Educational journeys to colorectal surgical expertise: The place and impact of simulation training

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Acknowledgements

I dedicate my thesis to the late, Mr Brian Rees OBE. His natural disposition to inspire those around him to be passionate about the advancement of surgical technology and more defined standards has left a lasting impact on me. I have been privileged to 'own the job' of surgical training because of his encouragement.

I want to thank my longsuffering wife and children for their patience and fortitude while I've been quite singular at times in trying to get this done. Nathan, you were not even born when I started this journey and yet you are now eight years old!

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At the time of writing, surgical training with simulation is moving at a faster pace than ever, incorporating more technologies than ever before. The outcome of this research will hopefully speak to that progress, to not lose sight of the fact that surgical simulation training possesses a culture all of its own. The shape of which in turn, defines the culture of surgical practice. The language of colorectal surgery is informed through the emerging dominance of clinical training away from the hospital. It is my hope that this work will extend and acknowledge that how we interact as trainers and educators to trainees, echoes in operating practice.

Abstract

Introduction: This thesis explores how surgical trainees engage in simulation-based training (SBT) as part of a structured programme and how they relate their training to the practice of laparoscopic colorectal surgery in the operating theatre (OT). Both these environments have their own sociocultural fingerprint, that is, social, cultural *and* cognitive patterns of activity, with a language and discourse unique to them. Conventional insights on how SBT benefits surgical practice outcomes are indicated by improved individual performance in specific technical tasks. In contrast, this thesis explores the strength of the social discourse in which such learning is situated, which mediates SBT to the OT. The research questions are:

- Through what social mechanisms are the complex clinical skills of surgery learnt through the Welsh Laparoscopic Colorectal Training Scheme (WLCTS), and translated into the operating theatre context?
- How do laparoscopic colorectal trainees perceive the value of and make their training meaningful?
- How could the learning theories discussed, inform a framework which can both acknowledge the social experience of simulation in facilitating the negotiation of learning and enable the professional development of the trainees?

Deep learning is a social exercise in the creation of 'semiotic' signals through negotiating multiple channels of social and material activity. Distributed cognition (DCog) and Cultural-Historical Activity Theory (CHAT) are employed as organising theoretical principles.

Methodology: Eight participants were observed across two hemicolectomy courses in the Welsh Laparoscopic Colorectal Training Scheme, where task completion required working in pairs. Over 11 hours of video data were analysed for trainee interactions across the simulated operating table. Scores were assigned to trainees' prior experience and changes in task complexity and partial regression analysis was used to explore relationships. Nine guided conversation-style interviews were conducted with colorectal trainees immediately after the courses, followed again six to eight months later with seven participants, where they described how they made sense of their co-participation in simulation within their operating practice. Abductive thematic analysis was used on a total of 10½ hours of transcript data, to identify key themes including semiotic signals, negotiated activity and mental rehearsal as a phase between simulation training and operating.

Findings: Task complexity was related to task completion time. The shared prior experience of trainees related to improved task completion times rather than individual experience. Prior

experience was linked to the way interactive social cues were utilised. Task complexity was linked to the way material artefacts were exchanged between trainees. Meaningful knowledge was acquired and exchanged through the learning design of graduated task activity, model and interaction fidelity, instrument sharing and verbal and non-verbal transactions. Such 'negotiated knotworking', as an extension of CHAT, is illustrated by the interactions of these social and material activities. SBT proved valuable in improving the capacity of trainees to reflect and mentally construct the operative context, which becomes important in rehearsing clinical activity.

Conclusions: The interaction of social and material exchanges during shared activity is where trainees make sense of their technical skills. Because such shared activity is present in both simulation and operation, simulation needs to provide not just task fidelity, but also an opportunity for social and material interaction in a way that is professionally recognisable in the OT. By utilising co-constructed activity and making use of multiple material and social interactions, the WLCTS enabled the development of surgical language and 'semiotic' association of mutual colorectal artifacts. Through mental rehearsal, trainees prepared, planned and made informed decisions. Sharing of prior experience signals the importance of co-dependence in role and activity negotiation. Because of these, socially organised learning theory which contains the operation activities within SBT and OT are suitable candidates for a learning framework.

Contents

Glossary

30^{O} scope	A laparoscopic device used in keyhole surgery for viewing inside the abdomen at an angle 30^{O} to the perpendicular.
ACT-R	Adaptive control of thought – rational; a theoretical cognitive model which considers new knowledge, either declarative or procedural to be broken down into irreducible units of learning. Gradually, through repetition and reflection, units are chunked together in a consolidation phase.
Anastomosis	The surgical (re-)connection of two luminal tissue specimens, in this case, either the small intestine or large intestine to provide continuity.
Appendicectomy	The removal of the appendix by surgery.
BSS	Basic Surgical Skills.
CCT	Certificate of completion of training.
CHAT	Cultural-Historical Activity Theory.
Cognitive dissonance	A psychological notion referring to the mental discomfort or tension that arises when a person holds two or more conflicting beliefs, attitudes, values, or expectancies. This discomfort motivates the individual to resolve the inconsistency to reduce psychological stress (Festinger 1962).
Colorectal	The surgical specialty is concerned with the lower abdomen extending from the terminal ileum to the anal sphincter.
Collectivism	Defined in this case, as a multidisciplinary social contract to achieve a common goal in the operating theatre. The social agreement towards a surgical outcome constitutes a form of collective. This behaviour is based on a social interaction which results from a phenomenon where groups self-organise around a common task (Park 1967; Amin and Roberts 2006; Moussaïd et al. 2013).
CoP	Community of Practice.
CSES	Core Skills in Emergency Surgery.
CT1-CT2	Core Training, levels 1 and 2.
DCog	Distributed cognition / cognitive distribution.
EBM	Evidence-based medicine.
EWTD	European working time directive.
Fidelity	The degree to which a context or simulation models a real context or environment.
Intracorporeal suturing	Suturing inside the body via keyhole surgery using specially designed needle holders.

Immersion training	An educational approach which places the learner directly into the environment where that learning will be applied.
Knotworking	Also, negotiated knotworking. A metaphor characterised "*by a pulsating movement of tying, untying and re-tying together otherwise separate threads of activity. The tying and dissolution of a knot of collaborative work is not reducible to any specific individual or fixed organisational entity as the centre of control. The centre does not hold. The locus of initiative changes from moment to moment with a knotworking sequence*" (Engeström 2018, p. 86).
Laparoscopic cholecystectomy	Abdominal keyhole surgery to remove the gallbladder.
Laparoscopy / Laparoscopic Surgery	Minimally invasive keyhole surgery of the abdomen using tiny incisions to insert a specialised camera and instruments. The procedure is viewed on a display unit.
LapCo	The National Training Programme in Laparoscopic Colorectal Surgery developed in England in parallel to the WLCTS in Wales.
Learning curve	An arbitrary scale of competence acquisition over time spent in a task-learning activity. The curve typically rises sharply before slowing to a plateau over time. Tasks that take relatively longer to master typically show more prolonged learning curves over those that take less time, where the rise is sharper. This is in direct contradiction with the incorrect common parlance of the "steep learning curve" to indicate a complex and arduous learning process.
Left-side / right-side	Reference to the side of the patient's abdomen which undergoes the colorectal procedure, usually regarding the colon.
MIS/MAS	Minimally invasive/minimal access surgery.
MMC	Modernising Medical Careers.
Morbidity	Physiological deviation from normative values, usually the degradation of health.
Mortality	The state of being subjected to death.
NICE	The National Institute for Health and Care Excellence.
Non-verbal communication / Non-verbal cues	Strictly, non-verbal communication refers to the use of non-verbal cues to convey a message, while non-verbal cues are the specific behaviours or actions contributing to non-verbal communication (Knapp et al. 2013). This thesis uses these terms interchangeably in referring to gestures exchanged during simulated surgical tasks, though the distinction between the two terms is acknowledged (Guerrero et al. 2018, pp. 77-78)
OSATS	Objective structured assessment of technical skills.
OT	Operating theatre.

Preceptorship	A structured, supportive period of transition from learning to applying a complex skill that requires a long and rigorous period of training. A preceptor is an expert professional who takes the *de facto* position of educator and facilitator, usually during the activity being learnt by a trainee. Preceptorship can be defined as *''an individualised teaching-learning method in which each student is assigned to a particular preceptor...so she [or he] experiences day-to-day practice with a role model and resource person immediately available within the clinical setting''* (Chickerella and Lutz 1981, p. 107).
PRHO	Pre-registration house officer. This terminology is not in current use, having been replaced by F1 (indicating foundation year 1). Junior house officers are now denoted by F2.
RCS	Royal College of Surgeons.
Resection	The excision of a diseased segment of tissue between two healthy segments which are then joined together. In resection of the bowel, the diseased segment is removed and the healthy lumen is joined together to allow a return to normal function.
Roeder knot	A specialised type of one-way slip knot used to ligate vessels in keyhole surgery.
SBT	Simulation-based training/simulation training.
Semiotic	Strictly, the study of signs and the development of meaning within them. Within a given environment, any object or person will take on meaning and language specific to *that* environment and its meaning is importantly, mutually understood by all actors within it observing the same 'sign'.
SHO	Senior house officer. This terminology is not in current use, having been replaced by CT1 and CT2 (Core trainee year 1 and 2).
Sociocognitive	The way the mind processes information for learning through the social exchanges in an activity; how individuals make sense of their own participation with others and events around them. Also, the content and structure of social knowledge (Blanchard-Fields 2001; Carley 2001).
Sociocultural	Related to the distinct groups of people in society and their habits, traditions and beliefs.
ST3-ST7	Specialist training levels 3 to 7.
WLCTS	Welsh Laparoscopic Colorectal Training Scheme.
ZPD	Zone of proximal development.

1 Introduction: The Welsh Laparoscopic Colorectal Training Scheme

This thesis explores how surgical trainees engage in simulation-based training (SBT) as part of a structured programme and how they relate their training to the practice of laparoscopic colorectal surgery in the operating theatre (OT). Both these environments have their own sociocultural fingerprint. That is, social, cultural *and* cognitive patterns of activity, with a language and discourse unique to them. This thesis seeks to offer an insight into first, the social mechanisms by which surgical skills are negotiated into trainees' practice; second, how surgical training becomes meaningful to the trainees; and third, this work constructs a model to help understand how surgical skills are transferred from simulation to proficient practice. I explore the interplay of cultural-historical activity theory (CHAT) and distributed cognition (DCog) as an organising principle to achieve this. From my personal position as an educationalist technician in surgical simulation, I have been directly involved in setting up, delivering and managing surgical simulation courses. It is this position that drove my motivation to undertake this study.

