequently wide local excision and sentinel node biopsy - the Consultant surgeon would perform the excision and then the staff grade doctor would secure haemostasis and close the wound. The post-graduate trainee observed during breast cases was at Core training level and was given the skin to close at the end of the 2 cases that they were scrubbed in for.

The colorectal operations were always attended by at least one postgraduate trainee, frequently two. 6, of the 11, left-sided cases were performed by post-graduate trainees while working under supervision, with the Consultant surgeon scrubbed in as first assistant. 5 of the 11 left sided cases were approached laparoscopically, of which a trainee was the primary operator for one of these. One of these cases subsequently converted to open. The right-sided cases and the small bowel cases were all commenced as open operations and the Consultant surgeon was the primary operator in all cases. The anal cases were performed by the trainee under the supervision of the consultant (6 cases) or unsupervised (3 cases); trainees assisted with Trans-anal Endoscopic Microsurgery (TEMS) procedures (2 cases). Unsupervised operating on anal cases was always by ST4 level trainees or above.

The trainees' involvement was highest in the general surgical procedures performing 7 of the 10 hernia repairs, 2 unsupervised and 5 under the guidance of either a staff-grade doctor (3 cases) or a more senior trainee (2 cases) who was scrubbed at the table. These hernia operations were all open procedures and were undertaken by Core trainees. The remaining 3 hernia repairs were performed by Consultant surgeons, two of these cases were bilateral and undertaken laparoscopically.

The 20 cholecystectomies were all initially approached laparoscopically. One was converted to an open procedure. In 17 out of the 20 cholecystectomies there was a post-graduate trainee scrubbed at the table, for the other 3 cases this was a staff-grade doctor. When there was a staff-grade doctor scrubbed at the table the Consultant surgeon invariably performed the operation. A post-graduate trainee was the primary operator for only 6 of the 20 cholecystectomies, the trainee was always ST4 level or above.

5.4.3 Embedded cases

The sampling of the embedded cases has already been described; choices were predominantly determined by participants' consent to collect audio and video data. All of these embedded cases were transcribed in full and uploaded into NVivo9 and then coded by the primary researcher using the content themes that had arisen from the interview study.

Table 8: Type of operation, venue and personnel present for the embedded cases

Date of operation	Name of operation	Approach	Trainer level and activity	Trainee level and activity	Others medical staff present	Venue	Length of operation / mins
Case 1 11.03.10	Cholecystectomy	Lap	Consultant Operating surgeon	CT2 Camera man		Main	47
Case 2 16.03.10	Subtotal colectomy	Lap	Consultant Camera man	ST8 Operating surgeon		Main	125
Case 3 31.03.10	Reversal loop ileostomy	Open	Consultant Operating surgeon	ST3 Assistant	5 x 3rd year medical students	Main	71
Case 4 09.04.10	Sigmoid colectomy	Lap	Consultant Operating surgeon	ST8 Camera man		Main	129
Case 5 27.05.10	Cardio-myotomy	Lap	Consultant Operating surgeon	ST5 Camera man CT2 Assistant		Main	162
Case 6 29.06.10	Paraumbilical hernia	Open	No direct supervision	ST4 Operating surgeon	Medical student Assistant	Main	72
Case 7 02.07.10	Anterior resection	Lap converted	Consultant Operating surgeon	ST8 Camera man / assistant	Medical student assistant	Main	125
Case 8 31.05.11	Cholecystectomy	Lap	Consultant Scrubbed supervising	ST4 Operating surgeon	Medical student Camera man	Day surgery	45
Case 9 10.06.11	Cholecystectomy	Lap	Consultant Operating surgeon	CT2 Camera man	Staff grade unscrubbed	Main	50
Case10 28.06.11	Cholecystectomy	Lap	Consultant Operating surgeon	CT2 Camera man		Day surgery	80
Case 11 01.07.11	Cholecystectomy	Lap	ST7 Operating surgeon	ST5 Camera man		Main	20
Case 12 05.07.11	Cholecystectomy	Lap	Consultant Operating surgeon	Staff grade Camera man	2 x Work experience students	Day surgery	60
Case13 16.09.11	Cholecystectomy	Lap	Consultant Operating surgeon	ST4 Camera man		Main	15
Case 14 16.09.11	Cholecystectomy	Lap converted	Consultant Operating surgeon	ST3 Camera man	Staff grade	Main	106
Case 15 05.10.11	Cholecystectomy	Lap	Consultant Unscrubbed supervising	ST5 Operating surgeon	CT2 Camera man	Main	63
Case 16 12.10.11	Cholecystectomy	Lap	Consultant Operating and Supervising	ST5 Assisting and Operating surgeon	CT2 Camera man	Main	90
Case 17 19.10.11	Cholecystectomy	Lap	Consultant Camera man	ST5 Operating surgeon	Staff grade / Camera man	Main	60
Case 18 19.10.11	Cholecystectomy	Lap	Consultant Operating surgeon	ST3 Camera man		Main	65

Quantitative data, regarding coding within these embedded subunits, is presented to give the reader a sense of the number of clips in different content areas that were created from the media files. No attempt has been made to standardise this coding. It has been performed by a single researcher and therefore exact numbers in each category are not reliable or reproducible. They are presented to illustrate how the researcher saw different content areas to be distributed within the embedded subunits. The content areas emerged from the interview data and so the observational data therefore provides triangulation of these findings and illustrated examples of these themes.

The numbers in this table relate to the number of media clips that were coded; some of these clips were long - several minutes, and some short - a couple of seconds.

Table 9: Number of clips coded in each of the content areas in the embedded cases

	Factual knowledge	Motor skills	Visual cue interpretation	Haptic cue interpretation	Adaptive strategies	Team-working and Managerial Skills	Surgical Attitudes and Behaviours
Case 1	4	0	3	0	8	3	0
Case 2	2	1	21	0	1	2	2
Case 3	12	0	3	1	2	5	3
Case 4	2	0	4	2	2	1	0
Case 5	2	3	18	5	0	2	1
Case 6	2	8	12	12	0	3	0
Case 7	1	0	7	13	5	9	4
Case 8	14	4	14	0	1	0	1
Case 9	3	0	15	1	6	2	2
Case 10	6	0	21	0	10	12	6
Case 11	9	0	6	1	4	7	3
Case 12	16	1	18	1	10	7	16
Case 13	3	1	1	0	1	2	1
Case 14	3	1	24	0	15	12	6
Case 15	6	1	32	2	13	5	5
Case 16	4	1	19	0	13	10	7
Case 17	0	0	14	5	4	1	3
Case 18	1	0	16	0	9	2	0
Total	**90**	**21**	**248**	**43**	**104**	**85**	**60**

5.4.4 Cross-case analysis of teaching and learning across content areas

Media clips have been used as illustrative examples of the pedagogic practices that were observed, they have been selected on the basis of clarity and brevity. A still image and associated transcript has been reproduced in this thesis, the selected media clips are available on CD at the back of this thesis.

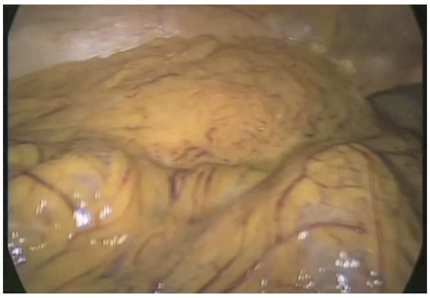
5.4.4.1 Teacher Centred Practices

Factual knowledge

Factual knowledge was observed as being taught by "quizzing" and "telling".

Quizzing

Video 1 'So next step D?'



Consultant:	Okay. *So next step D?*
ST8:	Some of the saline in there, please. That's nice and warm.
Consultant:	Okay, *so next step D?*

ST8:	We will put in – well of course if we are going to go left, well flip the omentum over the liver.
Consultant:	Yes, well why don't we put our ports in first of all yes? *So which port?*
ST8 :	Well we said this one here*. The stitch one and then the supra-pubic one. Two 12's.*
Consultant:	*12's please.*

Case 2_MainTheatres_LapSubTotalColectomy

<u>Quizzing and Telling</u>

Video 2 'What are the complications of stomas?'

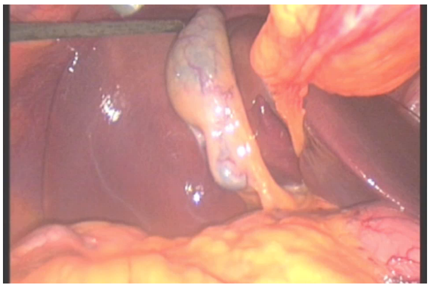
Consultant:	This must be a little hernial sac, I think. That's it. *What are the complications of stomas?* That's a common question. Okay, *parastomal hernias*.
Consultant	Sorry?
Female medical student:	*Leaking?*

Consultant:	*They can leak, so with a bad stoma fitting appliance, they can get seepage and leakage*. What would that cause?
Female medical student:	Could get peritonitis.
Consultant:	Yes, that's not common. I mean, that's usually for other reasons if that occurs. *But you can get – you know, poor stoma appliance fitting, you get seepage and skin irritation.* Okay, anything else?

Case 3_MainTheatres_Reversal_Ileostomy

<u>Quizzing and telling</u>

Video 3 'So what are the indications for surgery for gall bladder polyps?'



Consultant:	So this gentleman's got gallbladder polyps. *Do you know what are the indications are for surgery for gallbladder polyps?*
Consultant:	Come on this is HPB... This is your neck of the woods, this is...(laughter) There's a big practice in Hong Kong

ST4: (laughs)

Consultant:	*Well if they're symptomatic full-stop, you know if they've got biliary colic symptoms.*
Consultant:	I'd grab...um yeah... I'd grab a bit higher actually, just that, yeah, that's it. Yeah.
Consultant:	And err, *but certainly single,*

ST4 (to camera-man): Come in

Consultant: *About more than about a centimetre in size,*

ST4 (to camera-man): Come closer

Consultant: So he's got one that's more than a centimetre in size.

Most of the time its adenomyosis, its not anything serious

ST4 (to student camera man): Come closer

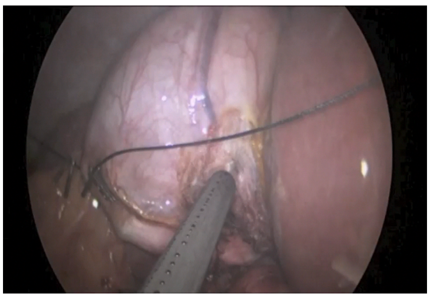
Consultant: But its not true polyps as such, but umm...

So, he's got gallbladder polyps.

Case 8_DaySurgery_LapChole

Quizzing and telling

Video 4 'What aberrant thing likes to come in from the side?'



Consultant:	What aberrant thing would be coming in from the side? Look here. Yeah?
CT2:	The cystic artery?
Consultant:	No. Well possibly but no. The right hepatic artery is what likes to come in from the side.

Case 10_DaySurgery_LapChole

"Quizzing" was frequently used in combination with "telling", dependent upon the adequacy of the answer given. The "quizzing" was used as an initiator, the person asking the question already had an answer in mind, and a response was invited from the learner. "Telling" occurred when the trainee's response did not match the 'model answer' expected by the questioner. The "telling" was a form of feedback.

It was noted that prominent "quizzing" and "telling" sequences involved medical students. These examples are given here as this style of explicit teaching was frequently observed in the operating theatre. Post-graduate trainees recalled these teaching strategies in their interviews; however, they were not frequently observed to be involved in these exchanges. The example in Video 1 of an ST8 being "quizzed" does not result in "telling" as the ST8 gave an adequate answer, confirmed by the questioner by a re-iteration of the answer "12's please".

Motor Skills

The interview data had found that surgeons perceived motor skills to be learned through "repetition" and "automation", rather than explicit teaching in the operating room. In the observational data there were a few instances of explicit verbal teaching relating to motor skills. These related to learning a 'basic manoeuvre' for example knot-tying:

<u>*Basic manoeuvres*</u>

Video 5 'If you want your knot to slide'

ST4: Do you want it to slide? What's usually the easiest way is to do two of the same. Now if, say, you put, quite rightly, you did an index and then a middle finger knot, which is fine. So you can carry on now. If you do two indexes or two middles – there you go, just need to hold one and then tie it.

Student: Do one more?

ST4: Yes, at the beginning of your knots it's something like this, if you want it to slide, if you want a knot to have variable tension then you need to apply two knots in the – two throws in the same direction. So you do two indexes or – you can keep going.

So, with prolene you need a minimum really of seven throws. I tend to do more on something like this.

So you need at the beginning to put two in the same direction and you get into a situation of where you put throws in the opposite direction and you then decide you want to slip your knot like we did just then, then you just need to lift up on one of the threads and it kind of unhooks the knot, you feel a click and then you can push it down.

Case 6_MainTheatres_ParaumbilicalHerniaRepair

5.4.4.2 Learner-Centred Practices

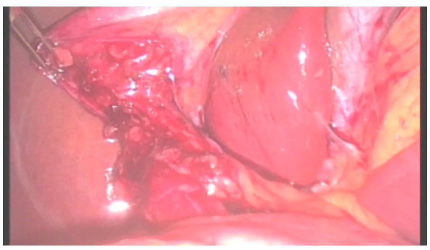
Using an observational methodology meant that learner-centred practices were missed, as the internal cognitions of the learner were not available for researcher scrutiny. Alternatively, the researcher may read something themselves into the data that the participants would not regard as learning.

Presented below are a few posited examples of learner-centred pedagogic practices that were captured during the observational study. In the first example, the trainee is in the role of operating surgeon and is attempting to return the hook to the place where the trainee had previously been dissecting – requiring hand-eye co-ordination. In this clip there is overshoot of the instrument and multiple correctional movements. This clip illustrates repetitious movements and learning motor skills by trial and error.

Motor skills

Accuracy, fine motor skill and hand-eye co-ordination

Video 6 Repetition and trial and error



ST4: Ooooh.

Consultant: Ooo. Come back with the camera.

ST4: Come back a bit

Consultant: Show him where he is…

Case 8_DaySurgery_LapChole

There was no explicit verbal ‘teaching’ aimed to guide the trainee upon how to execute the movement. This data lent support to the idea that motor skills were, in part, being learnt through hands-on repetition, practice and trial and error, rather than explicit verbal teaching.

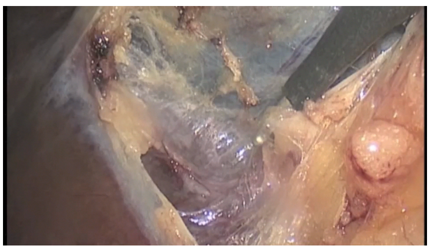
Haptic cue interpretation

Frequently only one of the trainer / trainee pairing had access to the haptic cues, due to only one of the pair having control of the operating instruments, for example in laparoscopic surgery. This meant that learning haptic cue interpretation had to be learner-centred. This may be contrasted with the visual cues in laparoscopic surgery where the visual field is made accessible via television monitors to all in the theatre, which may foster discussion and explicit teaching.

In this example from a laparoscopic operation the ST5 level trainee is in control of the operating instruments, whilst the Consultant surgeon is viewing the video screen. The Consultant therefore can only refer to visual cues whereas the ST5 refers to haptic cues that are transmitted through the laparoscopic instruments.

Learning 'the feel'

Video 7 'It just feels deflated'



ST5:	I think we must have leaked something
Consultant:	Sorry what?
ST5:	I think I've perf'd the gallbladder cos its...

Consultant: Why?

ST5: Cos I can see a bit of bile, and it just feels deflated.

Okay, there's more to come there

Case 15_MainTheatres_LapChole

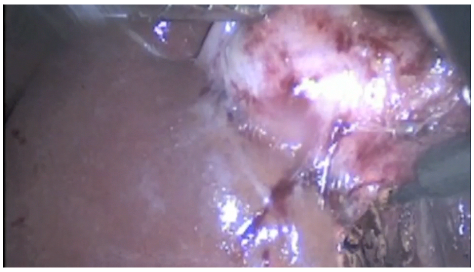
The trainee, in conclusion, explained to the trainer why he thinks he's 'perf'd the gallbladder' by reference to the haptic ('it feels deflated') and visual ('I can see a bit of bile') cues. This is not explicit teaching activity of haptic cue interpretation, as the trainer does not have access to the same haptic cues, but rather learning 'the feel' by feeling it.

Adaptive strategies

In the observational data there were multiple examples of the trainer employing adaptive strategies when things did not go exactly to plan. To learn from observing, in these cases, required learner-centred practices such as reflection-on-action. At times the trainer attempted to alert the learner to the fact that they were utilising an adaptive strategy, in this case using the learner's first name to draw their attention 'Its very badly stuck X … I'm just going to have to peel the liver capsule'

<u>Drawing the learner's attention</u>

Video 8 'I'm just gonna have to peel the capsule'



Consultant: It is very badly stuck X I...

Sometimes you just...