The notion of a pathway is apt; the current state of surgical training is a modularised, sequential process which suits a linear, stepwise approach (Cabada et al. 2009; Intercollegiate Surgical Curriculum Programme 2018). The gradual acquisition of surgical competence by surgical trainees in a modularised fashion could determine their perceived professional value, based on how far along the steps they are (Briers 2010). Surgical trainees begin their journey by having to establish their credibility through their aptitude (Bishawi and Pryor 2014; Royal College of Surgeons of England 2018). This is usually begun by attending the intercollegiate Basic Surgical Skills (BSS) course. The end point of the pathway is marked by a certificate of completion of specialist training (CCT). In reality, the pathway is not a seamless transition of stages linking one part of training to another. Rather, the process is fragmented by non-linear intersections of learning steps and approaches. This is problematic; there is no unity of learning approach from one transition to the next. To clarify this point, in Wales, individual surgical trainees access a range of diverse mandatory and optional courses which suit their own perceived training needs. Skills courses often rely on traditional educational theories based around "see one, do one, teach one" (Kotsis and Chung 2013) and psychomotor skills acquisition (Fitts and Posner 1967). These drive the notion that "Halstedian"[1]-style apprenticeship is still applicable to frameworks envisaged by a stable operating team working environment (Hamdorf

[1] William Halsted, a U.S. surgeon, created hospital 'residencies' for training surgeons where effective surgical practices were passed on to a wider trainee cohort via the operating table.

and Hall 2000). More recent training courses focussing on laparoscopic surgery accommodate experiential and andragogic learning frameworks (Rogers 1969; Knowles 1984). To a greater or lesser extent, these intersections within the learning process contribute to the way meaning is made to course participants. In brief, the process of making meaning is how people understand and perceive themselves and others in activities in which they are involved (Ignelzi 2000) and in learning, what knowledge they ascribe to signs and processes in an activity (Thibault 2003).

1.1 Overview

In this chapter, I introduce the tension created by the rise of SBT in the face of changes to working and training time, and opportunities for clinical practice in the OT. I explain the difficulties surrounding approaches to measuring the impact of simulation in clinical skills acquisition. Having introduced the notion that SBT has empirical support, I then place it within a historical context, arguing that SBT has arisen as a consequence of policy and sociocultural shifts. A cursory discussion on the challenge of exploring the SBT impact from a surgical outcome standpoint, problematises the heterogeneity involved in trying to dissect the contributing factors which might explain outcomes arising from the acquisition of surgical skills. The historical outline also details the rise of training in laparoscopic surgery which served as a springboard for the development and design of the Welsh Laparoscopic Colorectal Training Scheme (WLCTS). A summary of the introduction provides an entry point into the literature review, which I begin with a discussion of learning theories involved in SBT. I then conclude by outlining the chapter structure comprising this thesis.

1.2 Simulation as a tool for surgical training

Since the acquisition of psychomotor surgical skills is a defining component of surgical identity formation (Pratt et al. 2006), simulation must be a key element of this process. Skills are transferred from SBT into the OT (Hamdorf and Hall 2000), but their contribution is hard to quantify. Moreover, not all SBT provides equal fidelity; taking an individual simulation and analysing what skills transfer has taken place is impossible without de-contextualising the kind of learning that participants have been exposed to and further, what individuals have taken from engaging in that learning experience (Fry et al. 2011). Some cognitive dissonance may exist among surgical trainees because of the difference between their expectations of the learning pathway and the experience when they are participating in it (Festinger 1962; Homer et al. 2000). As practise and time allowed for training are now more limited than in previous years, SBT assists the trainees in achieving a standard clinical competence. Formal training opportunities outside of the OT are becoming increasingly important and targeted (Greenaway 2013). Still, some studies have indicated concern that decreased training time results in reduced competency (Canter 2011; Morrow et al. 2013; Hoffmann et al. 2017). A

separate policy body suggested the bigger concern is that there have been reduced opportunities for experience leading to proficiency (Independent Working Time Regulations Taskforce 2014). The simulated environment and the OT diverge; the patient forms part of the clinical learning context, of which the latter has a greater number of variables that are only appreciated with experience. Trainee surgeons also practise their skills within a team. There are two separate points to note from this; first, teaching and training within an OT require extensions of time (Hernández-Irizarry et al. 2012) and financial investment (Hwang et al. 2010; Allen et al. 2016). Second, the OT provides both many human factors and issues around controlling variables, which compound the complexity of studying how learning surgical skills impact patient outcome (Fry et al. 2011). Moreover, it makes elusive which methods of learning demonstrate comparatively better value for surgeons, in terms of improving their learning curve (Hopper et al. 2007; Pusic et al. 2012).

While data showing that both the uptake of, and increased patient access to laparoscopic colorectal surgery are positive (Association of Coloproctology of Great Britain and Ireland 2020), changes in surgical direction require a learning curve, whether targeted simulation is part of the process or not. Surgical outcomes, which include postoperative mortality and morbidity linked directly to surgical intervention, are hard to pinpoint; the factors contributing to postoperative outcomes are widely heterogeneous. Nevertheless, it is important to search for evidence to show how SBT contributes to improving surgical outcomes. Exploring how surgical SBT influences surgical outcomes and surgical proficiency has been dominated by quantitative studies, as reported in systematic reviews by Aydin et al. (2022), Davies et al. (2013), Meling and Meling (2021), or studies of simulation validity for specific procedures, such as Ansell et al. (2012; 2013; 2014a), Bittner et al. (2010) and Patel et al. (2016). Such studies are limited in that, focussing on a narrow outcome, they describe a limited aspect of a much wider picture. Such studies discuss the transfer of specific skills from a learning environment into the OT measured by individualised and specific task output. Extraordinarily little evidence exists to support the transfer of the sense of competence and formed meaning from the social culture of the simulated environment or the equivalence in value of skills acquired by simulated operations to the clinical setting. Further, the relevance of such data might be obscured by the wide heterogeneity of measurable factors contributing to surgical outcomes (which can compound and obfuscate the picture). Moreover, the authors of such studies often write from a background of familiarity with surgical routine, accepting that cause leads to effect (Sroka et al. 2010; Agha and Fowler 2015; Waterman et al. 2016; Yanagawa et al. 2019). There is, however, a caveat; quantitative data contributes a useful frame for a story in which its significance can be enriched through context provided by the qualitative experiences of the trainees.

The rising predominance of simulation in surgery requires a little explanation of recent history within surgical training. This is first, to outline the current policies and accountabilities in which colorectal SBT is situated and second, to demonstrate how much professional change has occurred through which surgical trainees have needed to navigate. This is important to set out because the facets of surgical culture and surrounding practice form a great deal of the surgical identity (Pratt et al. 2006; Nestel and Burgess 2014). It should be noted that an exposition on surgical professional identity is not the purpose of this thesis. Some reference to it is worthwhile, since meaning making is implicitly linked to sense of identity (Goldie 2012; Iatridis et al. 2021). The current formative social trend within the culture of surgical practice is driven by evidence-based medicine (EBM) *and* increasingly value-driven policies of the NHS, that is, policies promoting measurable targets for treatment with limited resources, but also accountability to patients and patient-informed care (Cosgrove 2013; Tan et al. 2021).

1.3 Historical context

Until the 1990s, surgical training was based on a traditional apprenticeship model. Within the NHS, training was relatively lengthy, lasting up to 15 years. An educational framework was non-existent and learning was consequential, formatively taking place as part of the clinical work when the opportunity arose. The *de facto* professional culture of surgery was to work long hours without much time to rest. However, by pure numbers, surgical trainees did gain extensive experience in diverse procedures and expertise in complications; by the time trainees became consultants, they purported to have spent around 30,000 hours in training (Chikwe et al. 2004). Yet, assessing skills was as unstandardised and informal as the learning. Moreover, the Royal College of Surgeons Fellowship (FRCS) exam was in essence a test of knowledge rather than surgical ability. In their text on surgical education, Kneebone and Fry mention that consultant selection was not based on performance criteria or tests of operative skills but rather, on informal judgements of senior colleagues (Kneebone and Fry 2011).

Furthermore, in the prevailing culture of deference toward surgeons both from the public and the medical profession (Cassell 1991; Katz 1999; Bosk 2011), surgeons were allowed to practise new techniques and embrace new technology without much accountability or external scrutiny. It was in this climate that keyhole or minimally invasive surgery (MIS) was introduced in the early 1990s (Kneebone and Fry 2011). Described by Cuschieri (1995, p. 9) as the “biggest unaudited free-for-all in the history of surgery”, one new advance, laparoscopic cholecystectomy, was embraced by many general surgeons who had little formal skills training; the central issue being that MIS harnesses a completely different skill-set than those required in open surgery. The uptake of the techniques by

early adopters led to increased injury to patients and unnecessary complications (Kneebone and Fry 2011). The profession realised that there was a demand for standardisation in safe techniques where MIS would be incorporated. The Royal College of Surgeons of England (RCS) was handed the responsibility to address this. This led to the development of the Basic Surgical Skills (BSS) course launched in 1995 (Thomas 2007), which has since become a stipulation for attaining a certificate of completion of surgical training.

The introduction of standard safe skills provided a new level of accountability, which began to challenge the internal culture of deference to individuals (Kneebone and Fry 2011). The 1990s also saw the public begin to question their regard for the medical profession due to a series of incidents highlighted in the media. In 1998, the Bristol heart surgeon scandal revealed how some surgeons knew they were operating with a mortality and morbidity rate above the normative values (Smith 1998). The unauthorised retention at Alder Hey of children's body parts (Mason and Laurie 2001) caused the public to question whether medics interests align with patients and the case of Dr Shipman who, being arrested in 1998 (Batty 2005) revealed the General Medical Council's (GMC) failings toward patients in preference of medics.

This succession of events delegitimised the profession's culture of self-regulation and autonomy and led to the rise of a patient-led health service culture, particularly, patient-informed training. This is important to note on two levels, first that the NHS plan is centred on the needs of patients; and second, healthcare provision is seen as a commodity to patients (Department of Health 2000). Therefore, targeted training, where service provision is more highly valued, is influenced by the needs of patients. The relevance of this becomes clearer below.