Peeling of the capsule there's nothing you can do about it.

Ah, no, no no no no

(bile spilling)

You see its really fused over here

CT2: Mmm

Consultant: I’m just gonna have to peel the liver capsule

Come back

Let me put the diathermy on...

(sighs) Gimme suction

She's on antibiotics right?

She’s on antibiotics?

Anaesthetist: Yep

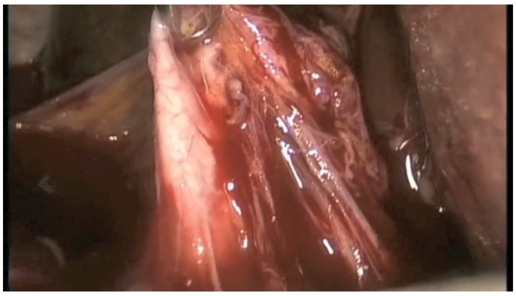
Consultant: Okay, diathermy again

Case 1_MainTheatres_LapChole

Team working and managerial skills

Team working and managerial skills were perceived by surgeons to be learned through observation and modelling – learner centred practices. There were multiple occasions when the researcher (herself a higher surgical trainee) perceived that team working and managerial skills were being modelled by the trainer. On these occasions what the trainer was doing was not explicitly communicated to the trainee, however upon retrospective analysis of the data these episodes could easily be identified as they frequently involved communication with other personnel in the theatre.

Video 9 'We seem to have got some bleeding A, not significant but just to let you know…'



Consultant: Have you got Endoclips please

(To the anaesthetist)

There seems to be bleeding A, not significant but just to let you know…

Case 18_MainTheatres_LapChole

5.4.4.3 Collaborative Pedagogic Practices

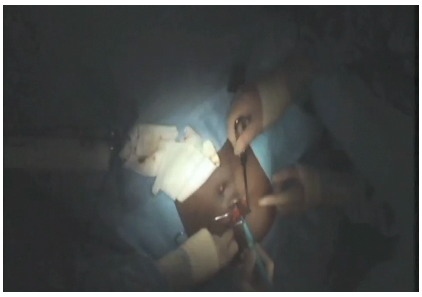
Visual Cue Interpretation

Examples of visual cue interpretation were found in both laparoscopic operations as well as open operations. Field notes and static images provided supportive evidence that visualisation was very important. See image 1 and image 2 for how the surgical team orientated their bodies and gaze towards the monitor screen in laparoscopic surgery or towards the operative field in open surgery.

In open surgery the visual field was only accessible to those ‘scrubbed’ at the operating table. Therefore, being invited to scrub for an open case was important as it allowed for learning about the unfolding visual cues.

<u>*Visual cue interpretation in open surgery*</u>

Video 10 ‘That looks like a paraumbilical or epigastric hernia to me’



Medical student: And you think that’s a lipoma within the…

ST4: Yes, I don't know at the moment. It looks – we haven't seen anything that looks like sac but we definitely have seen something that looks like defect, don't you think? We'll see…
I mean that looks like a paraumbilical or an epigastric hernia to me. But…

Scrub nurse: Did you say it was a hernia?

ST 4: Yeah… we'll have to get right down to the fascia to confirm that there's a defect, but it looks like it…

Case 6_MainTheatres_ParaumbilicalHerniaRepair

Visual cue interpretation could relate to identification of structures, for example, the cystic duct and cystic artery during a cholecystectomy. It could also centre upon identification of different pathological states - recognising normal and diseased tissues. In this example the marbled appearance is being interpreted as 'adenomyosis':

Visual cue interpretation of pathology

Video 11 'It looks like she's got adenomyosis'

ST7: It looks like she’s got adenomyosis…

Can you see that?

ST5: Mmmm…

ST7: You see that marbled appearance…?

ST5: Yeah…

Case 11_MainTheatre_LapChole

More detailed analysis of episodes of visual cue interpretation provided further insights into how this is learned by the trainee. This was termed co-construction. The process of Co-construction was different from any of the pedagogic practices already illustrated and required further detailed analysis.

Co-construction could be divided into two distinct subthemes:

- ‘Exploring’ what is seen
- Conclusively ‘Defining’ what is seen.

‘Exploring’ involved a dialogic sequence between the trainer and the trainee and could be further categorized into ‘Socratic’ exploring and ‘Authentic’ exploring. ‘Socratic’ exploring was when the trainer guided the trainee’s eye to ‘see’ what the trainer was seeing, whereas during ‘authentic’ exploring neither the trainer nor trainee were certain of what they were ‘seeing’ and explored together.

In an attempt to objectivise these subtle differences within the sub-theme of ‘exploring’, epistemic modality of linguistic expression was used. Epistemic modality refers to the an expression of likelihood that a certain state of affairs is, has been, or will be true (Nuyts 2001). In the context of the surgical dissection, epistemic modality refers to how ‘sure’ the trainer and the trainer were about what they were seeing. Whilst all of the examples within the sub-theme of ‘exploring’ involved some degree of discursive collaboration, there were distinct differences in the language used by the trainer and trainee. The table below sets out words that featured in the transcripts that may be graded as high, moderate and low certainty.

Table 10: The relationship between specific words and relative modality of language

Relative modality	Examples
Absolute or high certainty	“Clearly is” “must be” “it is” “will be”
Moderate certainty	“will almost certainly have to be”, “should be” “now seems to be”
Low certainty or uncertainty	“could be” “might be” “possibly is” “maybe”

Through the categorisation of language used by the trainer it was possible to create two different categorises of ‘exploring’ - Socratic and authentic.

'Exploring' what is seen - Socratic

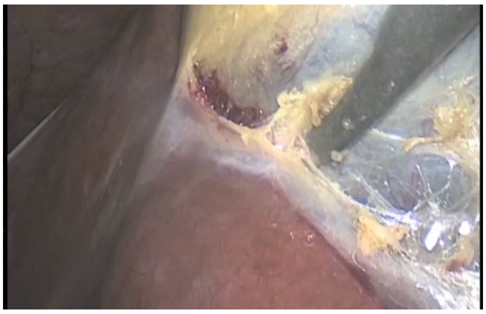
Defined as - A dialogic sequence between trainer and trainee in which the trainer guides the eye of the learner to 'see' what he is seeing. There is exchange of visual interpretations between trainer and trainee in which the trainer uses language of high modality whereas the trainee uses language of moderate or low modality. This indicated that the trainer was more certain than the trainee of what he was seeing.

<u>Socratic exploring</u>

This field note was made by the researcher in the operating theatre and refers to the monitor screen that is being viewed by the trainee who is operating.

Field note: *"(Consultant name) is pointing to the screen using his finger to indicate where he wants (ST5 name) to dissect"*

Video 12 'Here is the right plane, in here'



Consultant: Yeah. yep, here it is, here's the right plane so you need to take all this stuff

ST5: In there?

Consultant: No

ST5: Its in here?

Consultant: So it's in there.... you... so move here

ST5: Kind of in there, okay.

Consultant: Yeah, that's it.

Case 16_MainTheatres_LapChole

'Exploring' what is seen - Authentic

Defined as - A dialogic sequence between trainer and trainee in which both trainer and trainee use language that is of low certainty.

<u>Exploring what's seen - authentic</u>

Video 13 'Its really weird, its twisting round each other'

Consultant: Look at that

Staff Grade: It's it's weird. I would go into that space

Consultant:	That might be the artery and that might be the duct (to ST7 Trainee) Can you see this anatomy?
Staff Grade:	Just twisted
ST7 Trainee:	Yeah, its really weird, it’s twisting round each other
Consultant:	Yeah, and what that’s doing is its, torting the Hartmann’s pouch over
Staff Grade:	Yeah, just move
ST7 Trainee:	And you think behind where you are now, back...
Consultant:	This one?
ST7 Trainee:	No, no. Back, back, back…
Consultant:	That?
ST7 Trainee:	No, next one back, that?
Staff Grade:	This is no, no maybe
Consultant:	That could be...

ST7 Trainee: Do you think it's an accessory du...

Consultant: Accessory artery?

ST7 Trainee: Could be...

Consultant: Could be yeah...

Case 12_DaySurgery_LapChole

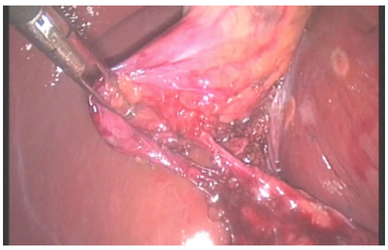
The final sub-theme related to 'exploring' has been termed 'defining' and was a construct that came at the end of an exploring sequence.

Defining

Defined as - Marking the end of a co-construction exploring sequence – either Socratic or Authentic. Both trainer and trainee use language of strong modality.

<u>Defining</u>

Video 14 'So you've got cystic duct, cystic artery'



Consultant: So you’ve got cystic duct, cystic artery and whole things is... I mean this is a fairly straightforward one but if you get a... difficult one...

ST4: Come back please

Consultant: You just need to make all this window so that's Calot's triangle, so this it the classic anatomy, the artery going through the middle of Calot's triangle.

Case 8_DaySurgery_LapChole

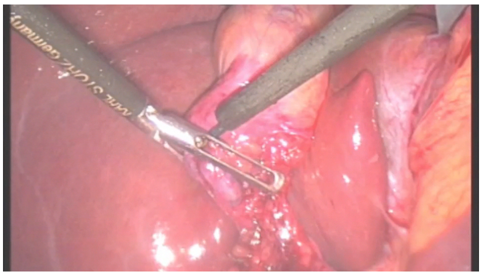
Non-verbal communication during co-construction

It was apparent that visual cue interpretation was learned through a process of co-construction, but this was not always conducted through verbal-verbal dialogue. In cases when the trainee was the primary operator, holding the operating instruments, the trainee's side of the dialogue could be conducted through gesture rather than verbal discussion.

The trainee, through his movements, made suggestions or declarations of what he thought they were looking at, and the trainer responded verbally. This was a physical-verbal co-construction, which was not apparent from looking solely at transcript data, but was clearly visible when analysing the media files. The trainee's action occurs milliseconds before the verbal utterance from the trainer.

Physical-verbal co-construction

Video 15 'So that's the artery - likely to be'



ST4: *(places hook behind a structure – identifying it as likely to be the artery)*

Consultant: So, that's the artery, likely to be, isn't it?

ST4: *(starts making up and down motion - showing he is sure that he has identified the artery)*

Consultant: So yep, just go up, up and down...

Case 8_DaySurgery_LapChole

Whilst analytical tools from linguistics, such as epistemological certainty and examination of the modality of the language, have been used in the scrutiny of transcripts, there are no tools for analysing the epistemological certainty of gestures. A fast and large amplitude movement may well signify a high degree of certainty but this may not always be the case, particularly when considering trainees who have not mastered basic motor control. In contrast slow and small amplitude movements may signify uncertainty; however, sometimes such movements are required due to the delicacy of the task.

Whilst this data reveals the phenomenon of physical movement contributing one side of the co-construction dialogue, it also alerts researchers to the danger of analysis of transcripts in isolation. During a laparoscopic cholecystectomy, placement of an instrument behind a structure and moving the instrument purposefully and repetitively up and down appears to constitute a 'declaring' that a structure has been positively identified. However, further detailed work would be required to create a 'movement dictionary' including codification of epistemological certainty of gestures for specific operations.

Haptic cue interpretation

When the trainer and trainee both had the opportunity to feel the same thing, the trainer makes what he is feeling verbally explicit for the trainee. For example, “his pelvis is like a rock” - using simile to express that the trainer thinks that the tissues feel ‘rock hard’. The trainee learns to interpret this ‘rock hard’ texture as due to “radiotherapy”.

<u>Haptic cue interpretation</u>

Video 16 ‘His pelvis is like a rock – radiotherapy’

Consultant:	Oh it’s bulky. Feel that.
ST 8:	Gosh.
Consultant:	So, put your hand in there. So, that weren’t coming out was it, really.
ST 8:	Can I have a Morris please and a Deaver…
Consultant:	Bulky thing, bulky thing, really bulky.
ST 4:	Another Morris
ST8:	Deaver please
Consultant:	Jesus. Sorry, it’s the right decision; it’s far too big. Diathermy. I feel better now. Right let’s get on with it. I’ll take that away; let’s open him up.
ST 8:	Thank you.
Consultant:	His pelvis is like a rock.

ST 8: Radiotherapy.

Case 7_MainTheatre_AnteriorResection

5.5 Discussion

This detailed investigation provided different insights into pedagogic practice in the operating theatre. The participant reported data captured during the interview studies captured perceptions of teachers and learners and provided some insights into implicit, internal, ways of learning. Observational methods, on the other hand, are biased towards the capture of explicit pedagogic practices. An observational method will not be able to illustrate implicit learning, happening internally within the learner.

Whilst it is not asserted that this investigation captured ‘learning’, there were certainly media clips that captured moments when a trainee appeared (to the emic researcher) to be implicitly learning. The researcher observed and noted occasions when the trainees were attentively engaged in a task that seemed of appropriate level for their learning, and hypothesised that these were episodes of implicit learning. In the following categorisation and discussion the practices were not segregated into explicit and implicit practices, as anything could be rendered explicit for a selected audience. For example, Video 6 has been chosen to illustrate a trainee learning fine motor-skill movements. This is an example of implicit learning, which has been rendered explicit for the reader by the researcher’s selection and highlighting (informed by her own experiences of being a surgical trainee).

The researcher noted episodes where (to her emic eye) the trainers modelled team-working skills or demonstrated ‘adaptive strategies’. There are examples in the data of probable implicit learning which are highlighted by the trainer. For example in video 8, the trainer attempts to make explicit, for the trainee, that he is using an adaptive strategy. He starts by attempting to catch her attention by using her name, and then by giving a verbal explanation, to justify what he is doing (stripping off the liver capsule can cause bleeding but may be unavoidable in cases of extreme inflammation when there is no longer a plane for dissection and the gallbladder wall and liver are fused together).

These implicit practices have been broadly grouped together and called learner-led pedagogic practices. Generally speaking, these were internal learning processes, although they could be made explicit by the researcher, trainer or trainee through metacognitive insightful comment.

Having acknowledged that this method would capture explicit teaching, it is worth further analysis of what these explicit practices 'looked like'. Explicit teaching was generally delivered through verbal discourse. This was sometimes signposted by the trainer through a change in the volume or tone of his voice, from the hushed intonations 'designed' to enhance the progress of the case, to the louder public quizzing which was 'designed' to be of educational benefit. [Whether the hushed intonations of the trainer, that the researcher perceived to be purely 'designed' to enhance the progress of the case, were in fact educational, could only have been confirmed by interviewing the learner at the end of the operation. The researcher would assert that during transcription of the audio record of these cases that she learned a great deal from these hushed intonations.]

Explicit teaching involved a large amount of trainer speech. This is illustrated by ‘explaining’ seen in video 5 entitled ‘if you want your knot to slide’ in which the teacher describes for the learner different knotting techniques. The teacher accompanied the verbal explanation with ‘demonstration’ by showing the learner how to form the different knots. Both emic and etic researchers classified this clip as explicit teaching.

The second type of example of explicit teaching is the ‘quizzing’ and ‘telling’ that was described by surgeons in the interview studies. Multiple examples of this construct were observed. The choice of content, timing of the interaction and ‘model answer’ were controlled by the teacher. The parallels with the Initiation – Response – Evaluation or Feedback (IRE or IRF) sequence described in the educational literature are clear (Mehan 1979). The IRE sequence refers to the turn taking between teacher and learner in which the first turn is a question or ‘Initiation’ from the teacher, the second is an answer or ‘Response’ from the student and the third is an ‘Evaluation’ by the teacher. Some authors would differentiate with an alternative sequence called Initiation – Response – Feedback (IRF) (Wells 1993) in which the third turn from the teacher is not a simple evaluative word such as ‘good’ or ‘yes’ but involves further information giving and can lead into further questions, the next ‘initiation’. Video 2 illustrates this type of sequence in which the initial question ‘what are the complications of stomas?’ leads to the teacher providing information, and then posing further questions.

It has been illustrated that ‘explaining’ ‘quizzing and ‘telling’ are explicit forms of teaching practice conducted through linguistic interaction, instigated and controlled by the teacher. These pedagogic processes are considered in this thesis to be ‘teacher-led’ because the content, timing and quality of the information imparted, and the delivery, were dependent upon the trainer’s assessment of what they believed the learners needed to know, and the trainer’s ideas about teaching delivery.