1998 also saw the introduction of the European Working Time Directive (EWTD) to the UK (Council of the European Union 2000); legislation designed to limit the working week of EU citizens to 48 hours. The introduction of the EWTD is significant, because it provided a demarcation from a less formalised set of working and learning conditions where doctors might have worked more than 80 hours a week, toward a more targeted work-life balance, where training opportunities became more restricted. At completion of training, surgeons will now expect to have undertaken only around 6,000 hours of practice (Chikwe et al. 2004).

To the surgical community, such a reduction in training time naturally raised speculations that trainees may not be as competent or sufficiently experienced to meet a range of surgical challenges (Kneebone and Fry 2011). Such notions forced rethinking a more structured and increasingly specialised training strategy (Reznick and MacRae 2006) with deliberate and intentioned practice (Colvin 2008).

To the trainee, the reduction in training time was not met without friction. While EWTD reduced the working and training time from one direction (Morris-Stiff et al. 2005), the publication of modernising policies (Barnes 2001; Four UK health Departments 2004) leading to the Modernising Medical Careers (MMC) programme at the turn of the millennium, implemented an intentional reduction in the training time required to reach consultant grade in a bid to increase their numbers within the NHS. This update was seen as necessary on the back of devolution since the English and Welsh NHS began to diverge at this time. Although MMC did lead to the UK surgical colleges combining to produce a curriculum for specialty surgical training (Intercollegiate Surgical Curriculum Programme 2014), the implied challenge to the existing sense of professional identity was clear in the reaction of medics to such profound changes (Brown et al. 2007; Griggs 2007). The traditional sense of meaning made by surgeons was grounded in characteristics such as deferential language seen in apprenticeship, acceptance of long hours and being seen to be prepared to work long hours (Kellogg 2011) which in turn gave them a place in the 'firm' structure and value in living vocationally as a surgeon (Becker 1977). MMC altered the career grades so that the house officer years changed from PRHO and SHO to foundation phase (F1 and F2) and core training years (CT1 and CT2). Junior registrars became Specialty trainees from ST3 to ST5, while senior registrars became ST6 and ST7 (Islam et al. 2011).

This represented a sea-change in medical training. Simultaneously, the chief medical officer in his 2008 annual report, endorsed simulation as a *de facto* approach to forming safe clinical habits (Donaldson 2008). Its message was tantamount to stating that the practice of clinical techniques without first having had SBT was no longer recommended; a view validated by surgeons invested in surgical education (Kneebone et al. 2004). Its publication provided some cohesion for the restructuring of training in medicine and surgery. This document serves as a useful proponent in laying policy for SBT. The increased traction surrounding surgical SBT may have begun to shape the cultural distinctiveness for the latest generation of surgical trainees.

It was in this shifting climate of surgical practice that the WLCTS was launched. In 2006, the National Institute for Health and Care Excellence (NICE) issued technology guidance (TA 105) on the use of laparoscopic surgery in the treatment of colon cancer. It stated that "Laparoscopic (including laparoscopically assisted) resection is recommended as an alternative to open resection for individuals with colorectal cancer in whom both laparoscopic and open surgery are considered suitable" (NICE 2006b). The development of this guidance was accumulated from a range of diverse evidence sources, the majority of contributions coming from patient-led and professional organisations (NICE 2006a). TA 105 is therefore an overt demonstration of patient-led influence on surgical training because its implementation required an up-skilling of surgical practice to

subsequently provide a laparoscopic service. The standard time allowed for NHS organisations to implement a TA guidance from NICE is usually three months from the date of its publication. However, a shortage of colorectal surgeons trained and able to undertake laparoscopic colorectal procedures meant that a three-year waiver was applied to allow training and uptake to take place (Coleman 2009; Evans 2010; NHS Wales Awards 2013). Significant funding was awarded by the Department of Health and the National Cancer Action Team to establish training in England. This programme became known as LapCo (Coleman 2009). Since surgeons and patients in Wales were not able to access this scheme, the Welsh alternative, WLCTS, was developed with some initial financial support from the Welsh Assembly for the first five years (Clarke 2013; NHS Wales Awards 2013).

In summary, key shifts include:

- A move to more formalised learning and assessment of surgical skills.
- Lessening of autonomy with heightened accountability.
- Less time in training.
- Growth of simulation training.
- Introduction of standardised laparoscopic training with a greater shift towards laparoscopic procedures in general surgery.

1.4 The Welsh Laparoscopic Colorectal Training Scheme

Where LapCo focused on up-skilling just consultant colorectal surgeons (Evans 2010), the WLCTS was developed with a twofold approach; established colorectal consultants and their teams would be visited by trainers to support up-skilling at their hospitals, or "whole theatre team" immersion courses were provided at high volume clinical centres hosting the visiting teams during surgery. In this way, the first approach was multidisciplinary, including surgeons and theatre teams (NHS Wales Awards 2013). The second and more long-term approach was to establish a laboratory-based course with targeted SBT at strategic intervals mixed into a two-year preceptorship-style scheme for colorectal speciality trainees, where consultants are actively engaged in the learning process at the operating table. Consultants without prior laparoscopic experience also had access to this programme. High fidelity, animal-based simulation models were designed based on the most crucial steps in right and left-side[2] colorectal procedures and presented in a training lab where the ergonomic surroundings would approximate the operating table environment. Industry partners were invited to 'sponsor' surgical accessories and energy devices used in the procedures, to build

[2] The arrangement of the gastrointestinal tract and its surrounding connective tissues is anatomically distinct. Surgical approach is separated according to the right-hand or left-hand side of the patient.

familiarity with the instruments and handling techniques novel to laparoscopic colorectal procedures.

During the phases of training between the courses and preceptored operations, live animal lab operations were also organised for the trainees at surgical industry training centres based in Hamburg and Strasbourg (previously Elancourt, Paris) (Beaton 2010). Preceptorship is a recently adapted term used in other disciplines and adopted into the clinical arena. A preceptor is an expert professional who takes the position of educator and resource for a trainee, usually during the specific activity being learnt. Throughout this thesis, I use the term 'preceptor', to describe and identify the position of the consultant surgeons as tutors in the SBT and as instructors in the OT.

The pathway of trainees on the WLCTS is outlined in *Figure 1*. It is a two-year training programme for specialty trainees with an emphasis on access to surgical skills using simulated procedures interspersed with a clinical preceptorship in the OT. The training course programme is staged on the premise that laparoscopic right-side operations are relatively more straightforward compared with the left-side, with laparoscopic appendicectomy being the most prevalent procedure to undertake as a colorectal trainee (Jaffer and Cameron 2008; Hiramatsu et al. 2018).

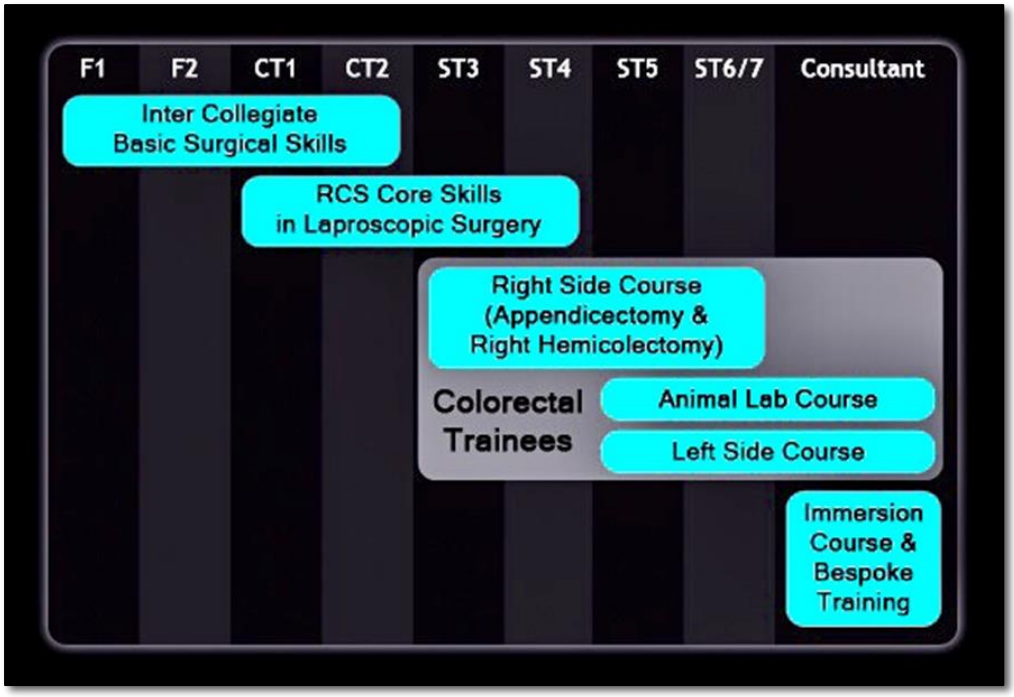


Figure 1. Surgical trainees' pathway through SBT. In colorectal specialisation year ST3, trainees are eligible to enter the WLCTS programme.

During the funded years 2008 to 2013, data was gathered by the Cancer National Specialist Advisory Group (NSAG) Colorectal subgroup for patients in Wales who underwent laparoscopic surgery for the treatment of colorectal cancer. Initial access to laparoscopic surgery rates from 2006 to 2007 showed

only 9.5% of Welsh patients were able to have a laparoscopic resection. From 2011 to 2012, access rates to laparoscopic colorectal resection in Wales were at 42%. During this phase, 50 trainees underwent the WLCTS programme and 21 consultant colorectal surgeons attended the immersion-style course (NHS Wales Awards 2013). Since the end of the funding period, immersion courses are no longer running, however, trainees continue to attend the WLCTS to sustain the provision of laparoscopic colorectal surgery in Wales.

The WLCTS is a modularised, competence acquisition training model taking place under time constraints and opportunistic learning in clinical practice. It is expected that surgical trainees will develop a sense of meaning, value, professional identity and awareness of their skills assets, perhaps more explicitly than in previous surgical generations. Targeted SBT may contribute to trainees' sense of value because it might imbue a meaningful and coherent competence pathway. It is not enough however, that simulation provides the hands-on skills; to be effective it must also approximate a high degree of fidelity to the clinical scenario. The WLCTS is a mix of short, intense simulations and lengthy opportunities to gain clinical competence. OT activity is undertaken by a multidisciplinary team; multi-professional individuals, each advocating their best for the patient from within their professional boundaries and all demonstrating collective intentionality. SBT in the WLCTS is a bounded aspect of surgical training aimed at one group of colorectal surgeons. Its participants must enter a negotiated partnership with the professionals who are present and already part of the colorectal OT. This negotiated partnership needs to remain central to both the sociocultural environments of SBT and the OT, sharing a degree of fidelity too, to facilitate the learning and meaning made by the trainee moving from one to the other.

1.5 Study aims, purposes and development

My research aims to highlight and define the sociocognitively organised learning experience of colorectal surgical trainees, who participated in the right and left-side courses provided in 2018 and 2019. Colorectal surgery requires the acquisition of psychomotor ability, yet the impact of SBT on operating practice may lie in how trainees make sense of their skills acquisition from simulation, through common factors shared between that environment and the OT. I contend that these common factors comprise social and professional interactions through the emergent SBT culture.

As the recent history indicates, there is a precedent for exploring and extending the impact of SBT on the trainees and what meaning they make from it, since historical change and reforms continue to act on them. The common thread between apprenticeship and SBT is the intrinsically social nature of surgical activity. Although, the social impact on surgical learning outcomes has been underdeveloped in favour of scoring changes in task completion time or economical movement as indicators for

progress. I argue that it is an error to overlook the social and collective activities of participation in SBT as a driver for learning construction.

Since learning does not occur in isolation (Gallagher and O'Sullivan 2012; Alexander and Boud 2018), I aimed to explore social interactions within the learning setting. I needed to consider practical approaches that allowed me to do this. Observation of the social and material interactions of trainees working in pairs may indicate learning exchange or co-construction and yield quantitative and qualitative information related to both the proficiency level of the trainees and the difficulty of the task. A deeper insight into the trainees' perceptions of their social interactions could also be gained through direct and intentional conversation. Further, I was concerned to review whether traditional learning theories adequately describe the processes by which skills are transferred into the modern, multidisciplinary operating team with a less deferential culture toward surgeons.

Colorectal trainees in Wales have been impacted by reforms in training. My collaboration with their training programme provides the basis of my choice to understand how they make sense of their simulation learning in a collective environment, that is, how their learning interactions in SBT give their skills meaning which is transferable to their OT practice. I explore how social learning theories may help promote a more socially integrated awareness of learning construction in future simulation programmes.

Since SBT represents a move away from a traditional apprenticeship, how trainees are imbued with *agency*, that is the ability of people to interact with their environment based on their power, intentions and interests (Banks and Barnett 2012) will shift. This acquisition of agency comes with trainees making sense of learning cues within their social environment, which here, is not begun in the OT but rather, in the training lab. This is therefore a semiotic[3] process (Pearson et al. 2016) and its link to agency acquisition requires a fresh explanation of the learning theory.

1.6 Summary

In this introductory chapter, I have outlined the context in which trainee surgeons in the Welsh laparoscopic colorectal training scheme (WLCTS) are situated. The professional, social culture of surgeons is moving from a more hierarchical way of working, to one with greater accountability to the multidisciplinary team and the patients, marking a shift away from implicit training across the operating table. Simultaneously, the learning of surgical skills has become more formalised and therefore explicit, including measured assessment. The working policy has forced a systematic

[3] Strictly, the study of signs and the development of meaning within them. Within a given environment, any object or person will take on meaning and language specific to *that* environment, and its meaning is importantly, mutually understood by all actors within it observing the same 'sign' (Pearson et al., 2016). Semiotics is a central concept within this thesis and is discussed later.

decrease in time available to train in the workplace both inside and outside of the OT. SBT has become the *de facto* approach for learning hands-on clinical skills, with particular emphasis on learning laparoscopic procedures for general surgery. There are five parts to this thesis. First, I explore the social impact of learning in the colorectal simulation courses in my review of the existing literature, which also operationalises my research questions (RQs). Second, choosing to undertake a mixed methods approach to data collection, I discuss my methodology. Third, I present the findings of my data and these are arranged into four separate chapters. Fourth, I present a discussion of those findings in the context of my RQs. Finally, I present a short conclusion presenting the challenges of my research and directions for further research.

2 Literature Review: From individualist to collectivist learning - understanding simulated and real operations as shared activities

In this chapter, I explore the transfer of surgical skills learnt in the simulation environment, to their application in the real world of the OT. My focus is on the development of specific procedural laparoscopic skills by Welsh colorectal trainees. Put simply, the way that laparoscopic, colorectal surgical skills are acquired in a simulated operating learning environment follows established theories of motor skills acquisition which promote the notion of goal-oriented learning. In and of itself, this is the convention and as a learning approach it is unproblematic; trainees after all, need to be trained and demonstrate increasing psychomotor competency. Where the problem arises however, is in looking at how learning by simulation in this isolated way contributes to the improved *application* of skills in the OT. Theories of motor skills acquisition are useful to demonstrate the cognitive and behavioural processes we go through when learning something involving fine motor dexterity. However, a surgeon never employs their surgical skills in isolation; the OT is a social context, with a host of tacit sociocultural rules. As such, "individually acquired" operating skills must be made known and meaningful in the social context of surgery.

My interest is whether the SBT not only supports the development of technical skills alone but if and how it also supports their application in the social work setting. I face challenges in exploring this. Patient outcomes have been used as a proxy indicator of skills proficiency. However, patient outcomes are known to be due to a wide range of factors. Another difficulty is using performance in the situated learning setting as an indicator of workplace performance; SBT may merely lead a trainee to become better in simulation since the simulated environment lacks the context of a real OT environment (Gray 2002; Walsh 2013; Yanagawa et al. 2019). Thus, to develop expertise, simulation-training programmes such as the WLCTS must in some way reflect the sociocultural context that is exhibited in the real-world setting.

The teaching of short, hands-on surgical courses is often underpinned by individualistic learning theories which are goal or skills-centred. However, SBT in surgical skills for use in the real world with limited perceptual feedback, is not enough on its own. It has been estimated that surgical technical ability accounts for 25% of the knowledge of a surgeon (Spencer 1978; Klein 2016). I contend that an exploration of how SBT transfers over to the OT requires framing with socially-oriented learning theories.

2.1 Chapter overview

In this chapter, I present a synthesis of sociocultural and sociocognitive learning theories which embed individualistic psychomotor skills acquisition. I first contrast the training approach of the recent past and its relevance to the current, contemporary dominance of the motor skills cognition approach. I then explore the design of the WLTCS with the emphasis on the contribution of individual skills acquisition, by first building a picture of the training design from the conception of learner needs objectives. Subsequently, I detail learning theories which support goal-oriented, individualistic teaching along with some of their potential weaknesses and how they tie into the WLCTS framework. I then introduce socially and cognitively focused learning theories with the support of relevant literature that demonstrate sociocultural and sociocognitive narratives in surgical practice. I diagrammatically illustrate how the learning theories connect and complement each other as a way of understanding the transaction of learning within the WLTCS in developing surgical expertise. Finally, I discuss the importance of reflection and emotion as tenets which are central to the development of thinking framed by an experience of SBT.

2.2 Targeted training through preceptored guidance

The "see one, do one, teach one" mentality of the apprenticeship narrative (Kotsis and Chung 2013; Romero et al. 2018) no longer dominates the current mode of professional practice, although preceptor-style teaching bears some resemblance to it (Bleakley et al. 2011). Current surgical practice and surgical agency is led by evidence-based practice, competence frameworks and SBT, with increasingly constrained time to 'do it all', that is, to work and to learn both formally and informally. This means that what time is available must be more targeted and effective (Kwaan and Melton 2012). From the perspective of a changing sociocultural discourse, this makes sense; the notion that the emergence of new ideas and practices as a result of external factors has arisen for example, through new technology and interconnecting ideas from other acting influences like the greater value placed on evidence-based practice.

Investigating how the simulation design of the WLCTS contributes toward the cognitive development of psychomotor skills is both useful and necessary because it is the context in which trainees begin to acquire fluency in their use of 'tools' particular to colorectal surgery. Skills acquisition has suited traditionally individualistic learning theory because individuals gain knowledge as private capital[4] (Sfard 1998; Bleakley et al. 2011). Yet, the transfer of that knowledge toward clinical outcomes is negotiated through the clinical OT as a team, especially when the trainees are preceptored by expert

[4] Simplistically, knowledge gained by an individual is regarded by them to be a commodity, because it adds both motivation to individuals learning surgery for highly valued skills and shapes their sense of professional identity.

tutors in the OT and the learning is achieved by participation. This is also the point at which the learning is contextualised and given meaning in the clinical workplace. Therefore, I contend that sociocultural theory offers a useful and holistic lens to demonstrate the impact of simulation as an activity leading to surgical proficiency. In a view supported by the work of Eraut (2007), Bleakley et al. (2011) and Mann (2011), this is a transformative process and the interplay of these theoretical learning narratives is complementary.

As a tool to facilitate learning, preceptorship has been embraced by the surgical profession as a short supportive period in specific areas of activity rather than as a full-blown apprenticeship (Feliciano et al. 2021). Wu et al. (2020) further claims that pairing a preceptor with a trainee fosters socialisation, critical thinking and competence leading to independence. A preceptor in surgery is most often the consultant who can instruct in such a way to support the transition of learned content into real life. Significantly, in Wales, all the preceptors for the WLCTS are also tutors for the hands-on SBT courses.

2.3 Task-oriented needs analysis underpinned by conventional learning theory

Like most surgical learning schemes, the WLCTS was designed following a rigorous learner needs analysis; that is, evaluating the elements that the trainees need to learn, leading to the setting of appropriate objectives according to Bloom's taxonomy of learning-in-action (Anderson et al. 2001) and in turn, the approach in which those elements should be delivered for training (Percival et al. 1993). The needs for these surgical outcomes were determined by the targets set by the NICE policy for the provision of laparoscopic surgery for colorectal cancer (NICE 2006b), the desire to improve patient outcomes, and assumptions made of the prior knowledge and skill-set of the doctors. Because the WLCTS is hands-on, a task-based approach to needs analysis was conducted, as supported by the work of Long (2005) and Kaewpet (2009), in focussing on the objective of learning toward the accomplishment of an active task rather than the syntax of an objective. The development of specific task-learning objectives followed once the task-based needs analysis was completed. Task-oriented analysis unifies several individual factors or objects comprising learning, into common objectives that are ultimately understood and evaluated in terms of their effectiveness in completing the task being performed (Long 1996; Lambert 2010). This kind of learning is therefore, task-specific and is designed to support the learner to be able to complete a section of a larger, more complex procedure by breaking it into smaller, practicable steps (Lee and Anderson 2001; Kim et al. 2013).