The difference between learner-led and learner-centred needs clarification at this point in the discussion. The term learner-centred has been used extensively in the medical education literature in the context of learner-centred teaching (Blumberg 1990). Learner-centred teaching is said by some authors to be about establishing the learner’s current level of understanding and basing further instruction upon this foundation. Weimer outlines how to make pedagogic interactions more ‘learner-centred’:

- Teachers do learning tasks less (let the students do more)
- Teachers do less telling; students do more discovering
- Teachers do more (instructional) design work
- Faculty do more modelling (of the learning process -- for student benefit)
- Faculty do more to get students learning from and with each other
- Faculty work to create climates for learning
- Faculty do more with feedback (formative 'along-the-way' and summative assessments; grades and comments)

(Weimer 2002)

Weimer's statements refer to teacher activities to improve the learner-centredness of the educational interaction. The 'quizzing' and 'telling' dialogues demonstrated in this observational data are regarded in this thesis as 'teacher-led'. However, the medical literature may regard these as learner-centred practices as the student's prior knowledge is explored and then built upon by the teacher with reference to their current understanding.

Different interpretations of 'learner-centred' education have been made in medical education literature (Irby 1994). Irby and Spencer's writings about 'learner-centred education' were much closer to what have been described as implicit learner-led practices, by this thesis:

"*Learner centred approaches challenge the traditional view of the teacher as the person who determines what, when, and how learners will learn, with didactic teaching as the predominant method. Creating an environment in which students can learn effectively and efficiently becomes the new prerequisite, demanding not only that teachers are experts in their fields but also—and more importantly—that they understand how people learn.*"

(Spencer and Jordan 1999)

In this discussion the researcher chose to use the terms learner-led, as meaning implicit and internal to the learner and teacher-led, meaning practices that were instigated and controlled by the teacher, which were frequently explicit.

Having acknowledged that an observational methodology would favour capture of explicit teaching, it is worth noting that the content areas perceived by surgeons and described in the interviews were all captured to a greater or lesser extent by the observational methodology. The findings of this investigation provided triangulation of the findings from the interview studies and arguably have increased the validity of the self-report data (Silverman 2010).

It is also worth considering which content areas were captured by the observational methodology. This investigation was not designed to provide statistical information about frequency of teaching in different content areas, but it is apparent from the numeric coding data that 'visual cue interpretation', (248 clips) was a prominent, and frequently captured, content theme of pedagogic activity. The researcher also notes that within operations of the same type (laparoscopic cholecystectomy) there was a strong positive association between the length of the case and the proportion spent 'interpreting visual cues'. The researcher, from her emic perspective, also noted that a more 'difficult case' was one in which the sensory cues were more difficult to interpret, or were of poorer quality - perhaps due to associated inflammation, bleeding or due to faulty equipment meaning that the image quality was poor.

5.5.1 Collaborative practices

It was illustrated that pedagogic activity in some content areas appeared to involve both implicit learner-led practices and teacher-led practices. These were collaborative pedagogic practices.

Learning sensory semiotics required a combination of learning through experience with living tissues and also through teacher guidance. The teacher's contribution was in 'co-construction' with the trainee. For co-construction to occur both the trainer and trainee needed access to the same set of cues. For haptic cue interpretation this required the trainee and the trainer to both have hands-on access to 'feel' the tissues. For visual cue interpretation this required the trainee to have visual access to the operative field, which required the trainee to be 'scrubbed' for open surgery, but was more easily facilitated in laparoscopic surgery through the projection of the operative image onto video screens.

Having access to the same set of sensory cues was essential for meaning making as trainer and trainee frequently used deictic demonstrative words such as "here" or "there". Deixis is a linguistic concept that relates to words and phrases having a fixed semantic meaning, but the exact meaning depends on a greater context. Deixis generally involves evaluating a point of reference, the observer then considers the deictic word or phrase in relation to the speaker and the reference point. Without context, in this case the view of the operative field, these words were non-specific and gave the learner no guidance as to where the trainer was referring. When these words were used in combination with pointing at an image upon a monitor screen, or with an instrument within the operative field, the specificity increased to the point where the trainer was able to convey usefully to the learner the interpretations of what they were seeing.

Co-construction may be viewed as a dialogic pedagogic practice as there was a requirement for exchange of interpretation between teacher and learner as part of a collaborative process. It is useful to look at the educational literature to understand what characterises dialogic processes of learning.

A young child learns about the world by ‘thinking together’ with a parent in order to understand the motivations behind actions which are usually verbalized by the question – “why”? (Mercer 2000). As the child gets older the ability to engage in ‘solo thinking’ is acquired. This is when the child no longer requires a collaborative inter-locuter to ‘work out what is going on’ but can reason internally. This resonates with Vygotsky’s ideas about ‘inner speech’ (Vygotsky 1978). During the ‘thinking together’ phase of child development, the parent may respond to the child’s questioning with short factual answers or a more elaborate explanatory rationalization, building from ‘understood concepts’ and incorporating other ideas. The first discourse may be termed a monologic discourse, where there is only one valid perspective (that of the parent). Monologic modes of teaching are commonly used in school level education where it constitutes a ‘transmission mode’ of teaching and learning. Bakhtin refers to this as an authoritative discourse where there is no opportunity for a student to seek clarification or further explanation about the subject as the content is delivered as un-contestable (Bakhtin 1981). Dialogic mode however requires exchanges between the teacher and learner. Bakhtin referred to this as an internally persuasive discourse in which the teacher allows for negotiability. For a dialogic discourse to occur, the teacher has to acknowledge that there is more than one perspective and be prepared to engage in further discourse around the topic to explore why the current beliefs are held and how the subject under consideration relates to them. It is thought that dialogic teaching fosters a deeper understanding and learning of the subject material rather than the mono-logic mode, which can lead to regurgitation of facts without true understanding (Lyle 2008). In this study 'declaring' what is seen may be viewed as similar to the authoritative discourse, and 'exploring', as the internally persuasive discourse described by Bakhtin.

During learning sensory semiosis, 'declaring' appears to reflect System 1 thinking (Law, Atkins et al. 2004) – an automatic recognition way of knowing what one is looking at. 'Exploring' appears to reflect System 2 thinking - where a rule based system is used to 'figure-out' what the surgeon is looking at. Both of these ways of thinking are represented in the dataset suggesting that both of these mechanisms are utilised in the training setting.

A novel finding of this investigation is that the co-construction phenomenon was shown to be conducted through verbal-physical discourse as well as verbal-verbal interactions between trainer and trainee. Allowing the trainee to have control of the operative instruments as primary operator has several positive pedagogic effects. Firstly, it enables the trainee to learn motor skills through repetition and practice – a learner-led process. Secondly it may provide the trainee with access to haptic cues in order to 'learn the feel' – also a learner-led process. Thirdly, having control of the operative instruments provides an alternative mode of communication for active participation in co-construction sequences. Trainees were able to gesture with the instruments as well as verbally contribute to discussion with the trainer.

This investigation has shown that sensory semiosis is an important content area of postgraduate learning in the operating theatre and that the prominent pedagogic practice in use in this domain is co-construction. These co-construction sequences may be conducted through verbal-verbal exchanges of interpretation between trainer and trainee or through verbal-physical exchanges. The author wonders whether it is through enablement of an alternative mode of communication for co-construction that trainees benefit most from being the primary operator under supervision.

5.5.2 Reflexivity

The multiple limitations of an observational methodology have already been discussed within this chapter – the bias towards capture of explicit pedagogic practices, the selective lens of the researcher, the subjective coding of media clips.

One should note that this was a single-case study, of the operating theatres at one particular institution and that this should not be taken to be a representative or typical case. The findings of this investigation are not designed to be generalizable, although feedback from the surgical community at conferences and international meetings suggested that the pedagogic practices that were observed were very familiar to surgeons from a diverse range of institutions in the UK and Internationally.

Sampling strategy was a ‘convenience sample’ of embedded sub-units which were dictated by the practicalities of data collection. This may have led to a bias of results, as due to video and audio recording restrictions, only particular surgeons could be included within the sample.

The choices of media clips and accompanying transcript to present in this chapter have been made by the researcher, and her own prejudices may have shaped what is presented to the reader. The nature of this type of research is that a huge amount of raw data is generated and progressively condensed down by the researcher. This selection of data is a crucial part of the analytical process, and selection takes place at many levels – what data to collect, how to process and present the data and how to conceptualise. It is acknowledged that the researcher was intrinsically involved in these processes and therefore is inextricably linked to the data presented.

5.6 Conclusions

This observational data provided triangulatory evidence of content themes of learning in the operating theatre. The processes of learning that were observed could be broadly classified as teacher-led, learner-led or collaborative practices.

Sensory semiosis was illustrated as being learned through a collaborative practice termed co-construction. This required both teacher and learner to have access to the same set of sensory cues.

Co-construction involved exchange of interpretations between trainer and trainee. This could be through verbal-verbal exchange between the pair or verbal-physical exchanges.

Distinct parts of the co-construction phenomenon were described – exploring and defining. The exploring category could be further divided into ‘Socratic exploring’ in which trainer guided the eye of the trainee to ‘see’ what they were seeing, or ‘authentic exploring’ where neither trainer nor trainee were sure of what they were looking at and explored on a more equal footing.

CHAPTER 6 - An experimental study to investigate which pedagogic practices are best for learning

6.1 Abstract

Aims

This investigation aimed to determine which pedagogic practice (Teacher-Led, Learner-Led or Co-Construction) was best for operative procedural learning.

Method

This is an experimental study with three groups (Group 1 = Learner-led, Group 2 = Teacher-led, Group 3 = Co-construction). Participants were randomised to these groups and exposed to 15 porcine cadaveric lap choles. There were assessed on 5 separate occasions. The ICSAD device was used to collect hand metrics, OSATS and CAT assessment tools were used to perform expert ratings of performance.

Results

Significant difference in performance scores ie. ‘Learning’ was demonstrated in the Co-Construction experimental group during the course of the experiment. There was no significant 'learning' demonstrated in the Teacher-led or Learner-led experimental groups. No statistically significant differences were found when making comparison between the pedagogic practices.

Conclusions

Learning of the operative procedure was statistically demonstrated in the Co-construction pedagogic group. Learning in the Teacher-led group tended towards significance but no learning was found in the Learner-led group.

Not one of the pedagogic practices was found to be statistically superior for inducing learning in this study.

6.2 Introduction

The qualitative work presented earlier in this thesis has explored surgeons' perceptions of teaching and learning, and has provided illustrative examples of pedagogic practices used within the theatre context.

This study was designed to investigate the relative effectiveness of the described pedagogic practices. The inductive work presented in the two preceding chapters suggested that different processes of learning are utilized for different content areas. Yet, in the operating theatre, surgeons are involved with whole operative procedures, not the constituent skills. Surgical trainees are accustomed to describing their learning with reference to their ability to 'perform' particular operations as primary surgeon or assistant. Surgical trainees do not describe learning visual cue interpretation skills or motor skills, they describe learning to 'perform' an anterior resection as primary surgeon, for example.

The aim of this investigation was to test the 'best pedagogic practice for learning in the operating theatre'. This is an important research question for both the clinical educator and the surgical trainee as due to work time restrictions there is increased pressure to maximise learning by means of applying and promoting the best pedagogic practice in the workplace (Benes 2006). Surgical trainees are keen to be the primary operator for procedures as this positively contributes to their logbook data, however, the surgical educator may have conflicting pressures for example efficient use of theatre time. It is important to know whether allowing the trainee to 'perform' the procedure under supervision is a superior pedagogic practice as there are significant economic implications for this model of training.

6.2.1 Aim

The aim of this study was to identify the most effective pedagogic practice for intra-operative learning.

6.2.2 Research Design

The research question was deductive and for this reason a hypothetico-deductive method for hypotheses testing was used, as this enabled the researcher to determine which method was superior. This method is in stark contrast to naturalistic inquiry, and it was hoped, this study would provide different insights.

In this paradigm of research, rigour and control is achieved by sampling techniques and through minimising potentially confounding variables. The pedagogic practices observed in the operating theatre were presented as learner-led, teacher-led or co-construction in the preceding chapter, these then formed the basis of this quantitative investigation.

6.2.3 Research questions

The specific research questions for this study were:

1. Can learning of an operative procedure be demonstrated using the three pedagogic practices (Teacher-led, Learner-led or Co-construction)?

2. Is one of the three pedagogic practices (Teacher-led, Learner-led or Co-construction) superior for inducing learning?

6.2.4 Rationale for research design

The deductive nature of the research question required a quantitative measure of 'learning' in order to make comparison between the experimental groups. Objective assessments were required with ‘before’ and ‘after’ measures, any difference in attainment level could then be considered to be ‘learning’.

A simulated operative case was chosen as an alternative to real human operating, due to ethical issues of allowing learners to perform a procedure upon a human patient. A simulation also afforded the opportunity to control the environment, and to isolate the influence of the pedagogic intervention over any possible confounding variables similar to an experimental laboratory.

There are different ways of providing a viable ‘control’ group through either a ‘within subjects’ or ‘between subjects’ design (Vogt and Gardner 2012). In a ‘within subjects’ study each participant acts as his or her own control; however, there is repeated testing and this can lead to ‘order effects’ (Vogt and Gardner 2012). This type of design can be particularly problematic for experiments investigating ‘learning’ as learning in one experimental condition cannot be un-learned prior to crossing over to the second experimental condition. Learning is not a linear process, leaps forward occur at different points, as described by ‘threshold concepts’, which are transformative and irreversible so that once the concept has been understood, there is no way back to a position of ignorance (Meyer and Land 2003; Meyer and Land 2005; Walker 2012).

A ‘between subjects’ design is an alternative way of providing a control, as there are experimental and control groups and these groups themselves contain different individuals. The advantages of this type of design are that the experiment does not need to be repeated with the participants crossed over into the other experimental condition. If a 'between subjects' design is used it is important that the two groups are matched. One of the ways of counter-balancing the diversity of the learners is to randomly select participants, and, if a sufficient number of individuals are included, the group will represent the diversity of the population under study.

When there has been random allocation to the experimental and control groups and the researcher has control of any possible confounding variables, this is a ‘randomized controlled trial’ (Vogt and Gardner 2012). The underlying principle is that the experiment is conducted upon a random sample from a population, and that providing the sample is representative of the population, the results may be extrapolated to the population as a whole - a statistical generalisation.

A large sample size was not practical, therefore a ‘matched subjects design’ was applied. There were separate groups for each different experimental condition, however, there was a reliance upon matching each subject in the experimental group to a subject in the control group. In this way the overall constitution of each group was broadly the same and so the groups could act as controls for one another. A matched participant design, therefore, requires fewer participants than a randomised controlled trial. The principle of a matched subjects design is to emulate the strengths of a “within subjects” design whilst avoiding “order effects” that may confound the results of this type of study.

Controlling for all of the potential variables increases the internal validity of the investigation but potentially diminishes the external validity as, so many factors have been controlled for, that the study group no longer has the same characteristics as the population under investigation.

A perfectly ‘pure experiment’ as a randomised controlled trial would have high internal validity as only the independent variable could be responsible for any change in the dependent variable: however, by its very virtue that every other condition is controlled for, a ‘pure experiment’ may no longer be representative of the conditions encountered in the ‘real world’. When investigating human learning there is no guarantee that the human learner will exhibit ‘normal learning behaviour’ under experimental conditions. A ‘pure’ experiment can therefore have low external validity.

The overall design of an experimental study is therefore a balance between the desire for scientific rigor whilst performing research that still has external validity and may be useful to end-users in the ‘real world’.

6.3 Method

6.3.1 Participants

Recruitment was via an email circulated to all Foundation Year doctors at two different major teaching hospitals in London. All respondents were placed on an ordered waiting list and recruited sequentially according to gender matching. For example the first respondent was male, therefore the first 3 male volunteers were recruited to the study, and were randomly assigned to an experimental groups by a sealed envelope technique, then erased from the waiting list.

Participants were matched according to gender, hand-dominance, colour-blindness, career intentions, medical grade (F1s and F2s), previous operative experience. In order to control for variability of previous operative experience, and to maximise possible learning effects, novices were chosen as study participants.

6.3.2 Measures

The two modalities in use for surgical assessment are validated rating scales (either global assessment by expert raters or procedure specific checklist scores) and motion metrics involving tracking of hand or instrument movements.

The *Imperial College Surgical Assessment Device (ICSAD)* (Moorthy, Munz et al. 2003), which uses Patriot or Isotrak II (Polhemus Colchester, VT) to collect

3D position data for each hand, was utilised, and from this, the number of movements and the path-length, was used to evaluate motion analysis data.

The *Objective Structured Assessment of Technical Skills (OSATS)* (Regehr, MacRae et al. 1998) was used as a global rating scale. The OSATS consists of 7 generic components marked on a 5-point Likert scale (Appendix F). The middle and extreme points are anchored by explicit descriptors to aid raters. A surgeon being assessed can achieve a minimum score of 7 and a maximum score of 35. The OSATS scale has established concurrent validity (Martin, Regehr et al. 1997) and has previously been utilised showing construct validity using the porcine cadaveric laparoscopic cholecystectomy model in the Distributed Simulation (DS) environment (Kassab, Kyaw Tun et al. 2011)[1].

The other rating instrument used was a procedure specific checklist score *Competency Assessment Tool (CAT*) (Miskovic, Wyles et al. 2011) which was currently undergoing validation at the research institution (Appendix G).

[1] DS refers to a portable, versatile simulated environment that uses an inflatable 360-degree enclosure which screens participants from their surroundings. Placed within the shell are simplified physical representations of selected components of the surgical environment. These include a scaled-down operating lamp; pull-up photographic banners of anesthetic machine and equipment trolley; and concealed portable loudspeakers that play heart monitor and background sounds recorded in a real OR.

6.3.3 Procedure

A simulated laparoscopic cholecystectomy was chosen as the operative case, as it is an index procedure of the Inter-Collegiate Surgical Curriculum Project (ISCP). A porcine cadaveric liver-gallbladder (Fresh Tissue Supplies, Etchingham, East Sussex) inside a box trainer (Pharmabotics Ltd, Hampshire, SO21 3BN, United Kingdom) was used as the simulation model for the laparoscopic cholecystectomy upon the basis of face, content, construct, concurrent and predictive validity.

The ‘operation’ was conducted using four standardized disposable surgical instruments (Covidien Surgical) and an Endoclipper (Ethicon). The laparoscopic port positions and thickness of 'patient’s' abdominal wall were also standardized for all participants. The experiment was conducted in the DS simulated operating theatre (Kassab, Tun et al. 2011). The only background noise was the sound of the heart-rate monitor which was set at a rate of 65 beats / minute for all participants.

All of the porcine cadaveric material came from healthy pigs about to enter the human food chain. The cystic duct and artery in the porcine model were much smaller than in the human, and in some specimens were indistinct from each other. It was, therefore, decided at the outset of the experiment that these structures would be dissected out and taken together.

Prior to randomization, all participants undertook a half-day one-to-one laparoscopic skills course. This course was similar to the laparoscopic module of the Royal College of Surgeons Basic Surgical skills course and followed a standardized curriculum including specific tasks within the box trainer including peg transfer, wire threading through hoops, cutting shapes out of a glove and balancing beads on pegs. The final part of the course was a step-by-step instruction of how to perform a laparoscopic cholecystectomy, a discussion of the porcine anatomy and viewing of a standardized porcine cadaveric laparoscopic cholecystectomy video. At the end of the half-day laparoscopic training course the participants were assessed cutting a circle out of a glove, using the ICSAD device to record hand metrics.

6.3.3.1 Research intervention

On the basis of previous work undertaken at the research institution, 5 assessments were chosen as a minimum to document the learning curve during porcine cadaveric laparoscopic procedures (Aggarwal, Ward et al. 2007). Two training sessions were applied per assessment. Each session consisted of three lap choles (2 training operations and one assessment). All participants were exposed to 10 training cases and completed 5 assessments. The assessments were performed after every 3rd case. All assessments were conducted independently with no instructional input. During the course of the study 225 simulated lap choles were completed.

Format of study:

- Session 1: Training 1, Training 2, Assessment 1
- Session 2: Training 3, Training 4, Assessment 2
- Session 3: Training 5, Training 6, Assessment 3
- Session 4: Training 7, Training 8, Assessment 4
- Session 5: Training 9, Training 10, Assessment 5

After each assessment, the researcher gave the participants 3 minutes of specific feedback on their performance.

Fifteen matched participants were recruited, underwent the half-day laparoscopic training course and were then randomised by sealed envelope technique to the three study groups.

Group 1: Learner-led pedagogic practices

The study participant was the “camera-person” for the operative case.
There were no explicit teaching interactions with the study participant.

Group 2: Teacher-led pedagogic practices

The study participant was camera-person, the trainer performed the case whilst explaining exactly what they were doing, describing what they were looking at, feeling, paying attention to, using simile and metaphor.

Group 3: Collaborative practices - co-construction

The trainee was assigned the role of operating surgeon and performed the simulated case with verbal instruction from the trainer.

Participants were given as long as necessary to complete the simulated operations.

The participants were required to leave a minimum of 48 hours and a maximum of 2 weeks between sessions.

The same trainer was used for all experiments, for all trainees throughout the study. Trainer experience, both at performing the simulated procedure and at teaching the procedure, was matched for across the experimental and control groups by recruitment and conduct of the experiment in ‘rounds of recruitment’. This meant that the trainer had one participant in each of the experimental groups of the study at any one time point.

All training and assessments were audio and video recorded and motion tracked. The video image was taken from the laparoscopic stack system (Karl Storz), the audio was recorded using a wireless microphone worn by the trainer on the collar of the surgical gown (XTag RevoMic). The ICSAD motion tracking device was secured to the back of the operating surgeon’s hands and the time taken to complete each simulated operation was recorded.

Image 3 DS simulated operating theatre set up for porcine cadaveric laparoscopic cholecystectomy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The image capture system on the laparoscopic stack saved the video files in 15 minute long clips as .mpg files. These files were then saved in a folder assigned a random number from 1 – 999. The numbers were generated by an internet based random number generator. The order of the clips from one case within the folder was denoted alphabetically for example 82a, 82b, 82c. Expert raters were, therefore, blinded to the experimental arm allocation of the subject and the session number. ICSAD motion analysis data was recorded via Isotrak II (Polhemus Colchester, VT).

The videos were scored by two expert raters, using both CAT and OSATS rating instruments. Both expert raters had performed in excess of 100 lap choles independently on real patients in the operating theatre. One of the expert raters had been involved in the development of the CAT instrument and had extensive experience of using quantitative scoring systems for rating surgical performance. The other expert rater, was a senior clinician with no previous experience of using quantitative scoring systems. Research ethics approval was given as part of an amendment to NRES 05/Q0408/70.

6.4 Results and Discussion

Table 11: Group demographics and baseline measures

	Group 1 **Learner-led**	**Group 2** **Teacher-led**	**Group 3** **Co-construction**
N	5	5	5
Male	3	3	3
Female	2	2	2
Age (Mean and SD)	27.4 (1.67)	25.2 (1.1)	25.6 (2.51)
Months qualified (Mean and SD)	10.8 (5.97)	9.40 (7.8)	7.4 (7.09)
Baseline left hand path-length in metres (Mean and SD)	14.7 (3.26)	8.47 (2.87)	11.7 (4.32)
Baseline right hand path-length in metres (Mean and SD)	9.31 (2.19)	6.82 (1.82)	7.21 (2.42)
Baseline number of movements left hand (Mean and SD)	491 (230)	319 (194)	309 (213)
Baseline number of movements right hand (Mean and SD)	156 (84.6)	81 (34.9)	88.4 (66.5)
Baseline time taken (Mean and SD) in seconds	414 (97.9)	309 (67.2)	356 (120)

6.4.1 Bias Analysis

Bias analysis was performed in order to ascertain whether the experimental groups were fair prior to starting to make comparisons (Table 13). Results showed no significant differences in baseline measures between the 3 experimental groups suggesting that matching and randomization processes had resulted in fair groups for comparison.

Table 12: Bias analysis of baseline measures which included demographics and motion tracking data obtained when participants performed a simple task in the box trainer

Parameter	*F*	*p*
Age	0.753	0.492
Months qualified	0.364	0.702
Baseline left hand path-length	0.780	0.480
Baseline right hand path-length	0.091	0.913
Baseline number of movements left hand	0.414	0.670
Baseline number of movements right hand	2.577	0.117
Baseline time taken	0.923	0.424

6.4.2 Missing data

One assessment video failed to record during the study – this was Participant 7 Assessment 4. Mean values at Assessment 4 Group 2 are therefore based upon only 4 data points.

Table 13: Descriptive statistics across all assessments and all experimental groups for CAT and OSATS and ICSAD device

	CAT Score Mean and SD	OSATS Score Mean and SD	ICSAD Left Hand Path-length Mean and SD	ICSAD Right Hand Path-length Mean and SD	ICSAD Number of Left Hand Movements Mean and SD	ICSAD Number of Right Hand Movements Mean and SD	ICSAD Time Taken Mean and SD
Group 1							
Assessment 1	21.6 (2.53)	17.6 (3.07)	244 (108)	143 (72.5)	3103 (1350)	2537 (2865)	44.9 (23.4)
Assessment 2	20.3 (4.50)	17.8 (3.72)	964 (737)	172 (86.3)	5275 (2641)	4126 (2045)	40.9 (19.9)
Assessment 3	21.2 (3.99)	18.5 (3.76)	180 (61.5)	97.9 (27.1)	3992 (2808)	3169 (2430)	46.1 (17.6)
Assessment 4	21.2 (3.21)	16.9 (3.13)	201 (20.8)	94.1 (40.0)	3517 (1257)	1853 (1428)	43.7 (14.9)
Assessment 5	21.4 (2.58)	18.6 (2.27)	402 (304)	198 (59.5)	6242 (3008)	3966 (1282)	55.4 (18.3)
Group 2							
Assessment 1	19.4 (5.66)	15.6 (2.50)	156 (42.2)	113 (15.6)	2512 (536)	2010 (878)	59.8 (21.0)
Assessment 2	19.1 (3.81)	17.3 (2.40)	132 (87.2)	91.7 (34.5)	2757 (663)	2051 (611)	55.7 (15.7)
Assessment 3	22.3 (1.76)	19.5 (1.22)	165 (61.5)	204 (142)	3001 (621)	4708 (3880)	52.7 (16.6)
Assessment 4	21.1 (1.97)	17.25 (3.42)	181 (57.3)	189 (104)	2903 (1527)	3391 (2908)	60.9 (16.0)
Assessment 5	23.8 (5.20)	20.1 (4.33)	251 (211)	217 (87.9)	3195 (665)	2769 (264)	55.2 (22.3)
Group 3							
Assessment 1	19.4 (2.19)	16.9 (4.10)	166 (59.3)	121 (66.5)	3593 (2480)	2864 (3037)	50.0 (15.6)
Assessment 2	19.4 (5.61)	16.4 (4.85)	858 (580)	150 (65.8)	4391 (1860)	3353 (1878)	51.8 (13.1)
Assessment 3	26.2 (2.41)	22.3 (3.19)	289 (111)	188 (111)	4014 (3065)	3944 (3245)	48.1 (16.0)
Assessment 4	24.5 (6.84)	21.2 (5.55)	170 (60.7)	122 (79)	3489 (3198)	2587 (2839)	45.2 (21.4)
Assessment 5	27.3 (3.96)	22.7 (3.78)	242 (97.7)	134 (55.9)	2882 (1616)	2490 (1891)	49.7 (25.6)

6.4.3 Reliability analysis

Cronbach's alpha was used to evaluate internal consistency of both rating instruments, and of the ICSAD device. Cronbach's alpha ranged between 0.766 and 0.917 for the CAT tool, between 0.853 and 0.951 for the OSATS tool, showing that both these rating instruments demonstrated a high level of internal consistency.

The ICSAD device had a Cronbach alpha of between 0.318 and 0.674 which showed poor levels of internal consistency between the parameters measured. The ICSAD motion tracking data was, therefore, not used for further analysis.

6.4.4 Inter-rater agreement

Intra-class correlation coefficient was calculated between the two raters across the five assessments for both the OSATS and CAT scoring instruments.

Table 14: Inter-rater agreement between Rater 1 and Rater 2 across CAT and OSATS scores

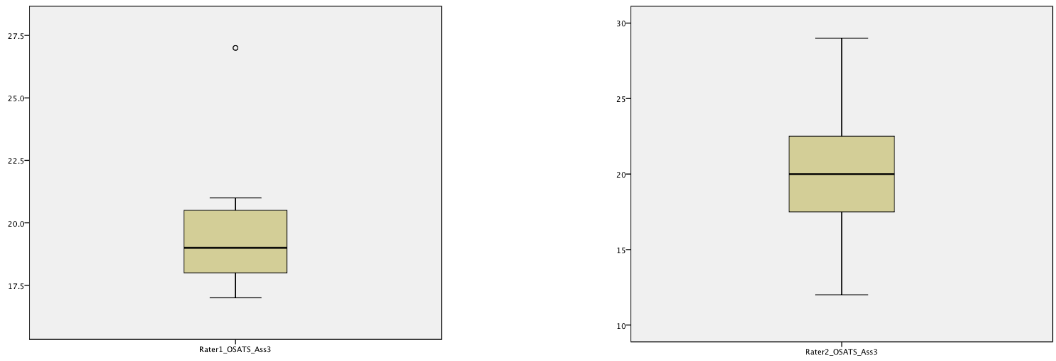
	CAT Score Intra-class correlation coefficient (ICC) and *p*-value	OSATS Score Intra-class correlation coefficient (ICC) and *p*-value
Assessment 1	0.716 ($p = 0.001$)	0.616 ($p = 0.006$)
Assessment 2	0.681 ($p = 0.002$)	0.681 ($p = 0.002$)
Assessment 3	0.708 ($p = 0.001$)	0.308 ($p = 0.123$)
Assessment 4	0.512 ($p = 0.026$)	0.606 ($p = 0.008$)
Assessment 5	0.5868 ($p = 0.009$)	0.195 ($p = 0.243$)

There was satisfactory inter-rater agreement for the CAT scoring tool with $p < 0.05$ in all assessments. There was a high level of inter-rater agreement in assessments 1, 2 and 4 when considering the OSATS scoring tool but poor agreements for assessment 3 and 5.

The low intra-class correlation coefficient for the OSATS score in assessments 3 and 5 drew attention to possible disagreement between the two raters - illustrated in figures 2 and 3.

Figure 2: Box and whisker plot of OSATS score at Assessment 3 for Rater 1 and Rater 2

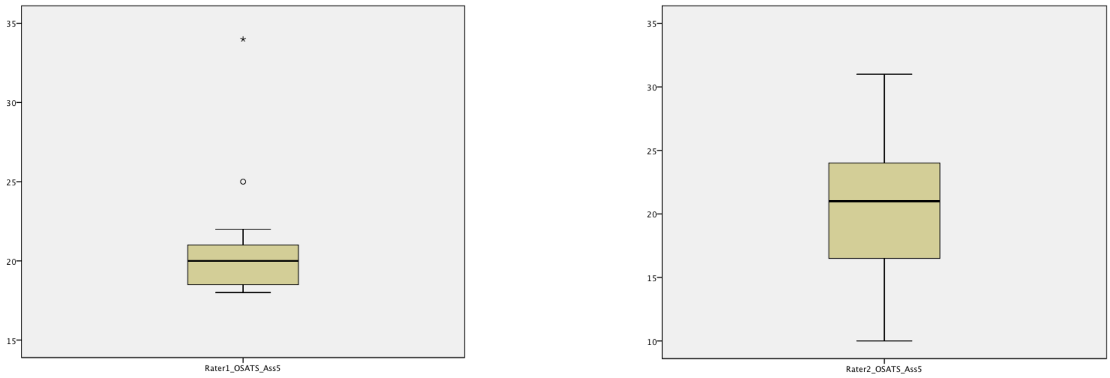
Rater 1 Rater 2



The box length on the box and whisker plots indicates the inter-quartile range. A circle on the boxplot graph denoted an outlier with a value between 1.5 and 3 box lengths from the upper or lower edge of the box. An asterisk denoted an extreme outlier – a value more than 3 times the interquartile range, from a quartile.

Figure 3: Box and whisker plot of OSATS scores at Assessment 5 for Rater 1 and Rater 2

Rater 1 | Rater 2



Rater 1 produced outlier ratings at both Assessment 3 and 5 including an extreme outlier at Assessment 5. Rater 2 in contrast did not produce any outlier readings. These outlier scores explain the low intra-class correlation coefficient demonstrated for OSATS scores in these assessments. The CAT tool was also considered and it was found that there were no outlier scores for Rater 2 at any of the assessment points using either the CAT scoring tool or the OSATS scoring tool. Rater 1 gave outlier and extreme outlier values when using both of these rating instruments. It was concluded that the unreliability was associated with Rater 1, rather than with a scoring scale, and so, despite multiple raters theoretically increasing the reliability of the results, this did not seem to be the case. After much consideration it was decided to base the further analysis upon Rater 2's scores only as there was concern about the reliability of Rater 1's marking.

6.4.5 Correlation between CAT and OSATS scoring scales

The final test of reliability of the data was to look at the correlation between OSATS and CAT scores using Pearson's rank coefficient. This determines whether both tests were measuring similar attributes. The Pearson rank correlation coefficient was calculated only using Rater 2's scores. Pearsons correlation coefficient was between 0.632 and 0.933 at $p<0.05$ for all five assessment points. This illustrates a strong correlation between CAT and OSATS scores.

6.4.6 Was learning 'demonstrated' over the course of the experiment?

The first research question was to ascertain whether it was possible to demonstrate 'learning' during the course of the experiment. Paired samples *t*-tests were used to examine OSATS and CAT scores at Assessments 1 and 5. Paired t-test showed no statistical difference between OSATS score at Assessment 1 and 5 in Group 1 (t_4 = -0.691, p = 0.528), Group 2 (t_4 = -1.658, p = 0.173) or Group 3 (t_4 = -1.826, p = 0.142). Paired *t*-tests showed no statistical difference between CAT scores at Assessment 1 and 5 in Group 1 (t_4 = 0.583, p = 0.591), Group 2 (t_4 = 1.328, p = 0.255), however, there was a significant difference between CAT scores at Assessment 1 and 5 in Group 3 (t_4 = 3.772, p = 0.02). This suggested that learning could be demonstrated in Group 3 using CAT scores.