Learning which is task-focused has long been the conventional approach to delivering surgical skills training because it facilitates the acquisition of technical skills. Importantly, these smaller individual steps comprising a larger, complex surgical procedure can be practised in a simulated environment

so as to integrate them at a later stage clinically. Smaller steps can be more feasibly set up in the practice room to be repeated. Generally, repetition of specific tasks results in improved performance of those tasks (Noble 1970; Connor et al. 2015). Psychomotor ability is more dependent on the level of practice than on variables such as the environment, leading Hamdorf and Hall (2000) to speculate that this point is crucial to advocating for practice away from the clinical space. However, this objective-oriented practice without context is not so useful to explain how surgical trainees generate meaning for their skills and embed them into their practice. It is not that analysing task acquisition is not useful, but on its own, does little to account for a sociocultural shift in the development of surgical expertise.

That said, task-oriented objectives, along with the theory of psychomotor skills acquisition *are* suitable as a foundation from which to begin because they are understood as the central objects of the learning activity and how the WLCTS is designed for distributed learning, which is sometimes also known as "spaced review". To explain this learning concept further, learners are given opportunities to learn skills by repetition over set, spaced periods of time (Thalheimer 2006) as opposed to learning skills in an intense manner, even involving repetition but within a timeframe without periods of space between those repetitions (also known as massed practice). Distributed practice as a learning approach is posited to have benefits in goal-directed learning and retention during the early phases of learning a complex skill (Kim et al. 2013). Moreover, within this model, the trainees do not practice their skills without placing them in context; they make meaning from them by developing a mental picture of the task as it would be embedded within the steps of an operation (Palter and Grantcharov 2012). Adult learners are also said to learn best when they perceive its usefulness to them, or make sense of the learning experience (Knowles 1984; Ferreira et al. 2018). Further, retention and deep learning are fostered by how instruction is delivered, by the way reflection is encouraged (Hays and Gay 2011; Young 2018) and by the close approximation of the simulated environment to the OT (Hays and Singer 1989; Kneebone 2010), that is, the degree of fidelity. Godden and Baddeley (1975) have demonstrated the influence of a close-context learning environment to improved retention when the learning context resembles the practice context.

The transfer of this idea to surgical practice is supported by a small study which found learning and recall of anatomy in a clinical environment where scrubs are required, were improved when students wear scrubs during anatomical dissection (Finn et al. 2010). Although a comparative study indicated no detrimental effect to learning material outside the OT where context is limited, such as in a tutorial room (Coveney et al. 2013), research by Entwistle supports the implication that close approximation of context benefits deep learning; simulation may carry a deep learning benefit into the OT (Entwistle 1991; Entwistle 2003). This idea is further supported by Warburton (2003) who

states that deep learning is intrinsically linked to underlying meaning. This again is provided by context, which is not difficult to find in surgical practice. However, the challenge is to expand the perspective of trainees beyond the acquisition of technical skills. An interesting viewpoint posited by Kneebone (2010) asserts that a surgeon's focus of work is the operative procedure immediately in front of them, a so-called centre of focus (*Figure 2*), which is enveloped by a secondary level of focus which for the surgeon is less crucial to the procedure, such as the simulated operative environment or the wearing of theatre scrubs (which would promote fidelity). This in turn is enveloped by a third and less distinct circle such as the exchanges that take place between other operative staff. The paper suggests that the primary focal point of a simulation should demonstrate the greatest degree of fidelity (Kneebone 2010). Further, Kneebone suggests that opportunities for rehearsal of technique forms a point of exchange between a simulation and the real procedure, where simulation is more than a practice activity, but a "way of seeing" which embeds in the trainees perceptual approach to clinical practice (Kneebone 2010). This equivalency can be thought of within the WLCTS, where preceptored operations take place. This is noteworthy, because it creates the idea that distributed practice with rehearsal and by preceptored support might form a shared object where simulated activity moves towards operative activity. The concept of 'activity' is expounded further below following a concise introduction of the social learning theories relevant to surgical learning and expertise.

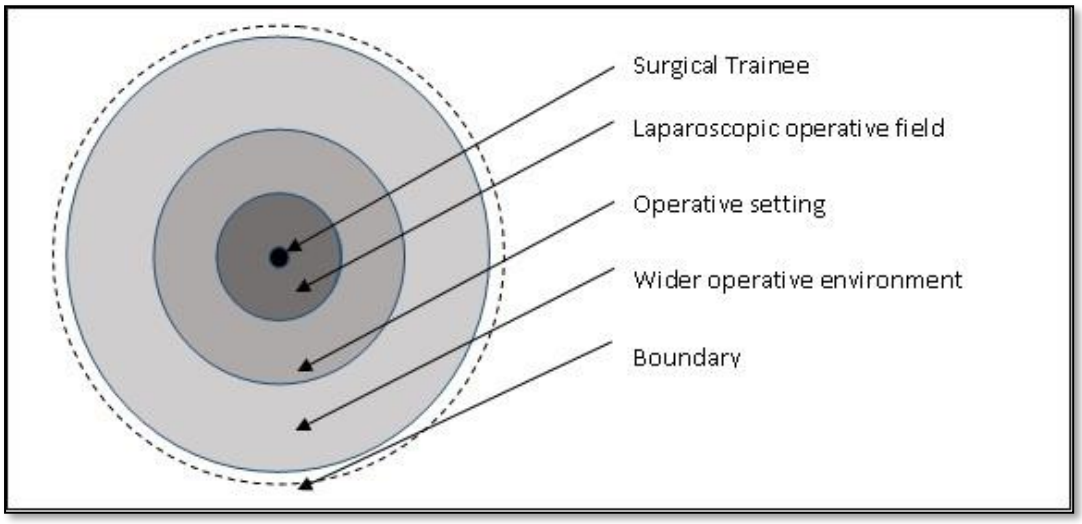


Figure 2. Showing circles of concentric focus where the greatest fidelity should be at the greatest focal point (adapted from Kneebone 2010).

As discussed in the introductory chapter, the two-year scheme begins with the colorectal trainees learning the steps of a right hemicolectomy in the simulation lab. *Figure 1* showed that the trainees beginning the scheme will have completed two practical task-based short courses; the first being in basic skills, which are the foundational building blocks of all surgery; the second, a course that

overviews key skills in laparoscopic surgery, covers foundational laparoscopic skills and introduces the sequential combination of psychomotor task activity in what has been termed a massed practice approach (Murray and Udermann 2003). At the foundational level, surgical activity is broken down into units of repeatable and practicable steps. The learning objectives set for the courses are based on the psychomotor theory of skills acquisition and retention where learning curves indicate increasing efficiency of motor coordination for unit tasks (Spruit et al. 2014; Jaber et al. 2021).

Conventional ideas of multiple skill consolidation, such as that of Newell and Rosenbloom's (1981) chunking theory of task learning and Neves and Anderson's (1981) two-part theory of knowledge compilation, also propositions the combination of basic units of task activity into increasingly complex sequences (Lee and Anderson 2001). For example, this consolidation occurs in part during one short course called core skills for laparoscopic surgery, when trainees practice a procedure for removing the gallbladder in a massed practice approach to training. A useful cognitive architectural framework known as adaptive control of thought – rational (ACT-R) describes how the mind systematically processes and makes sense of irreducible components of knowledge; the framework may be a possible contender for linking individual activity to the social, but it is beyond the scope or lens of this thesis.

Importantly, it is up to this point in their training that the surgical trainees have faced objective assessment of their skills (OSATS). That is, the intentional measuring of the acquisition of a set of de-contextualised psychomotor skills as objectives. Task-based objectives continue to be central to the WLCTS, although the learning is designed to help the trainees combine sequences of tasks to follow and practice vital sections of a laparoscopic procedure.

2.4 Contribution of individual learning theories

Two traditional constructivist theories of skill acquisition which have been influential in SBT are those of Dreyfus and Dreyfus (2000) who describe a five-stage model of adult skills acquisition, and of Fitts and Posner (1967) who posit three-phases of skill development.

The Dreyfus model posits the beginning of skills acquisition, without providing a context for learning tasks. Gradually the context is built-in, then emotive commitment to the outcomes of the actions occurs, then situational discrimination of practice to achieve goals with more economy of action and lastly, intuitive activity based on the subconscious decision-making characteristic of expertise (Dreyfus et al. 2000). Fitts and Posner's three learning phases are, *cognitive, associative and autonomous*. These three phases of skill acquisition refinement have been regarded by educationalists as the most influential for describing how skills improve, leading to the development of synonymous three-phase descriptions by other educational theorists: Kopta (1971), Anderson

(1982), Rasmussen (1986) and VanLehn (1996). Anderson's cognitive theory modifies Fitts and Posner's narrative to *declarative, transitional-associative and procedural* stages. With that of Kopta, of *cognition, integration and automation* respectively, they are perhaps more useful to surgical skills practice. However, the former is perhaps better in describing the physical changes in cognitive architecture within the brain. Including this is useful because of how neurones which activate together will *associate* together over time (Hebb 1949). Conceptually this may be understood as the gradual attainment of (cognitive processing) fluency (Unkelbach 2006; Reber and Greifeneder 2017). During the declarative phase the trainee is explicitly conscious of the movements they are required to master, akin to the popularised notion of 'conscious incompetence' in coaching and management parlance (Curtiss and Warren 1973) where at the beginning, the trainee is ignorant of what they do not yet know and cannot do. The transitional phase mixes conscious motor skill with increasingly greater portions of consolidated skill which requires no conscious effort. This might be akin to moving between 'conscious incompetence' and 'conscious competence', where the trainee knows what they cannot yet do, then subsequently they become able to perform but with full concentration and awareness. However, failure of a procedure can still occur because of the existence of yet unconsolidated skills. With further practice, the procedural phase means the trainee is at a stage where no conscious thought is required to exercise a set of hands-on manoeuvres; the motor skills having been cognitively assimilated; akin to 'unconscious competence', where the trainee performs consolidated skills competently and without needing to actively think about them.