A Pearson product moment correlation was performed as this bases the analysis upon scores at each assessment rather than just a consideration of Assessments 1 and 5.

Table 15: Correlation between OSATS score and assessment in the three experimental groups

	Pearson product-moment correlation	p-value
Group 1	0.036	0.864
Group 2	0.372	0.074
Group 3	0.428	0.033

Table 16: Correlation between CAT score and assessment in the three experimental groups

	Pearson product-moment correlation	p-value
Group 1	-0.065	0.757
Group 2	0.368	0.077
Group 3	0.543	0.005

These correlations suggest that significant 'learning' could be demonstrated across the assessments in Group 3 (Co-construction). There was a trend towards significance in Group 2 (Teacher-led) suggesting that some learning occurred. The p value for Group 1 was high suggesting that no learning occurred in Group 1 (Learner-led).

6.4.7 Was one pedagogic practice superior for learning?

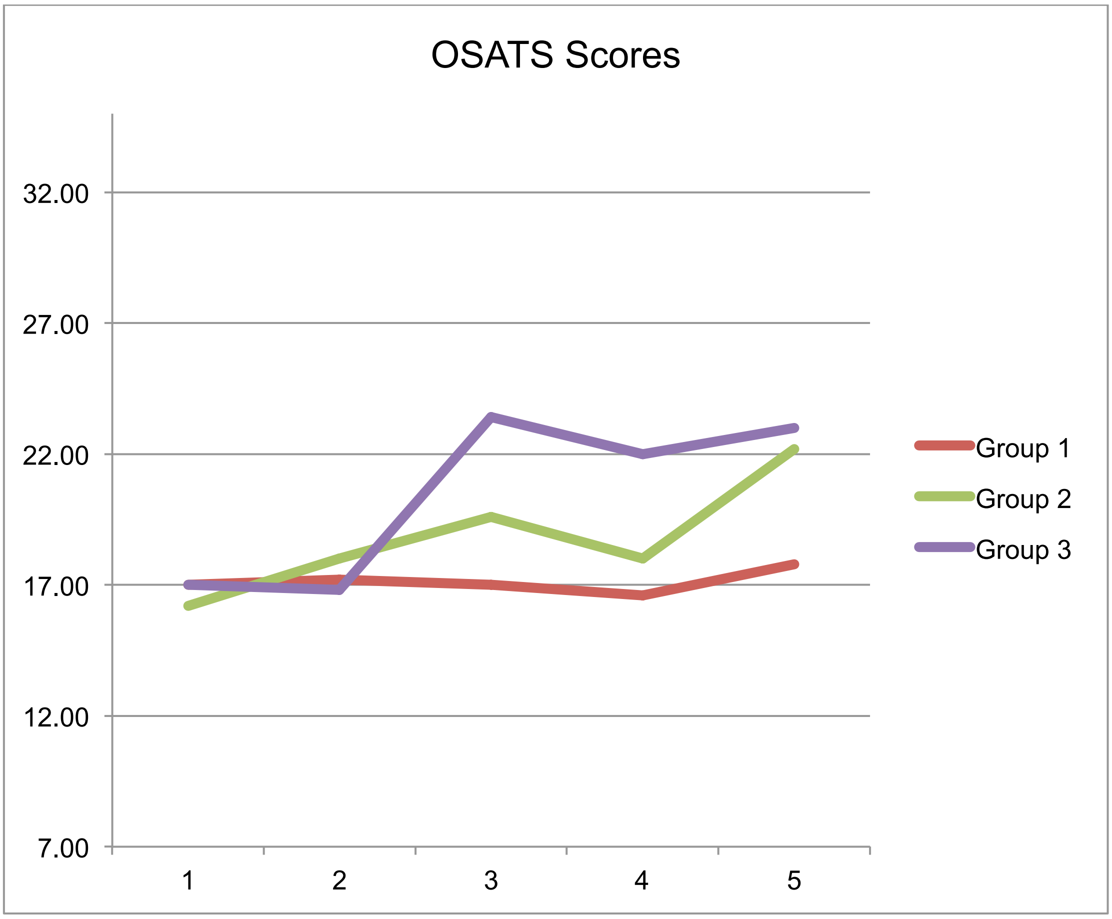
Experimental groups were compared by examining score at Assessment 5 minus score at Assessment 1. A one-way ANOVA was performed to test for significant differences in 'learning' (score at Assessment 5 minus Assessment 1) across the 3 experimental groups using OSATS scores. The results were not statistically significant ($F_{(2,14)} = 1.072$ $p = 0.374$) suggesting that no one of the pedagogic practices gave rise to a greater increase in demonstrable 'learning'. This was repeated using CAT scores. The results approached statistical significance ($F_{(2,14)} = 2.923$ $p = 0.093$) but did not find significance at the $p<0.05$ level. This test suggested that no one of the pedagogic practices was superior.

Analysing the data in this way considered only scores at Assessment 1 and Assessment 5. It was possible that by Assessment 5 that all 3 groups had completed their learning curve and that this was why no significant differences were found between the 3 experimental groups.

One-way ANOVA was performed, to test for significant differences between the experimental groups at the 4 points of the learning curve, by using score at Assessment 2 minus score at Assessment 1. Then a separate one-way ANOVA was performed using score at Assessment 3 minus Assessment 2 and so on. OSATS scores tested in this way showed no statistically significant differences between the 3 groups. Analysis using CAT scores found a possible difference in the experimental groups between Assessment 2 and Assessment 3 ($F_{(2,14)} = 3.68$ $p = 0.057$). Further post-hoc comparisons between the groups were not performed as this result was only approaching significance. These tests suggested that there may be a difference between the experimental groups at the mid point of the learning curve (between Assessments 2 and 3).

Further analysis was performed using two factor mixed model repeated measures ANOVA. This examined differences between experimental groups and assessment points using individual participant data rather than group data. Factor 1 was the between subjects factor (Experimental group) and Factor 2 was the within subjects factor (Assessment 1, 2, 3, 4, 5).

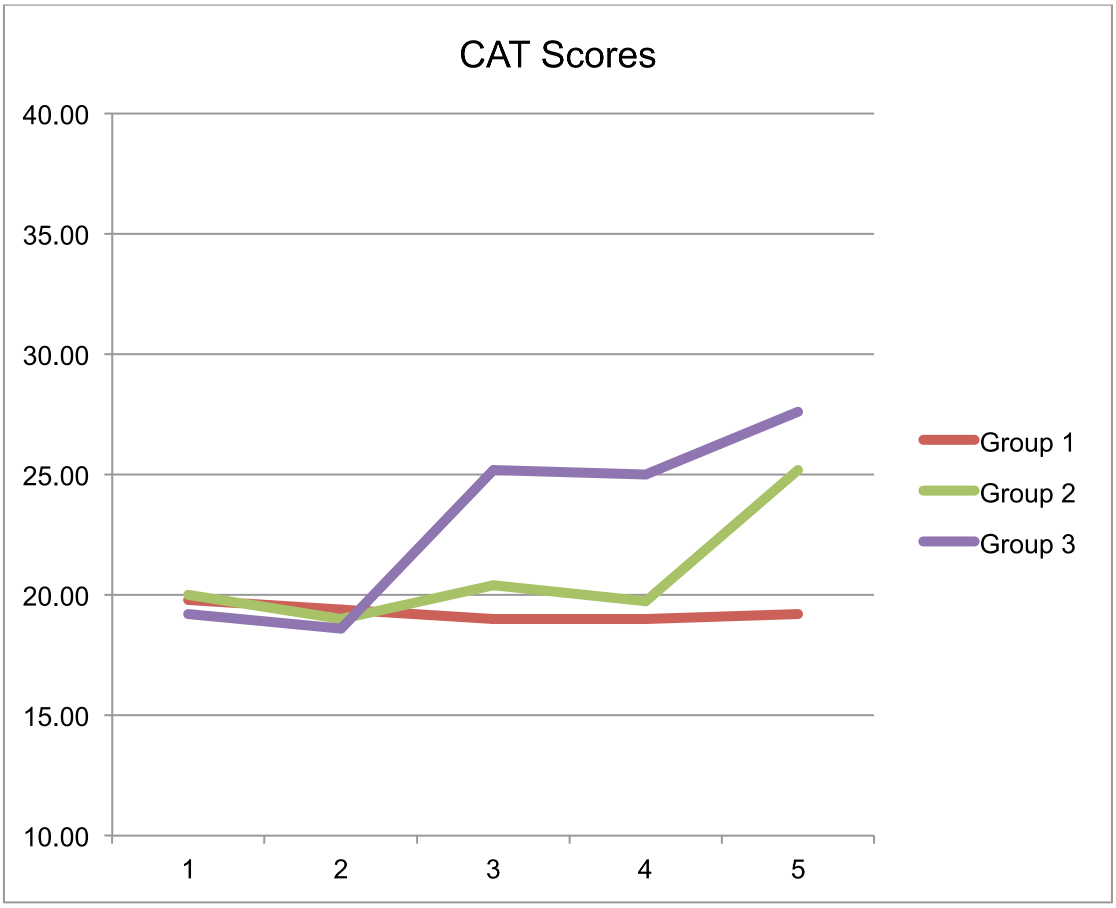
Figure 4: OSATS scores (out of a minimum of 7 and maximum of 35) at each of the 5 assessment points for each of the 3 experimental groups



Within subjects effects F (4, 44) = 3.493 p = 0.015

Between subjects effects F (2, 11) = 1.562 p = 0.253

Figure 5: CAT scores (out of a minimum of 10 and maximum 40) at each of the 5 assessment points for each of the 3 experimental groups



Within subjects effects $F\,(4, 44) = 3.711$; $p = 0.011$

Within subjects contrasts $F\,(2, 11) = 1.656$ $p = 0.235$

Two factor ANOVA found no significant main effect of 'experimental group'. There was a significant main effect of ‘assessment’ and there was no interaction between experimental group and assessment. This suggested that when individuals' learning curves were considered, there were no significant differences between the experimental groups but there were significant differences in scores at the sequential assessment points through the study.

6.5 Discussion

The results showed that statistically significant 'learning' was demonstrated over the course of the study in the Co-constuction group, as found by the Pearson product-moment correlation. Results from the Teacher-led group tended towards significance. No learning was demonstrated in Learner-led group. Despite this suggesting that Co-construction might be a superior pedagogic technique, statistically superiority was not found when the three experimental groups were compared.

One difficulty with establishing superiority of one pedagogic technique was that when mean scores in each group were considered the variance of the mean scores was large - as the group consisted of individuals. The two factor ANOVA analysed individual subject learning curves, but in this study there was a great deal of variability in the performance of individuals and this may have contributed to the fact that no significant differences were found between the experimental groups.

An unexpected finding was that the learning curve appeared to flatten between Assessment 3 and Assessment 4. The OSATS scores even suggested a deterioration in performance at Assessment 4. This was found in both the OSATS and CAT data (see Figures 4 and 5). It was unclear why performance did not improve along the expected trajectory. It may be speculated that the deterioration in performance scores was due, in part, to decreased motivation of the learners, as early on in the study, the participants were very focussed upon learning and improving, by Assessment 4 the novelty had worn off. Assessment 5 however was the final hurdle and represented a final 'try' for the learners at mastering the procedure. An alternative explanation for this observation is that learning is thought to be saltatory (this still does not explain any deterioration in performance at Assessment 4) - happening in jumps forwards, rather than a simple progression.

When considering what constitutes best pedagogic practice, it seems desirable to generate a steep gradient in the learning curve in the early phase. There was some evidence in this experiment to suggest a difference between the experimental groups between Assessments 2 and 3 - at the mid point of the learning curve, however this was not statistically significant at the $p < 0.05$ level.

Few robust conclusions may be drawn from this study other than that further work examining pedagogic practice and learning needs to be under taken. Implications and recommendations for changes in practice should not be made based upon this data. What can be concluded was that there was a significant positive correlation between performance scores and assessment number in the co-construction group but not in the teacher-led or learner-led groups. It is worth considering the potential implications of utilising co-construction in the operating theatre. Co-construction in this study involved the trainee handling the instruments and 'performing' the procedure under the direction of the trainer, compared with Teacher-led which involved the trainer performing the procedure but explaining every step, or learner-led when the learner attentively watched the trainer but in the absence of explicit teaching activity. The difficulty of translating these findings into improved pedagogic practices in the operating theatre is that to utilise Co-construction as a pedagogic technique, the trainee has to have sufficient basic motor skills to perform the actions suggested by the trainer. In this study all learners had a half-day intensive one-to-one basic surgical skills course to ensure that they had developed sufficient motor skills and familiarity with the instruments to be able to execute the instructions of the trainer. In the workplace setting many Foundation Year doctors complete a 2 day RCS accredited Basic Surgical Skills course, in which the focus is upon basic motor skills, prior to commencing as a Core Trainee, however the time lapse between completing the BSS course and the opportunity to perform a procedure under instruction in the real operating theatre is variable.

The researcher would suggest that for Co-construction to be used as a pedagogic practice in the operating theatre, the trainee must be familiar with the operative instruments and possess basic motor skills. The other factor worth considering if co-construction were promoted as a pedagogic practice is that the trainer must 'trust' the trainee to listen carefully and attentively and respond to the directions of the trainer. This requires a close, trusting and respectful relationship.

The other frequently cited barrier to allowing the trainee to 'perform' the procedure under instruction in the operating theatre is that it is thought that this pedagogic activity within a training case takes longer (Bridges and Diamond 1999). The training cases were not formally analysed in this study, however, the researcher observed that the training cases took longer to complete when the learner was in the co-construction group compared with teacher-led or learner-led.

These results resonate with the existing surgical literature which reports that learners value 'doing' the case (Mukhopadhyay and China 2010), that good trainers allow trainees to be hands-on (Cassar 2004) and logbook data (Dunnington 2009) which is a record of number of procedures 'performed' by the learner (even if these are 'performed' under instruction) is a valuable metric rather than number of procedures 'observed'.

6.5.1 Limitations

One of the limitations of this study was that retention of learning was not tested - it would have been interesting to investigate whether one pedagogic practice was superior in its ability to lead to long-term learning of the operative skill. This is particularly relevant for junior learners who may rotate through different specialty surgical departments and have long periods of time before being required to re-apply the specific skills that they had learned.

It is unknown whether the learning curve for this procedure for these learners was completed in this study, continuing this study with further training episodes and Assessments may have established whether the learning curve was complete.

This study included very small participant numbers in each experimental group and as a result numeric results have been borderline in their statistical significance. The effect size of the experimental group was relatively small, and so one should be cautious not to over conclude from the results. Both the data collection and rating of video clips was very time consuming and this was balanced against the ability to include a larger number of participants in the study. One alternative would have been to use a shorter or simpler simulated operation. The porcine simulated lap chole was thought to closely replicate a human operation and was favoured over virtual reality or part-task simulations however the compromise has been the small number of participants in each group. As a result, many of the statistical tests have generated non-statistically significant results.

One of the particular difficulties encountered during statistical analysis was that paired samples t-test relies upon the assumption that there are a large number of participants in the study and that their results follow a normal distribution. It was found that there was a great deal of individual variation in performance at the different assessment points, this may have been due to dynamic factors such as trainee tiredness and stress. Such factors were acknowledged to be difficult to control, and this formed part of the rationale for assessing trainees on five different days in the study.

There were some specific difficulties with data collection that became apparent during the course of the study. The ICSAD device was troublesome in terms of connections and zero-ing throughout data capture and the lack of internal consistency found by Cronbach alpha of the ICSAD device metrics may have been due to there being a large amount of ‘noise’ within the dataset. The simulated operation was lengthy and complex necessitating several instrument changes. Every instrument change generated large hand movements that could be considered to be an artefact, as they were unrelated to the surgical skill of the operating surgeon. The movement tracking data captured all of these instrument changes and whilst software filtering may have been used to 'clean-up' this data, there was also the potential issue that the size of the specimen and exact positioning of the porcine liver-gallbladder within the box trainer contributed to longer time-taken and path-length for some of the participants. Due to these concerns about reliability and accuracy of the ICSAD metrics during this investigation, it was decided not to use this data for further analysis.

Another difficulty that was encountered with measurement of performance, was inconsistency between the two expert raters. During the analsyis, individual rater results were explored and it was found that Rater 1 produced a number of 'outlier' and 'extreme' scores. Rater 1 was an experienced clinician but had little previous experience of using validated rating instruments, whereas Rater 2 had extensive experience of using Rating instruments and had been involved in the design of the CAT assessment tool. Whilst the researcher had trained Rater 1 to use the OSATS and CAT tools, the two raters were based remotely from one another and there was no opportunity at the outset of the study to perform collaborative ratings and comparison of the results to ensure that they were rating similarly.

The scoring scales used in this investigation; OSATS and CAT, use a summation of scores marked across a number of domains. Whilst it can be expected that an ‘expert’ will perform well at ‘tissue handling’, ‘time and motion’ and ‘knowledge of specific procedure’ and that a novice will perform poorly in all of these areas, a summation of score from each of these domains relies upon the assumption that ‘learning’ happens at the same rate across all of these domains for all learners. For example one learner may become ‘expert’ at ‘knowledge of specific procedure’ but still be at novice level for ‘time and motion’ until much later in the learning curve, whereas another learner may become 'expert' in the domain of 'time and motion' but not in the domain of 'knowledge of specific procedure. The summation of scores allows no insights into the domains in which the learning took place, nor whether this varied for the different pedagogic practices. Whilst it was possible to perform a sub-scale analysis to analyse ‘learning’ in each of the specific domains, this was not undertaken as there were high levels of internal consistency across all of the items rated by both the OSATS and CAT tools, suggesting that, either, all of these areas were being learned at the same rate, or alternatively that scoring in each domain was not entirely independent. Expert raters may have used information pertaining to one domain to weigh into judgements concerning performance in other domains. For example if the learner clearly displayed poor ‘instrument handling’ it is plausible that this also weighed into the raters scores for ‘respect for tissues’. Sub-scale analysis was not performed in this investigation as the internal consistency of the items within the scales was high and sub-scale analysis seemed unlikely to provide different insights.

The level of inter-test agreement was also found to be very high using Pearson’s rank correlation. This is unsurprising as the rating instruments were used side by side so that the assigned scores from one assessment were available to the rater when scoring using the second rating tool, and this may have led to bias of the second ratings. The raters were not asked to use the rating tools in a specific sequence. In retrospect, the researcher would suggest that the ratings should have been performed in isolation from one another, so that the expert rater would have watched and rated all assessments using the OSATS tool, and then watched and rated all assessments using the CAT tool. This would have required the expert raters to have watched each assessment twice, potentially doubling the time required to perform the expert ratings. The average time taken for a participant to perform one assessment was around 40 minutes. Each rater viewed and rated 75 assessments. The time requirement to perform the ratings was therefore around 50 hours. It was unrealistic to ask the raters to watch each video twice in order to perform independent ratings using the OSATS and CAT tools. The OSATS and CAT ratings therefore cannot be considered as totally independent scores as the result in one rating tool may have biased the score when using the other rating instrument.

Other specific limitations pertain to the details of the study design - for example initial bias analysis was performed between the groups, however, the baseline performance metrics measured, did not directly pertain to the operative task set in this study. In retrospect, one might have captured the participants' baseline performance in the simulated operation rather than the much simpler task – cutting a circle out of a glove. This would have provided a baseline measure of performance in the task of interest. Establishing a baseline of performance in the task of interest would have also allowed plotting of scores at point zero – before the experimental teaching interventions commenced. In this investigation no baseline measure was made of performance in the simulated lap chole, the first data point was at Assessment 1 which was after two training sessions not at point zero.

Additionally, learners were not matched at the start of the study for their preferred learning style. Some of the learners may have been kinesthetic learners having a preference for being hands-on whereas some of the participants may have had visual or auditory learning preferences.

Cadaveric animal tissue was used in the simulation, and although this made the task more 'life-like', an inherent difficulty with using biological materials was that there are small individual variations and differences in the anatomy making some operations 'easier' or 'harder' than others and therefore meaning that the procedure was not entirely standardized.

Another limitation in the study design was that the researcher was the 'trainer' during the experiment and therefore involved in the pedagogic intervention itself. One advantage of this was that the same trainer was used for all participants in the study, but, this also led to a potential bias of the results. One way in which the researcher attempted to counteract this bias was by being blinded to the specific checklist items of the CAT tool. The researcher was unaware of the specific categories and attributes that were being scored on this rating instrument and therefore performed and taught the simulated operation as she would have taught laparoscopic cholecystectomy in the workplace, rather than minded by the individual items on the checklist.

6.6 Conclusions

Learning of the operative procedure was statistically demonstrated in the Co-construction pedagogic group. Learning in the Teacher-led group tended towards significance but no learning was found in the Learner-led group.

No single pedagogic practice was found to be statistically superior for inducing learning in this study.

CHAPTER 7 - Overall findings of this work

7.1 Introduction

This concluding chapter brings together the strands of work in this thesis synthesising the conclusions of each piece of investigative work to provide practical suggestions for surgical educators and learners. This final chapter is written in the first person, as was the earlier section entitled 'perspectives' to allow the reader an insight into the personal development and transformational change that occurred in the researcher during the writing of this thesis.

Firstly to summarise my work - I started by conducting a narrative review of the literature, as it stood, at the outset of the period of research. This literature review has subsequently been expanded to include a couple of key papers that were published during the writing of this thesis. The aim of the narrative literature review was to set a background for the reader and to highlight the broad literatures that have examined surgical training.

Secondly, I provided a theoretical framework for readers not versed in the educational literature, providing a brief overview of the relevant constructivist theories of learning.

The empirical work I conducted during this period of research utilised three different methodological approaches. I used grounded theory in the context of an interview study, case-study method in the context of an observational study and lastly, experimental work to investigate best pedagogic practices. These are different ways of examining the underlying research questions, and I believe that use of these contrasting methods is one of the particular strengths of this body of work.

This concluding chapter is a critique of the methodologies and the research work that has been conducted and provides practical suggestions for the surgical teacher and learner based upon the overall findings of this thesis.

7.2 A critical discussion of the methodology

The use of contrasting methodologies within this thesis may be termed mixed-method research. Mixed-method research is thought to be superior by some authors as it may increase the integrity and applicability of findings when studying complex interactions in medical education research as the different methodologies can provide different insights (Schifferdecker and Reed 2009). However, one of the particular challenges I faced, was the negotiation of tensions between the different research traditions in terms of their values and processes (Lingard 2008). This was one of the central themes throughout the writing of this PhD thesis – negotiating tensions between my desire to produce objective ‘scientific’ findings, and findings that still had relevance to the setting, context and surgeons that were being studied. These tensions were heightened by my positioning within a university college of science, at which there was no humanities department and only limited experience of inductive qualitative research. I was fortunate, through contacts of my primary supervisor, to work collaboratively with a sociologist from the Institute of Education and to spend 4 months at research institutions in Canada as part of a RCS Harry Morton travelling fellowship. During this period of time, the contact with sociologists, linguists and other surgeons involved in qualitative research within medical education, played a formative role in the shaping of both this thesis and research work and also my own future academic interests and personal development. Their mentoring and encouragement with the qualitative aspects of this thesis was crucial.

In a quantitative report the data itself is presented to the reader, in contrast, an inductive qualitative research report presents selected items to the reader in order to illustrate themes. The selection of what to present to the reader is made by the researcher. Not all of the key decision-making processes that guided these selections are visible to the reader, and so the reader must trust the integrity of the researcher. In qualitative paradigms, the trustworthiness of the researcher lies at the heart of the concept of validity (Denzin and Lincoln 1994). The reader must make decisions about trustworthiness of the researcher based upon the positioning of the research within the wider literature, whether the research resonates with their own experiences of teaching and learning in the operating room (if they are a surgeon reader), and the transparency of the researcher in terms of their explanations of the manner in which the research was conducted and the choices that were made during data collection and analysis.

I have described in detail how the data in this thesis was collected, recorded and analysed. The original audio and video files, field notes from the operating theatre and interview transcripts are available from me, should the reader wish to view any of the original data. Analysis and interpretation have also been described in detail. Where quotations or media clips are referred to, they are referenced to the original observation episode or interview. These can be tracked back to the source material either using NVivo 9 or search facilities within Microsoft Word.

I have tried to take a reflexive stance throughout this thesis providing a critique of each investigation at the end of each empirical chapter. My own perspective as an educator and a surgical trainee was described to allow the reader to understand my situatedness within my research frame. Potential biases have been discussed, as have strategies used to limit predisposed interpretations, such as multiple person analyst teams and emic and etic perspectives upon the data. I hope that I have been able to provide the reader with insight into my perspectives but also to reassure the reader that my intention has been to provide a fair, honest, true reflection of the data collected. It is then up to the surgeon reader to determine the validity of the work in terms of how closely the findings resonate with their own experiences. This has, to an extent, been explored during the research through member-checking but it is only at this point in the thesis that I am able to draw together the complementary lines of investigation and present a coherent whole.

The bulk of the funding for my salary during this research came from the Royal College of Surgeons of England, rather than directly from the university department. This allowed me a degree of freedom from the institution and allowed me to explore different research paradigms without the constraints of needing to conform to expectations of the university department. The only requirement was that I would provide a short report back to the RCS for publication in their annual review publication of research projects. This meant that a huge amount of freedom was afforded in terms of methodologies and conduct of the research work encapsulated in this thesis. I therefore made my methodological choices without constraint, and chose strategies that appeared best suited to the research questions.

A large bulk of previous research work has classified surgical learning into technical and non-technical skills without a clear definition of what actually constitutes a technical or non-technical skill. I have deliberately avoided using these terms in this thesis to allow the reader to explore what may be included within these umbrella terms. The initial inductive question about what is learned in the operating theatre makes no suppositions about categories of learning, seeking to investigate inductively the content of learning in the operating theatre. Further inductive work was then used to explore processes of learning in the operating theatre - both the processes of learning that are perceived by learners and can be described, and also the processes of learning that can be observed.

In addition I used quantitative methods in this thesis in response to a more deductive question investigating superiority of pedagogic approaches. This use of contrasting methodologies has allowed me to learn about and demonstrate my understanding of both paradigms. This aspect of the thesis allowed for new insights and subsequent discussion into the relative strengths and weaknesses of both approaches for answering questions about human learning.

The resulting thesis may seem a contradiction at times, and the investigations somewhat conflicting in terms of underlying values and assumptions. In part, this was because I wished to explore the usefulness of both strategies, and then make my own conclusions about their relative value and merits. Using a range of different methodologies certainly led to multiple different insights into the topic under investigation, which is a strength of this thesis. As a result I have been able to make a holistic synthesis of findings, to inform my suggestions for surgical teachers and learners presented in this concluding chapter.

7.3 A critical evaluation of the thesis

One of the major challenges that I faced during the writing of this thesis was defining the scope of the research. There were a multitude of different areas of interest and the inductive nature of the early research just served as to open my eyes to the vast complexity of surgical teaching and learning. My primary focus came to be investigating the teaching and learning of procedural skills in particular sensory semiosis. This meant that other areas of learning in the operating theatre, such as non-technical skills were selectively under-explored.

Looking retrospectively, this selection may have been made in part due to my personal interests but these choices were also made as a result of the data that was collected. For example, the observational investigation included video data from the operating theatre and ethics committee approval was conditional upon video images being only of the operative field, rather than a whole-team view of the interactions in the operating theatre. This shaped decisions about what to investigate in more detail. If ethics approval had been given to capture a whole team view, the thesis may have looked very different and I may have chosen to provide an in-depth analysis of how non-technical skills are learned.

A critique of this research is, therefore, that it only presents a partial and incomplete view of teaching and learning in the operating theatre as not every content domain was explored in detail. The justification for concentrating efforts upon sensory semiosis was that this was a new content area that emerged during the course of the research about which relatively little was known and promised to be an interesting and novel line of investigation.

I acknowledge that the thesis is lengthy, this is partly due to the nature of the data – presentation of quotations and qualitative pieces will inevitably lead to an increased word count. The other contributing factor is that I have gone to some length to discuss with the reader the relative merits of the different research paradigms, this has echoed my own internal deliberations during the research design. The thesis is situated at an inter-section between the surgical literature, the educational literature and the cognitive psychology literature. Concepts and findings are drawn from all of these domains, with many philosophical and methodological arguments being drawn into discussion. Many of these concepts and much of the vocabulary used will be unfamiliar to the surgeon reader. I have attempted to explain concepts and vocabulary throughout, however it is difficult to be certain to what extent the balance has been struck between over-simplification and accessibility for the reader. The fact that much of the discussion has been about methodological issues reflects my own internal struggles between these paradigms.

7.4 Implications for teachers in the operating theatre

This thesis shows and makes explicit the multiple different content areas of learning in the operating theatre. The data also suggests that learning in different content domains is through different pedagogic processes.

- This work provides a content framework of attributes learned in the operating theatre. This is useful to guide observations of trainee performance in the workplace.
- This content framework may be used to guide feedback to trainees to increase the specificity of suggestions for improvement.
- Specific pedagogic practices may be helpful to assist trainee learning in particular domains. For example collaborative discussion (a co-construction) with the trainee about what they are 'seeing' or 'feeling' rather than the trainer 'telling' the trainee what they 'see' or 'feel' may prove useful in learning sensory semiosis.
- This research provides some evidence that by allowing the trainee to perform the operation with verbal instruction, rather than observing it with no explicit teaching, the early learning curve may be steeper. The implication for teachers is that trainees, where possible, should perform operations under instruction, and where this is deemed too high a risk, the trainer should explicitly discuss their strategies, thought processes and decisions.
- In order for physical - verbal co-construction to be safely utilised as a pedagogic practice (allowing the learner to perform the procedure

under instruction) the learner must already have acquired basic motor skills and a familiarity with the steps of the procedure and instruments. This acquisition of basic motor skills could be assessed and verified in simulation before progression to the operating theatre

7.5 Implications for simulation educators

- Now that the content areas of learning in the operating theatre have been made explicit it is possible for simulation educators to use this information for simulation design. Having outlined the domains of learning it is possible to make active choices about what to re-create for learners in simulation, rather than all simulations being made as 'realistic' as possible.
- The necessity to develop complex ‘life-like’ models for skills simulation is questionable as interpretation of real tissue cues, both visual and haptic could be undertaken in the operating theatre through collaborative discussion. The place of simulation may be for the initial learning of the steps of the operation, motor skills acquisition and practice and familiarity with the instruments.
- After initial learning (through explicit teaching) of the basic manoeuvres (knot tying etc.), higher motor skills learning (economy and efficiency) appears to be as a result of repetition and practice. Provision should be made for repetitive practice of motor skills in simulation laboratories after the initial learning episode with a trainer - rather than an isolated course.

- Team-working, management and leadership were found to be learned through observation. The implication for simulation educators is that for scenario work it may be beneficial to provide exemplar scenarios where excellent practice is modelled by faculty. The researcher has observed that trainees are always keen to watch other trainees taking part in scenarios, and would suggest that this is because learning is through a process of modelling what they perceive to be good behaviours. Rather than trainees watching one another in scenario work, it may be beneficial for faculty to perform an exemplar scenario and for the learners to be involved in reflecting upon and exploring with faculty the strategies that they observed being used.

7.6 Implications for learners

- Active observation rather than ‘osmosis’ was reported to lead to learning. Trainees would benefit from reflecting upon their own learning objectives and what might be learned in the course of observing procedures in the operating theatre.
- Dialogic interactions may be a more useful learning tool than teacher ‘telling’. The learner is encouraged to offer their own interpretations of what they are 'seeing' or 'feeling' and to engage in dialogic interaction with the trainer where possible.
- Once basic manoeuvres have been learned, further motor skills acquisition may be as a result of repetition and practice. Learners could improve their time and economy of movement by repetition and automation of their motor skills, away from the operating theatre for example in simulation. Once initial motor skills have been mastered the on-going repetitive practice leading to automation does not appear to require explicit teaching activity, rather self-critique, so could be undertaken on an individual basis in learners own time.
- There is some evidence in this thesis that team-working, leadership and management skills are learned through observation of a trainer through a process of modelling behaviours. The researcher would suggest from that long hours spent in the company of a trainer with strong non-technical skills may be the best way to facilitate learning of these attributes.

7.7 Implications for the profession

Many surgeons would agree that 'apprenticeship-style' learning on the job is no longer an appropriate way to educate surgeons in the twenty-first century. However, the literature review and empirical work suggests that apprenticeship style learning has many benefits - the long hours, days and months spent with the trainer were thought to be important in the learning of professional skills; such as communication skills, managerial and leadership skills. Consultants with strong inter-personal skills should be chosen for lengthy placements and thought should be given as to which trainees would derive most benefit from a placement with such a trainer. Placements may no longer be dictated by the specialty of the trainer but by the particular attributes that they can offer.