Discussing psychomotor skills acquisition should also include a note on the taxonomic work of Fleishman et al. (1984), who identified two types of motor abilities; perceptual motor abilities and physical proficiency abilities, the former of which identify psychomotor skills relevant to surgery such as multi-limb coordination, fine dexterity and reaction times. This taxonomy is worth noting since it allows process measurement of skills acquisition (Edwards 2010; Handley 2018). Psychomotor abilities such as surgical dexterity can be evaluated separately for a skills acquisition threshold. From this, it follows that simulation learning paradigms need to account for the cognitive combination of separate skills and further, these separate abilities vary to different degrees between surgical trainees (Fleishman 1984; Shebrain et al. 2019).

Figure 3 models the gradual improvement in hands-on dexterity for task learning over time based on the aforementioned goal-directed learning theories and maps over what is known as the 'learning curve' (Hopper et al. 2007). The shape of the learning curve for psychomotor skills is supported by evidence on skill acquisition rates, which indicate that the time required to complete a task decreases as practice volume increases. This relationship is described by a diminishing completion time with an increasing rate of proficiency.

The three stages of skills acquisition as modelled by Fitts and Posner (1967) and Anderson (1982), have been redeveloped by Kim et al. (2013) who, proposing an integrated theory of skill acquisition and retention across the stages of learning, also consider the influence of distributed (or spaced review) practice (*in red in Figure 3*).

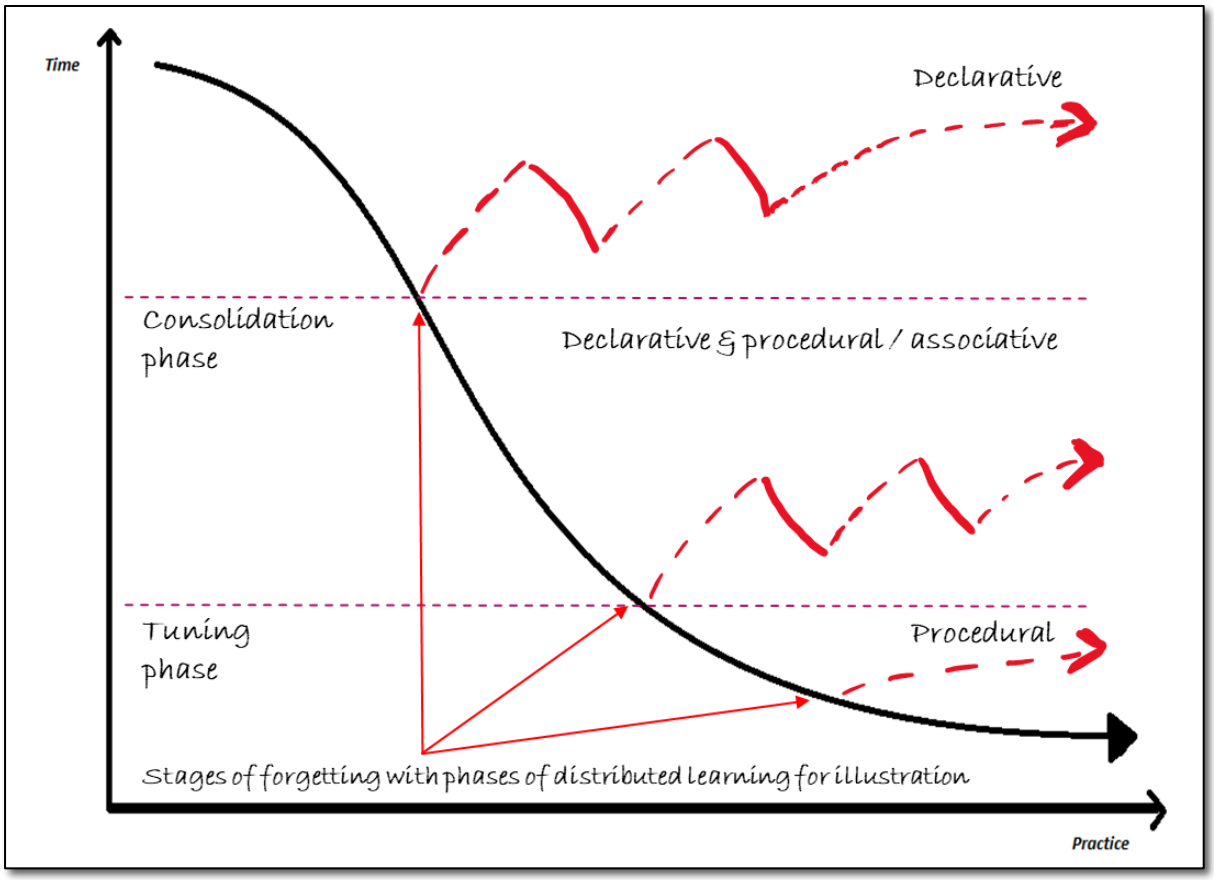


Figure 3. Three-stage motor learning theory based on Fitts and Posner (1967), Anderson (1982), Rasmussen (1986) and VanLehn (1996) - adapted from Kim et al. (2013). The red broken lines indicate phases of forgetting. Further repetition or review of the skill by distribution is indicated in unbroken red.

To clarify, simulation procedures intend to train the surgeons to improve their hands on-skills specific to the procedure. Since a reduction in time taken to perform a skill or consolidated set of surgical skills is indicative of improvement, the learning curve diminishes until a plateau of performance emerges. Gaps between practice opportunities will inevitably lead to gradual forgetting. However, further practice stimulates and aids retention. According to Kim et al. (2013), this distributed learning is beneficial at the declarative and associative stages of the learning curve, whereas massed practice or single event SBT is suitable for surgical trainees at the procedural stage.

In summary, the integrated model of *Figure 3* is still explicitly goal-directed and linear, and the learning curve is a useful illustration of improving task performance. However, in the WLCTS, development of clinical expertise is reflected in cognitive processes which build on repeated practice and *in situ* experience, which continues to both contextualise and facilitate skills transfer across

operative procedures requiring similar skills. Because the acquisition of experience requires activity and participation both within SBT and the OT (which is professional), surgical trainees must also negotiate their learning in terms of specific sociocultural aspects, which involves a cognitively nonlinear and iterative process. This also includes trainees realising their increasing agency within an operative team who share decision-making, which in turn impacts on patient outcomes.

2.5 Consolidation of individual skills

These theoretical domains of skills acquisition which are embedded in SBT, impact the surgical trainees on the WLCTS. They are engaged in integrating and consolidating their individual psychomotor skills into a set of cognitive processes, while simultaneously participating in practical scenarios which aim to mimic the exchanges taking place in the OT. Moreover, when trainees leave the simulation laboratory, they undertake several preceptored operations where they will accrete further experience by participation and negotiated activity, which is to be understood here as a series of social transactions that become embedded into the OT culture. Another way of putting this is that as the trainees foment their colorectal techniques and get guidance on their decision-making processes, they gather increasingly more of the language and social constructs which belong to the colorectal surgeon specialty. This is a key point because the notion of showing expertise is not only about the precise execution of psychomotor *learning*, but of the manner this activity is identified with being a colorectal surgeon.

The transfer and impact of training leading to surgical expertise may be understood as a transaction in learning activity dominated by hands-on, practical tasks within social contexts. Traditionally, clinical studies use dexterity outcomes to indicate the influence of learning by simulation and the validity of simulation models to represent task fidelity. For example, Ansell et al, (2015) indicate that in fine-needle aspiration skills training, trainee performance during simulation may be used to predict clinical movements or evaluate motor skills required for surgery, by assessing the gradual refinement of the representational hand movement in the simulation task. This is also emulated within endoscopy simulation (Ansell et al. 2014b), within basic surgical skills task training (Shingler et al. 2013) and in vascular simulation (Mitchell and Arora 2012). These exemplar papers on learning and skills show a tacit appreciation of individualised and traditional theories of learning. For instance, Shingler's paper demonstrates a decreasing time required to perform some surgical simulation dexterity tasks in proportion to increasing trainee seniority (2013), while similar research on time as an indicator of improved dexterity in simulated therapeutic endoscopy is also seen in Ansell et al. (2014b). This is backed up by performance studies on the assessment of technical skill transfer from bench models to humans and reviews of randomised cohort studies (Anastakis et al. 1999; Wanzel et

al. 2002; Sturm et al. 2008; Mitchell and Arora 2012; Dawe et al. 2014; Patel et al. 2016). Since it has been well documented that individualised learning approaches have been historically embedded within surgical education where adult learning strategies are employed (Mårtenson 2001; Rolfe and Sanson-Fisher 2002; Mukhalalati and Taylor 2019; Goh et al. 2021; Nel et al. 2021), this traditional learning narrative is understandable. Bleakley et al. (2011) have however suggested that the plentiful medical literature embedding and citing individualised learning theories may be reinforcing bias towards them. Moreover, the traditional task-time or hand-economy views as indicators for demonstrating skills transfer by clinical outcome, are problematic (Bleakley 1999) for two reasons. First, one key theory on which they are based has come under scrutiny for the questionable rigor. Specifically, Knowles' andragogic theory of adult learning (Knowles 1984) makes assumptions on the way adults learn as opposed to the learning of children and guides educators toward principles to consider when teaching adults based on these assumptions. Knowles' assumptions underpin much of the framework on which surgical skills acquisition programmes are built. Yet, Davenport (2013) has pointed out that some of Knowles' assumptions lack empirical evidence and as a whole, they lack a conceptual framework; both of which a theory requires (Blondy 2007). Therefore, as he points out, the term 'andragogy' is more useful as a descriptor for adult learning rather than a theory. Second, traditional theories of skills acquisition (such as the convention of Knowles, Anderson, Dreyfus and Dreyfus, and Fitts and Posner mentioned above) lack the ability to accurately predict skills transfer into clinical context because of the wide heterogeneity in factors which could contribute to measurable outcomes in surgery. To clarify this point, acquired clinical skills are manifested in organisational, collaborative activity; of which both facets are absent during individualised task-based focus in learning simulated skills.

In summary, the conventional theories are limited to explaining the development of skills within one area of activity as an indicator of progress. And for these theories to transfer across from one social unit of activity, namely the simulation room to the OT, they need to be socially contextualised. Therefore, they must be explained within a social learning framework which considers transfer conduits such as boundary-crossing 'objects and artefacts' (Lee 2005). These can be either material objects, interactions or even other people which become understood between participants to convey symbolic knowledge or physical meaning within one environment, but which can share that same meaning in another environment and therefore facilitate the construction of meaning and understanding there. Understanding skills transfer by a sociocultural focus, rather than by demonstration of individual task dexterity alone (which is typically measured quantitatively) is, therefore, an important yet under-utilised narrative in surgery. Semiotics (Scott 2014) is one such adjective for describing how people make meaning from 'signs' such as activities, gestures, images

and objects. It is manifested through the physically tangible (i.e., material) and socially organised settings. It is a useful lens because conceptually the interpretation of a sign-meaning is a socially agreed construct (Thibault 2003). An object, an organised sequence of activity, or a negotiation of, for example, surgical language across an operating table, can all create and convey specific meaning because of the social environment in which it is conveyed (Ignelzi 2000). Without further need for discussion on semiotics, this concept serves as a useful way to understand how boundary objects convey meaningful embedded knowledge between the two social systems of SBT and OT. Boundary objects do however go further than this notion. They are intersectional points between two or more separate systems of social activity where there is mutual agreement as to the meaning and information they convey by their place in the system (Bechky 2003). This is important as they link separate social communities to a common activity or activities (Wenger 1998). Therefore, there is precedent to explore surgical skills through a sociocultural lens. Since 2011, medical educationalists have seriously addressed learning through this narrative (Bleakley et al. 2011), recognising that it helps to challenge educators to reframe the goals of learning in medicine and describes a more meaningful insight into how learning transforms practice (Lave and Wenger 1991; Hodges and Kuper 2012).

2.6 Theoretical concepts of learning as a social activity

The narrative of the colorectal trainees comprises two socially-oriented domains, i.e., cognitive activity (theory of mind) and social activity. They are interlinked by the mental patterns which trainees develop and engage to make sense of their learning activity in the real world (Mislevy 2010). Because the development of expertise is seen in how a person thinks and responds to their environment in which they have imbued meaning, the cognitive, semiotic model of distributed cognition (DCog) is a useful approach. It allows for and incorporates the idea that trainees negotiate a multitude of simultaneously interacting elements in an activity. This latter notion involves the participation of other actors and actants in a social system of activity. Therefore, cultural-historical activity theory (CHAT) is given consideration as it not only acknowledges negotiated activity, but it also incorporates a social, co-constructed learning approach. Underlying this activity is a collectivist, social contract by which trainees negotiate their skills. The developing argument, therefore, attempts to link cognitive acquisition and learning by participation in a socially organised system. These socially organised theories are progressive divergences of Vygotsky's groundwork (d.1934). He posited the importance of tools or artefacts around which specific contextual knowledge is based and contributed an important framework of thought toward a basis of social constructivism theory used in integrated learning. He also argued that learning does not take place in isolation. Therefore, social participation and cultural environment are large factors in how learning is constructed and

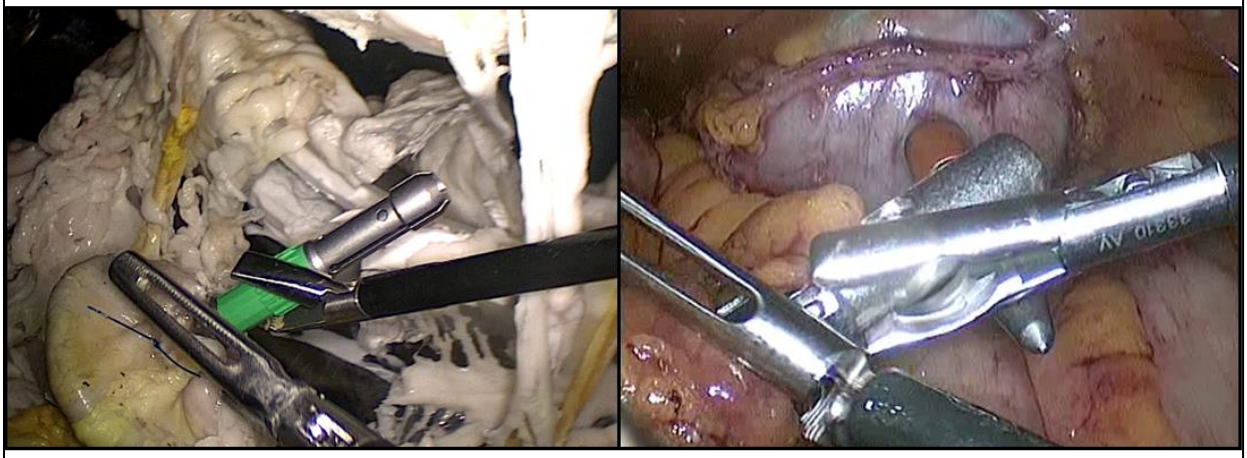
then mediated. Vygotsky's notions around how knowledge is internalised and extended with the participation of others (Vygotsky et al. 1978) are central foundational aspects of social learning theory. These notions have been described through the idea of the zone of proximal development (ZPD), which refers to a learner's ability to complete tasks when assisted by more capable people (Walker 2010), often through the provision of a 'scaffolded' learning support structure (Wood et al. 1976). This grounding in knowledge acquisition by context is useful as it provides a foundation from which to think about social learning theories and the acquisition of expertise in surgery. These latter notions highlight that there is currency in the sharing and acquisition of surgical knowledge, and that concept is exploited in the communities of practice (CoP) model which deserves discussion. These concepts are expanded below.

2.7 Distributed Cognition

The theory of DCog is a sociocognitive learning perspective which maintains that knowledge and cognition are not bounded to an individual but rather, distributed within an environment, its objects and its participants (Hutchins 1991). It is a descriptive framework to help explain human work systems (Hutchins 2001; Hutchins 2014). DCog allows for interactive cognition, which occurs between two or more individuals and/or material objects participating within a context. It is a way of thinking about cognition that allows analysis of relationships between knowledge in the mind and the environment in which the mind is situated (Cole and Engeström 1993). For the study of how training in the simulation lab transfers to clinical practice within the OT, this idea is useful. The knowledge of how to practically undertake the surgical procedures is distributed across these two learning systems between the trainees and trainers and it is mediated through the use of, for example, surgical instruments and the learning of gestures and language particular to colorectal surgery. The (surgical) culture provides an environment which lends a peculiar perspective for learning and reasoning [which is unique to surgery] (Hollan et al. 2000). DCog purports that learning is not only based on the interactions of participants in a social professional activity, but the interactions of themselves also constitute co-constructed learning (Suthers 2006). By way of example, this is illustrated in *Figure 4* which shows equivalent sections of a colorectal procedure being undertaken under the guidance of a consultant both in simulation and in an operation. Because DCog is a way of understanding how knowledge is understood and represented internally and externally (Zhang 1997), objects involved directly in a learning activity take on meaning and are therefore understood semiotically (Seel 2012). In other words, objects and activities specific to surgery are imbued with mentally and socially-agreed knowledge, which is reinforced during SBT. Both perceptual and motor skills are mentally rehearsed and therefore internalised, and then extended into the environment through the use and manipulation of objects and signs, and therefore

become externalised. I contend that DCog provides a template social mechanism for co-constructed development of clinical skills which begins in SBT. Practically, it is plausible to observe these external cognitive processes in the simulation setting indicated by the transactions of language and instrument use. There is empirical precedent for this approach within surgical training. For example, Pimmer et al. (2013) draw on an ethnographic account of medical students acquiring language and picking up socially agreed meaning through the clinical environment in support of DCog.

Images taken from screen as an example of the elements of cognition, distributed through the objects and gestures which form knowledge co-construction in simulation and are subsequently shared and represented in real surgery.



Left image: Snapshot of simulated left-side anterior resection part of procedure taking place during left-side SBT

Right image: Snapshot of actual clinical footage of equivalent left-side anterior resection (from surgical training archives).

Both images show the use of laparoscopic tools for manipulation of tissue and circular stapling device. In SBT they are unfamiliar devices, gradually taking on familiarity of handling and coordination.

Expert: May point to the use of the laparoscopic tool in juxtaposition to tissue on the screen (shown on left image). May gesture a movement (shown on right image) while simultaneously reinforcing verbal instruction using surgical vernacular.

Trainee: Sees the expert's external 'construct' and can begin to internally represent in integrate it with other psychomotor steps.

Figure 4. Illustration of how Distributed Cognition becomes constructed through social interactions, using multiple sources from which to build meaning using theoretical perspectives of Pimmer et al. (2013). The reinforcing actions of the expert could externalise a cognitive construct for this point in the surgical activity.

Additionally, analyses of cognitive fidelity to physical fidelity using task-based procedural learning, that is, the extent that simulation may stimulate the same cortical responses as those of the real task, found that simulation produced a comparable and complementary cognitive response to reality (Hale and Stanney 2002; Hochmitz and Yuviler-Gavish 2011; Forrest et al. 2013). The use of DCog as an approach initiates questions about what learning elements of the right and left-side courses can be observed and are engaged through cognitive distribution and whether they are effective.

2.8 Cultural-Historical Activity Theory

Learning is socially constructed and takes place within a social activity (Vygotsky 1978); teams are comprised of diverse (multidisciplinary) specialties who are both associated by and come together (often loosely) for specific clinical cases. Here, the learning between team members is mediated by common tools, such as surgical instruments and sterile techniques. Moreover, the mind of an individual is arguably un-dissociable from its social and material contexts (Vygotsky et al. 1978; Bleakley 2011), meaning that the working of thought is always located around an external social or material object. CHAT encompasses the dynamic of situated learning through time, relating individual agency to wider social context through common objects and artefacts that mediate learning and professional development, as it was originally expounded to do (Engeström et al. 1999b). The central premise of the theory is that activity (and indeed learning as an activity) is both a culturally and historically mediated phenomenon (Engeström et al. 1999b), because it does not occur in isolation from social culture or the context of past activity. Additionally, learning activity involves the use of historically comprised mediating artefacts as mentioned above and requires a sociocultural arena to show its meaningfulness. Common artefacts or boundary objects link networks of activity, as previously discussed. The focus moves the individual from a place of learning by acquisition to that of learning as a consequence of participation (Sfard and Prusak 2005). In CHAT, the work or lab-based context is described as an activity system.