Surgical technical learning is perhaps not best suited to the apprenticeship model of learning as large periods of time may be spent observing the master surgeon in an apprenticeship system. Co-construction in the operating theatre was described as an active pedagogic strategy with dialogic exchanges (either verbal-verbal or verbal-physical) between trainer and trainee. In order for co-construction to be used as a pedagogic tool, the trainee must already possess basic motor skills, knowledge of the steps of the procedure and a familiarity with the equipment and instruments. A surgical 'boot-camp' at the start of every new rotation in which the steps of the common procedures were explained, where there was the opportunity for motor skills practice and where the trainees gained familiarity with the tools that they would then be using in the operating theatres during that rotation would be beneficial. The researcher believes that this approach would increase the likelihood of co-construction being used as a pedagogic tool in the operating theatre.

- Not every Consultant surgeon should have a surgical trainee
- Surgical 'bootcamp' at the start of every rotation to ensure indications, steps of procedure, complications and instruments are known as well as a check of motor skill ability prior to training in the operating theatre.

7.8 Further work

Learning in the operating theatre has been shown to be very complex and there are a plethora of different avenues for further exploration.

The researcher would suggest that one of the content areas in which insufficient data was captured in these investigations was surrounding the learning of adaptive strategies. This is an important topic of inquiry. How a trainee surgeon learns strategies to deal with unexpected findings and complications is essential when considering how to prepare surgeons for emergency workload, as well as critical incidents, complications and errors in the operating room.

Another interesting line of inquiry would be to explore with surgeons and trainees what they ‘see’ in different selected video clips and to start building an educational library of such materials.

Non-technical skills learning deserves further investigation in particular how learning of these attributes may be related to observation of trainer behaviours. This is important research as the findings may guide the placement of trainees with particular trainers.

Further quantitative research is required to investigate surgical learning, both longitudinally, to determine learning curves over prolonged time periods and across multiple procedures as well as how pedagogic practice relates to learning. It would have been interesting to quantitatively investigate how more senior surgeons learn, when exposed to the pedagogic practices investigated in this thesis.

The other potentially rich research domain is simulation, and whether learning in the content domains outlined in this thesis, in isolation, proves beneficial, compared with learning in a fully contextualised, ‘realistic’ simulation environment.

7.9 Conclusions

This thesis outlines the findings of a large body of research work that has been undertaken over the course of 3 years of full-time study. The content themes and pedagogic processes outlined, have already provided me with helpful anchors for structuring formative assessment and feedback to surgical trainees, as well as helpful insights into my own learning.

I would assert that the most interesting output of this work has been making explicit that sensory semiosis (making sense of what the learner sees and feels) is one of the most important content areas of surgical learning. Sensory semiosis was found by this research to be learned through a process of co-construction between the trainer and trainee either through verbal exchanges between the two, or through physical-verbal exchanges if the trainee were in control of the surgical instruments. These findings have multiple different implications for teachers and learners as well as the profession.

However, I would assert that the most marked output of this period of post-graduate study has been the transformative change in the researcher, from a ‘clinician with an interest in education’ to a ‘surgical educator and educational researcher’.

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Appendices

Appendix A

Systematic literature review

A systematic literature review requires a narrow research question, so rather than exploring broadly what is currently known about postgraduate surgical learning in the operating theatre the researcher needed to pare down the question to allow careful definition of terms and systematic searching of databases.

There were 2 sub-questions:

- What does the literature tell us about content of postgraduate surgical learning in the operating theatre?
- What does the literature tell us about processes of learning utilised by surgical trainees in the operating theatre?

As a start point, the researcher chose to systematically review articles pertaining to the content of learning in the operating theatre. The rationale was to identify all published articles in which differences were found between fully qualified surgeons and post-graduate trainee surgeons. The researcher assumed that differences found between the two groups would be as a result of their learning experiences in the operating theatre. The rationale was that by illuminating the attributes in which there were objective differences between Consultants and trainees, light could be shed upon content areas of learning in the operating theatre.

The researcher set out to perform a systematic review according to guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (Liberati, Altman et al. 2009).

Search Strategy

A broad search of the English language literature was performed firstly in July 2010 and repeated in August 2012 using Ovid MEDLINE (1996 to October week 1 2012), EmBASE (1996 to October week 1 2012), PsychINFO (1987 to October week 1 2012). The search terms were established after a series of discussions between a medical educator (DN) and a surgeon in training (AC) and iterative cycles of searching honed the search terms as much as possible whilst ensuring that key articles were still retrieved.

Search fields used were abstract (ab) and title (ti). Text words with wildcards were used to systematically search the databases.

Literature Search Strategy through OVIDSP

1. Consultant$1.ab,ti
2. attending$1.ab,ti
3. faculty.ab,ti
4. teacher$.ab,ti
5. expert$1.ab,ti
6. residen$.ab,ti
7. trainee$1.ab,ti
8. junior doctor$1.ab,ti
9. learner$1.ab,ti
10. surg$.ab,ti
11. 1 or 2 or 3 or 4 or 5
12. 6 or 7 or 8 or 9
13. 10 and 11 and 12
14. limit 13 to (english language and humans and journal article)
15. limit 13 to comparative study (MEDLINE only)

Inclusion / exclusion criteria

A systematic approach to literature review requires strict inclusion and exclusion criteria to ensure that results are relevant to the research question. Many studies have found Consultant surgeons to be significantly faster than post-graduate surgical trainees at completing operations. Yet, instinctively we know that post-graduate surgical training is not solely about making the trainee faster at a procedure that they are already able to perform, it is also about the learning of that procedure. “A fast surgeon is not necessarily a good surgeon.” (Darzi, Smith et al. 1999) Time taken was not thought by the surgeon researcher to be an appropriate measure of skill and so all studies that reported only time taken were excluded from the review.

The researcher wished to identify domains where there were differences between fully trained surgeons and residents. She therefore chose to identify comparative studies in which other conditions were standardised or where other variables were controlled.

Inclusion criteria	**Exclusion criteria**
Empirical studies	Letters, comments, editorials, review papers
Postgraduate surgical trainees compared with Consultants	Medical students, physicians
	Expert / intermediate / novice categories
Attendings compared with residents	
Controlled trials	Studies only reporting time taken
General surgery	Patient outcome data
	Length of patient stay data
	Orthopaedic, vascular, endoscopy,

gynaecology, ENT, urology, plastics, cardio-thoracics, paediatric surgery

Two reviewers then screened the abstracts for inclusion (AC and AH). The full texts of these articles were then obtained. Conflicts between reviewers were subsequently discussed until 100% agreement was achieved on the final studies to be included in the review.

Data extraction

The following information was extracted from each study:

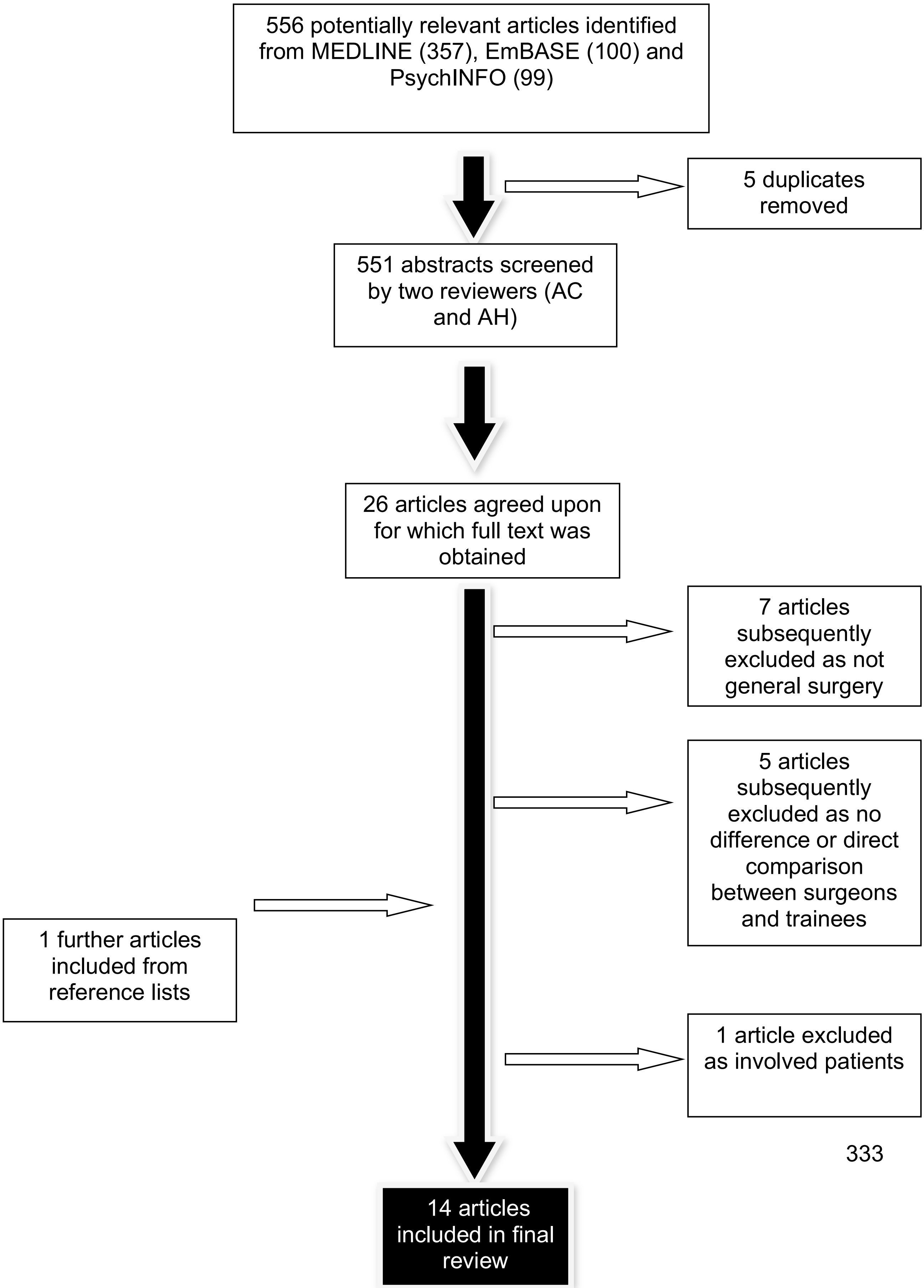
- First author
- Year of publication
- Study participants in each group (n)
- Skill / Attribute or task compared
- Level of significance (p value)

Results

The initial database search after limits were applied yielded 357 articles MEDLINE, 100 articles EmBASE and 99 articles PsychINFO. After duplicates were removed this returned 551 articles for further consideration.

Selection of articles for review

CONSORT diagram illustrating flow of articles in study



Author	Year	Participants	Skill / Attribute	Significance
Coverdill (Coverdill, Adrales et al. 2006)	2005	Surgeons n = 146 Trainees n = 113	Attitude to work hour restrictions	<0.05
Datta (Datta, Bann et al. 2004)	2004	Surgeons n = 9 Trainees n = 25	OSATS score (7 item)	<0.01
Datta (Datta, Mackay et al. 2001)	2001	Surgeons n = 13 Trainees n = 38	ICSAD Time taken ICSAD Path length ICSAD Number of movements	<0.001 p = 0.21 <0.001
Dubrowski (Dubrowski, Sidhu et al. 2005)	2005	Surgeons n = 7 Trainees n = 6	Wrist rotation Average force Force-rotation initiation time Suturing time	<0.01 <0.01 <0.01 <0.01
Francis (Francis, Hanna et al. 2002)	2002	Surgeons n = 20 Trainees n = 20	ADEPT Instrument error rate Time taken ADEPT Task completion score	0.007 p= 0.42 p = 0.4
Gerdes (Gerdes, Kahol et al. 2008)	2008	Surgeons n = 9 Trainees n = 5	Cognitive ability (attention, visio-spacial ability, inter-modal transfer) after sleep deprivation	<0.05
Jack (Jack, Kenkare et	2010	Surgeons n = 61	Learning preferences Kolb’s learning	<0.01

al. 2010)		Trainees n = 96	style inventory	
Kobayashi (Kobayashi, Jamshidi et al. 2011)	2011	Surgeons n = 5 Trainees n = 21	MISTELS Peg transfer	<0.01
			MISTELS Pattern cut	<0.01
			MISTELS Extra-corporeal knot	<0.01
			MISTELS Intra-corporeal knot	<0.01
Oostema (Oostema, Abdel et al. 2621)	2008	Surgeons n = 3 Trainees n = 19	Time	<0.01
			Path length	<0.01
			Smoothness	<0.01
Pellen (Pellen, Horgan et al. 2009)	2009	Surgeons n = 18 Trainees n = 61	ProMIS laparoscope orientation	p = 0.003
			ProMIS sharp dissection - accuracy	p = 0.261
Stefanidis (Stefanidis, Scerbo et al. 2007)	2007	Surgeons n = 3 Trainees n = 9	Laparoscopic suturing	<0.001
Swanson (Swanson, Antonoff et al. 2010)	2010	Surgeons n = 229 Residents n = 39	Myers-Briggs Type Indicator	<0.01
Woodrum (Woodrum, Andreatta et al. 2006)	2006	Surgeons n= 5 Trainees n = 20	LapSIM time	<0.05
			LapSIM Pathlength	<0.05
			LapSIM Errors	<0.05

Assessment of adequacy of search parameters

In December 2012 a systematic review was published examining the construct validity of different motion analysis tools (Mason, Ansell et al. 2012). Construct validity is the ability of the test to differentiate between novices and experts. Whilst the researcher's systematic review collated studies that demonstrated differences between fully trained surgeons and trainees (a subtle difference from experts and novices), she expected there to be significant overlap in the literature papers identified.

Of the 12 papers that reported construct validity identified by Mason et al. all twelve were identified by the initial database search strategy. However, there was an overlap of only three papers into the final review (Francis, Hanna et al. 2002) (Oostema, Abdel et al. 2008) (Pellen, Horgan et al. 2009) as many of the papers included by Mason et al. categorised novices and experts (Moorthy, Munz et al. 2004) (Smith, Torkington et al. 2002) or did not perform a sub-group analysis, comparing surgical trainees with Consultant surgeons (Pellen, Horgan et al. 2009).

Assessment of study quality

All of the comparative studies that measured surgical skills objectively, included only small sample set numbers, especially in the fully qualified surgeon group (n between 3 and 20). Such small numbers in one of the study groups could easily lead to bias of results. The researcher became particularly concerned about the validity of some of the study findings due to incongruity of findings between the studies. For example Datta et al (Datta, Mackay et al. 2001) use the ICSAD device and found time taken and number of movements to be significantly different between residents and fully qualified surgeons, but not hand path-length; Oostema (Oostema, Abdel et al. 2621) and Woodrum (Woodrum, Andreatta et al. 2006), however, find hand path-length to be significantly different.

The studies in which there are larger numbers, are those which captured self-report data – perceptions or preferred learning styles. These differences have not been found through objective testing but represent perceptions of the two study groups.

Data synthesis

The majority of the articles that were found, through systematic literature review pertained to differences in motor skills – economy and efficiency parameters such as time taken and path-length. Further synthesis did not seem appropriate due to the diversity of different simulators and conditions in which these studies were undertaken.

Critique of systematic literature review

This systematic approach to literature review required strict inclusion and exclusion criteria. To avoid potential biases, only studies that controlled for, or standardized variables, were included. This led to the exclusion of any studies conducted in the workplace, due to the difficulties of standardization of the working conditions and also the exclusion of all studies involving individual patients due to patient variability. The only studies included in this systematic literature review were conducted in strictly controlled conditions, namely the simulation laboratory.

The researcher realised that using this approach to making explicit what is learned, assumes that any differences found, between Consultant surgeons and trainees, were as a result of their surgical training, rather than life experiences, generational factors or additional maturity. It did not discriminate whether these skills, attributes or superior task performance had been learned in the operating theatre, in other hospital settings or through life experiences in general.

The researcher also appreciated that the findings of this exploratory systematic review were biased towards attributes that were quantifiable; for which metrics could be obtained from the simulator itself, or for which a scoring system already existed. Using systematic literature review to make explicit how post graduate surgical trainees learn in the operating theatre or what factors affect their learning did not seem appropriate as both of these are inductive questions.

The researcher therefore concluded that the strict inclusion criteria and narrowness of focus led to limitations upon the usefulness of the review, and its subsequent validity, and that systematic review of the literature may not be the most appropriate method of setting the scene for the reader. A narrative review seemed more appropriate.

Appendix B

Interview topic guide

Thank you for agreeing to take part in this interview. It will probably take between 30 and 45 minutes - is that all right?

I'm doing a PhD with Dr. Roger Kneebone and Professor George Hanna looking at postgraduate surgical teaching and learning in the operating theatre and I'm interested in obtaining the views of teachers and learners.

I'd like to record our conversation - hope that's OK with you? The interview will then be transcribed for analysis - What you say will be anonymous and un-attributable to you, although we plan to publish the outcomes from these interviews (using quotations).

<u>Introductory questions</u>

I am interested in teaching and learning in the operating theatre – are you involved in these activities? How?

<u>Key questions</u>

Surgical training inevitably involves time spent in the operating theatre – *what* do you think post-graduate surgical trainees are taught in the operating theatre? *What* have you been taught? *What* do you teach?

What do you think post-graduate surgical trainees learn in the operating theatre?

Thinking about your time in theatre *how* does teaching happen, by this I mean what practical ways have you experienced or used?

Which ways of teaching have you found to be most effective?

I would like you to think about your time in theatre and ask you *how* do you think learning happens, *how* have you learnt your skills?

What ways of learning do you think are most effective?

What factors do you think affect teaching in theatre, perhaps think about quantity of explicit teaching and factors that affect the quality of the teaching?

What factors do you think affect learning in theatre?

What do you think are the advantages are to teachers of teaching in the operating theatre?

What do you think the advantages are to learners of being taught in the operating theatre?

What are the benefits to ‘the system’ by which I mean the NHS of teaching in theatre?

What are the difficulties for the teacher of teaching in the operating theatre?

What are the difficulties for learners of learning in the operating theatre?

What are the constraints of the system to teaching happening in the operating theatre?

What are your thoughts about learning with simulation?

Closing question

Anything else important that you would like to comment on that you think has been overlooked?

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Appendix C

Mapping Educational Activity in the Operating Theatre

Principal Investigator: Dr Roger Kneebone

Participant Information For Interview Study

Version 1.0. 20.08.2010

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

The project aims to investigate teaching and learning in the operating theatre. We want to find out what people are learning in the operating theatre, how they learn it and what factors affect their learning. We believe it is important to investigate this before we can think about how clinical education could be improved.

Why have I been chosen?

Over the course of the project we will be collecting data from a number of different teachers and learners. These might be surgical staff, anaesthetic staff, nursing staff or operating department personnel. We would like to study a wide range of different teachers and learners.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. You are still free to withdraw at any time and without giving a reason. A decision to or not to take part, will not affect you in any way.

What will happen to me if I take part?

We would like to talk to you about your perceptions of teaching and learning in the operating theatre. The interview will take around 30 – 45 minutes and will be audio-recorded. The audio-recording will then be transcribed and this will be analysed. What you say will be anonymous and un-attributable to you, although we plan to publish the outcomes from these interviews (using quotations).

What are the possible disadvantages and risks of taking part?

We want to ensure that third parties cannot get hold of the data we collected and use them in appraisal or journalism. Therefore, data are protected through encryption of data and stored on password protected USB sticks which are kept in secure offices.

What are the possible benefits of taking part?

The primary benefits from this work are for the advancement of scientific understanding of teaching and learning in the Operating Theatre. The availability of these data may lead to improvements in clinical educational practice, here at the hospital where you work and elsewhere.

What happens when the research study stops?

As this is a non-clinical, non-interventionist research, termination of the study does not affect you in any way.

What if something goes wrong?

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Principal Investigator, Roger Kneebone. The normal National Health Service complaint complaints mechanisms are also available to you. If you are still not satisfied with the response, you may contact the Imperial AHSC Joint Research Office.

Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you will have your name and address removed so that you cannot be recognised from it. Procedures for handling, processing, storage and destruction of data are compliant with the Data Protection Act 1998. In cases of litigation we may be legally obliged to disclose our recordings.

What will happen to the results of the research study?

The results of the study will be presented at conferences and published in journals focused on medical education and work-based learning, probably in the years 2010-2013. You can request copies of these presentations and publications. The audio-recordings will only be played and presented to members of the research team, but written, anonymized transcripts of the audio-recordings may be presented and published. We always use pseudonyms to conceal your identity and workplace.

Who is organising and funding the research?

The research is based at Imperial College London and also approved by Imperial College NHS Trust. The London Deanery and the Royal College of Surgeons fund the research.

Who has reviewed the study?

This study was given a favourable ethical opinion for conduct in the NHS (or private sector) by St Mary's Research Ethics Committee (Ref nr 10/H0712/1).

Contact for Further Information

Please email alexandra.cope07@imperial.ac.uk if you'd like to know more about the project. You can call her on 07968212869.

What do I need to do if I would like to participate?

If you would like to participate in the study, please sign the attached consent form and return to Alexandra Cope. We will give you a copy of the written information and signed Informed Consent form to keep.

Thank you for taking part in this study.

Imperial College
London

Mapping Educational Activity in the Operating Theatre

Informed Consent For Interview Study

Version 1.0. 20.08.2010

Principal Investigator: Roger Kneebone

r.kneebone@imperial.ac.uk

Please initial box

1	I confirm that I have read and understand the participant information sheet dated 20.08.2010, version 1.0 for the above study and have had the opportunity to ask questions which have been answered fully.	
2	I understand that my participation is voluntary and I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.	
3	I give permission to:	
	be audio-recorded during an interview study.	

4	The compensation arrangements have been discussed with me.	
5	I agree to take part in the above study.	

Name of Subject	Signature	Date

Name of Person taking consent	Signature	Date

Principal Investigator	Signature	Date

1 copy for subject; 1 copy for Principal Investigator

Appendix D

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Pedagogy of the Operating Theatre Interview Study

Study Candidate Number	
Gender	
Age	
Number of years qualified	
Place of work	
Grade	
Specialty	
Subspecialty (if applicable)	
Any educational roles eg. clinical supervisor, educational supervisor, programme director?	
Any formal training in teaching e.g. RCS Training the Trainers, Masters in Education	
Do you receive teaching in theatre?	
Overall, how satisfied are you with the teaching that you receive? (0-5)	0=Very dissatisfied 3=neither satisfied or dissatisfied 5= Very satisfied
Do you learn in theatre?	
Overall, how satisfied are you with your learning in theatre? (0-5)	0=Very dissatisfied 3=neither satisfied or dissatisfied 5= Very satisfied
Do you teach in theatre?	
Overall, how satisfied are you with the teaching you do in theatre? (0-5)	0=Very dissatisfied 3=neither satisfied or dissatisfied 5= Very satisfied

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Mapping Educational Activity in the Operating Theatre

Principal Investigator: Dr Roger Kneebone

Participant Information Sheet

Version 3.0. 18.02.2010

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

The project aims to map the operating theatre as a site of teaching and learning. We want to find out how theatre staff learn to do their work, through teaching each other or simply by watching other people doing their work. We believe it is important to investigate this before we can think about how clinical education could be improved.

Why have I been chosen?

We aim to include all theatre staff and students physically co-present during the operations which we would like to observe. The operations which we like to observe include general and GI surgery. Over the course of the project we hope to observe about 40 different staff members, including nurses, anaesthetists, surgeons, ODPs and theatre support workers.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?

We would like to carry out observations in operating theatres. That means that we might be looking at the work you're doing and the teaching and learning you may be involved in. We may ask you some questions afterwards. You will not be observed for more than 15 hours, spread over no more than 5 operations, in the period between 1.02.10 and 1.09.12. We would also like to make recordings. There are three types of recordings we'd like to make: field notes, audio-recordings and video-recordings. Field notes are the notes which we write down in a notebook while we are observing. Audio-recordings capture what is said by people who are within about an arm length's distance from the microphone. Video-recordings capture the hand movements of the surgeons and scrub nurses standing at the operating table. The camera we use is built in the operating light and focused on the operative field. The other video source we use is the view from the laparoscopic camera. If we want to make audio and/or video-recordings we will kindly ask permission for that before the start of the operation.

What do I have to do?

There is nothing you need to do. We are interested in the work in theatres as it happens. We do not intervene in the work in any way.

What are the possible disadvantages and risks of taking part?

We want to ensure that third parties cannot get hold of the data we collected and use them in appraisal or journalism. Therefore, data is protected through encryption of data and stored on password protected USB sticks which are kept in secure offices.

What are the possible benefits of taking part?

The primary benefits from this work are for the advancement of scientific understanding of teaching and learning in the Operating Theatre. The availability of this data may lead to improvements in clinical educational practice, here at the hospital where you work and elsewhere.

What happens when the research study stops?

As this is a non-clinical, non-interventionist research termination of the study does not affect you in any way.

What if something goes wrong?

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Principal Investigator, Roger Kneebone. The normal National Health Service complaint complaints mechanisms are also available to you. If you are still not satisfied with the response, you may contact the Imperial AHSC Joint Research Office.

Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you will have your name and address removed so that you cannot be recognised from it. Procedures for handling, processing, storage and destruction of data are compliant with the Data Protection Act 1998. In cases of litigation we may be legally obliged to disclose our recordings.

What will happen to the results of the research study?

The results of the study will be presented at conferences and published in journals focused on medical education and work-based learning, probably in the years 2010-2013. You can request copies of these presentations and publications. The audio-recordings, video-recordings and field notes will only be played and presented to members of the research team. Video-recordings of hand movements and transcripts of audio-recordings may also be presented in the context of scholarly publications, academic symposia, university classes, and professional training activities. Thus, audio-recordings will not be played in public, but written, anonymized transcripts of the audio-recordings may be presented and published. We always use pseudonyms to conceal your identity and workplace.

Who is organising and funding the research?

The research is based at Imperial College London and also approved by Imperial College NHS Trust. The London Deanery and the Royal College of Surgeons fund the research.

Who has reviewed the study?

This study was given a favourable ethical opinion for conduct in the NHS (or private sector) by St Mary's Research Ethics Committee (Ref nr 10/H0712/1).

Contact for Further Information

Please email Jeff Bezemer (j.bezemer@imperial.ac.uk) or Alex Cope (Alexandra.cope07@imperial.ac.uk) if you'd like to know more about the project. You can call them on 07910174556.

What do I need to do if I would like to participate?

If you would like to participate in the study, please sign the attached consent form and send it to Jeff Bezemer or Alexandra Cope using the return envelope. We will give you a copy of the written information and signed Informed Consent form to keep.

Thank you for taking part in this study.

Imperial College London

Mapping Educational Activity in the Operating Theatre

Informed Consent Form

Version 2.0. 4.02.2010

Principal Investigator: Roger Kneebone

r.kneebone@imperial.ac.uk

Please initial box

1	I confirm that I have read and understand the subject information sheet dated 18.02.2010, version 3.0 for the above study and have had the opportunity to ask questions which have been answered fully.	
2	I understand that my participation is voluntary and I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.	
3	I give permission to	
A	be observed when I am working in theatre.	

B	be recorded in written field notes when I am working in theatre.	
C	be audio-recorded when I am working in theatre.	
D	be video-recorded (light-handle camera or the laparoscopic camera view) when I am working in theatre.	
4	The compensation arrangements have been discussed with me.	
5	I agree to take part in the above study.	

Name of Subject	Signature	Date

Name of Person taking consent	Signature	Date

Principal Investigator	Signature	Date

1 copy for subject; 1 copy for Principal Investigator

Appendix F

Objective Structured Assessment of Technical Skills (OSATS)

Variable	Rating					
Respect for Tissue		**1**	**2**	**3**	**4**	**5**
	N/A	Often used unnecessary force on tissue or caused damaged by inappropriate use of instruments		Careful handling of tissue but occasionally caused inadvertent damage		Consistently handled tissues appropriately, with minimal damage
Time and Motion		**1**	**2**	**3**	**4**	**5**
	N/A	Many unnecessary moves		Efficient time and motion, but some unnecessary moves		Economy of movement and maximum efficiency
Instrument Handling		**1**	**2**	**3**	**4**	**5**
	N/A	Repeatedly makes tentative or awkward moves with instruments		Competent use of instruments, although occasionally appeared stiff or awkward		Fluid moves with instruments and no awkwardness
Knowledge of Instruments		**1**	**2**	**3**	**4**	**5**
	N/A	Frequently asked for the wrong instrument or used an inappropriate instrument		Knew the names of most instruments and used the appropriate instrument for the task		Obviously familiar with the required instruments and knew their names
Use of Assistants		**1**	**2**	**3**	**4**	**5**
	N/A	Consistently placed assistants poorly or failed to use assistants		Good use of assistants most of the time		Strategically used assistant to the best advantage at all times
Flow of operation and Forward Planning		**1**	**2**	**3**	**4**	**5**
	N/A	Frequently stopped operating or needed to discuss next move		Demonstrated ability for forward planning with steady progression of operative procedure		Obviously planned course of operation with effortless flow from one move to the next
Knowledge of Specific Procedure		**1**	**2**	**3**	**4**	**5**
	N/A	Deficient knowledge. Needed specific instruction at most operative steps		Knew all important aspects of the operation		Demonstrated familiarity with all aspects of the operation

CAT
Competency Assessment Tool
©by Imperial College London

Competency Assessment Tool (CAT) for Laparoscopic Cholecystectomy

Date: ....../......./...... Participant code number: .... Assessor..

TASK	INSTRUMENT USE		TISSUE HANDLING		NEAR MISSES AND ERRORS		END-PRODUCT QUALITY	
EXPOSURE Adequate exposure of cystic artery and cystic duct	Insertion of ports:		Incision of peritoneum at Calot's triangle		This task was performed with:		Were the cystic artery and duct identified?	
	1 ☐ Hazardous	Dangerous technique (not visualised), hazardous or wrong position	1 ☐ Uncoordinated	Stiff and uncontrolled movements, overshooting	1 ☐ Damage	Macroscopic perforation, burn or grasp marks, bleed	1 ☐ No	Anatomical structures insufficiently identified
	2 ☐ Inadequate	Incompetent (several attempts) or ergonomically poor position	2 ☐ Hesitant	Controlled movements, but hesitant and inefficient.	2 ☐ Near miss(es)	Bloody dissection, too close to sensitive structures	2 ☐ Vaguely	Main structures identified, wrong plane, covered by tissue
	3 ☐ Safe	Safe insertion and ergonomically good position	3 ☐ Skilful	Smooth, controlled and meaningful movements.	3 ☐ No damage	No damage to bowel, major blood vessels	3 ☐ Yes	Main structures identified
	4 ☐ Masterly	Masterful insertion, ideal positioning	4 ☐ Versatile	Masterful instrument use, effective movements.	4 ☐ Tissue-protective	Performed with best possible tissue protection	4 ☐ Anatomical	Crystal clear demonstration of anatomy
	x ☐ N/A	Not applicable	x ☐ N/A		x ☐ N/A		x ☐ N/A	
CALOT'S TRIANGLE DISSECTION Safe dissection of cystic artery and duct	Use of haemostatic tool (clip applier/ diathermy/ stapler):		Dissection of artery and duct:		This task was performed with:		How was the management of the cystic pedicle?	
	1 ☐ Hazardous	Insufficient view, uncontrolled movements	1 ☐ Hazardous	Insufficient view, uncontrolled movements	1 ☐ Damage	Macroscopic perforation, burn or grasp marks, bleed	1 ☐ Uncontrolled	Duct/ artery not secured or leakage/ bleeding
	2 ☐ Laborious	Awkward and repeated unnecessary attempts	2 ☐ Inefficient	Several, hesitant cuts	2 ☐ Near miss(es)	Bloody dissection, too close to sensitive structures	2 ☐ Imprecise	Duct/ artery not accurately secured before dissection
	3 ☐ Efficient	Instrument accurately placed and engaged	3 ☐ Safe	Safe dissection under view	3 ☐ No damage	No damage to bowel, blood vessels or biliary system	3 ☐ Safe	Duct/artery safely secured before dissection
	4 ☐ Masterly	Highly efficient and safe use of instrument	4 ☐ Efficient	Smooth and efficient dissection	4 ☐ Tissue-protective	Performed with best possible tissue protection	4 ☐ Flawless	Duct/artery perfectly secured before dissection
	x ☐ N/A		x ☐ N/A		x ☐ N/A		x ☐ N/A	
RESECTION Safe removal of gallbladder d in correct plane between GB and liver	Use of graspers/ dissection tools:		Use of non-dominant hand (NDH):		This task was performed with:		Was the gallbladder safely removed from the liver bed?	
	1 ☐ Uncoordinated	Stiff and uncontrolled movements, overshooting	1 ☐ Stagnant	NDH does not move	1 ☐ Damage	Macroscopic perforation, burn or grasp marks, bleed	1 ☐ Wrong plane	Resulted in biliary spillage, wrong tissue plane
	2 ☐ Hesitant	Controlled movements, but hesitant and inefficient.	2 ☐ Lagging	NDH is adjusting with delay or without efficiency	2 ☐ Near miss(es)	Bloody dissection, too close to sensitive structures	2 ☐ Inconsistent	Not consistently in correct plane, minor spillage
	3 ☐ Skillful	Smooth, controlled and meaningful movements.	3 ☐ Meaningful	Meaningful adjustment of NDH to improve exposure	3 ☐ No damage	No damage to bowel, blood vessels or biliary system	3 ☐ Satisfactory	Correct plane
	4 ☐ Versatile	Masterful instrument use, effective movements.	4 ☐ Forward planning	Strategic and intelligent adjustments by NDH	4 ☐ Tissue-protective	Performed with best possible tissue protection	4 ☐ Ideal	Correct plane, highly efficient
	x ☐ N/A		x ☐ N/A		x ☐ N/A		x ☐ N/A	

Version 3, 25/08/2010
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