Representing the activity of a system under analysis is useful to help understand the complexities of collaboration and inter-professional goals. In CHAT, the activity system is analysed as a whole unit (Vygotsky 1987; Gedera et al. 2016) where learning is not necessarily the central part of the activity being investigated but will occur as a consequence of it. The main tenet of CHAT is that it focuses on joint, goal-directed activity, where individual experience is not at the centre (Engeström et al. 1999b). A socially organised system with a goal is here, often understood as a collaboration of multiple separate ‘threads’ of activity (Roth and Lee 2007) (which can either be represented by both actors and artefacts), where these threads combine at knots or nodes only to disassemble and recombine at a different point of focus, depending on where the activity or the learning is

emphasised (Engeström and Sannino 2021). This is known as negotiated knotworking (Engeström et al. 1999a).

Thinking of the components of activity which comprise the WLCTS, the SBT sessions for both the right and left-side of the programme are a system which could be represented by CHAT and so can the preceptored operative training activity. Further, work in the OT which follows the training to undertake laparoscopic procedures is also a system of activity. CHAT represents all these individual units of activity diagrammatically by triangles, linking the essential and irreducible components that form the system. *Figure 5* illustrates the CHAT model with its linked components.

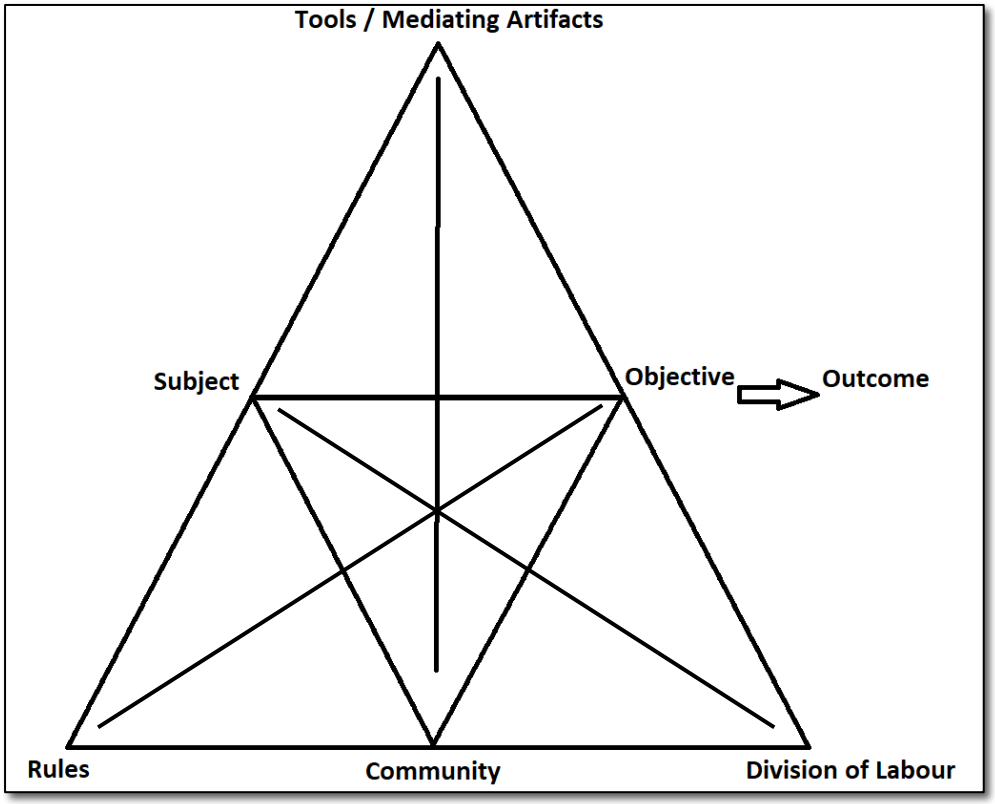


Figure 5. Activity system, second generation model of CHAT adapted from Engeström (1987).

The subject, being the person or group involved in the activity, moves toward the objective of the activity, with the available resources and communication strategies. This activity is constrained by tacit social rules that regulate the subject(s) involved. The community is the group which shares the same goals of the subject though not necessarily the same interests. The division of labour is how the roles of activity are assigned to bring about the objective (Yamagata-Lynch 2010). Units of activity represented in this way, are not isolated and CHAT allows for the linking of separate activity systems via shared objectives and outcomes. As discussed above, activity systems are linked by the sharing of common boundary objects which allow the transaction of learning from one activity to another. Specific to the WLCTS, goal-directed learning transacts via boundary objects from simulation to the

OT, since both systems share common boundary objects and some common objectives. These are identified by the use of instruments that carry both embedded and procedural knowledge provided by historical reflective analysis of the simulation activity as a means to undertaking the operative procedure in a stepwise fashion. The use of "colorectal surgery language" is also a learned artefact which facilitates the crossover of surgical knowledge. This is illustrated in *Figure 6*. Transaction between these two social systems of activity is also bi-directional; trainees can follow a distributed learning pattern of practice in the OT and move back into the lab for further SBT. The purpose of representing activity in this way is to support understanding of the collective learning context and how all parts of the activities relate to one another (Yamagata-Lynch, 2010). CHAT is embedded in this representation; how training takes place is governed by the overall culture of the surgeons which determines their language, distribution of cognition into their environment and the tacit rules. And, since past activities and social context affect new or further activities, the historical element is also represented here. The importance of a developing common language between the two systems is also worth restating; it also supports the contribution of CoP as a way in which learning brings the trainee colorectal surgeon into the fold of the surgical community. Within the contention of my discussion, CoP is embedded within CHAT and is discussed further below.

Within medical education literature, there are examples of learning research using CHAT as an organising framework, such as Cleland et al. (2016) who analysed basic surgical training from a social perspective with interview data to conclude that trainees use their training to acquire a social capital belonging to surgical progression and support and identifying characteristics of the professional community. Further, a systematic review of health tracking studies which produce quantitative data analysed their content thematically, using activity theory to look at the interplay of various health activities to see how they negotiate toward a health outcome (Almalki et al. 2016). Additionally, in an ethnographic study of medics learning in a clinical setting, CHAT was used to present an understanding of six separate factors of activity all combining to co-construct an outcome (Smith et al. 2004). Implicitly, it is the negotiation of multiple threads of activity which is part of the focus. The most recent empirical example makes the knotworking element of CHAT explicit. In their use of focussed interviews, Elmberger et al., showed how the complex activity system of a clinical workplace involves the negotiated knotworking of collaborative activity to enable teaching faculty to develop (Elmberger et al. 2020). The negotiated knotworking focus of CHAT has been used as a lens in other studies of clinical education, where themes from interviews were identified to show how multiple forms of activity converge around learning goals within clinical teams as an activity system (Larsen et al. 2017). Kerosuo, in 2003, analysed the routines used for patient data gathering. It suggested that knotworking of activities through one routine, can be recreated in another through

the mediation of objects which cross the boundaries of distinct activity systems (Kerosuo and Engeström 2003). DCog is the focus to ask what elements of activity are being exploited by the surgical trainees in SBT. The precedent from existing studies can support an organised analysis of observed activity constructs from a negotiated knotworking lens. They also raise the possibility that insight into the way any activity in simulation is mediated, might be achieved through thematic analysis of trainees' perspectives on their participation in the WLCTS. Further, it is possible that the complexity of tasks can be observed in the way multiple activities combine.

2.9 Communities of practice

Regardless of the degree of the individual sense of agency inherent in each trainee surgeon, in joining the WLCTS and the OT teams they then belong to a group of professionals committed to a shared purpose and shared activity. Participation in the surgical activity whether it is simulation or clinical is an opportunity for dynamic social learning. Developed by Lave and Wenger (1991), the central tenet of the CoP model is that it is a conceptual lens, which facilitates a discourse around organisational learning (Cox 2005). Key elements embedded within CoP are the theory of situated learning by "legitimate peripheral participation" (Lave and Wenger 1991). Simply put, within the context of the WLCTS, this is the notion that novice trainees begin their laparoscopic colorectal learning as soon as they become situated in this specialty cohort and they do it via a gradual process of becoming socialised to that professional body; engaging with the language, taking on the tenets that form colorectal surgical identity. As the trainees aggregate learning and experience within what could be termed the occupational community (Orr 1996), they move from a metaphorical position of the periphery to the centre of the group. Mutual knowledge and experience further strengthen the activity and dynamic of the group in principle. There is some difficulty in the use of the term 'community' which includes both surgical novices and experts since it implies sameness (Cox 2005) and a CoP is a group of people who differ in skill level and knowledge. However, a more useful way of viewing the occupational community is a body of professionals at different locations of skill and learning who exhibit 'mutually defining identities.' This aspect of CoP, supported by Wenger (1998), is useful for exploring the place and impact of simulation on the surgical trainees because the learning scenario involves introducing a body of trainees who may come from different backgrounds and levels of experience to laparoscopic colorectal surgery and its language. Moreover, WLCTS also introduces the trainees to the established community of expert surgeons who are situated in a place of established agency, which comes through fluency in laparoscopic colorectal surgery. Hildreth et al. (2000) have empirically examined how knowledge was shared and distributed through a virtual community of professionals within an organisation crossing national lines. The rationale of these authors is that the CoP transcended national boundaries using shared media as boundary crossing

objects in which ‘soft’ knowledge was shared and distributed, that is, knowledge comprising experience, tacit skills and internalised work processes, and by definition is difficult to capture. Further, a review of medical CoPs has extended medical professionals’ abilities to enable their learning through knowledge sharing and boundary crossing (Barry et al. 2017). Meanwhile, an empirical comparison of collectivist learning models in medical education has identified a possible dissonance between the transient way interprofessional learning may occur through knotworking, compared to the need for more stable, long-term collaborations of the professional community (McMurtry et al. 2016), which is where expertise may be manifest. The WLCTS is made of faculty and trainees who all belong to colorectal surgery. These cited empirical works raise speculation that the WLCTS provides a structure where the sharing of experience is enabled. Therefore, there is clearly an argument for acknowledging a CoP framework as a mechanism of meaning-making and expertise acquisition within the overarching activity system. Conceptualising colorectal surgical trainees as belonging to their own CoP also raises enquiry concerning whether their level of experience affects their social-learning interaction during the left and right-side courses.

In summary, CoP models focus on how individuals learn and share knowledge through participation in a shared activity or domain. While these models are useful for understanding how individuals socialise and learn within a community, they do not fully explain how innovation occurs within the context of the community (Bleakley et al. 2011). In contrast, the CHAT model of expansive activity focuses on how individuals actively innovate and create new knowledge through belonging to a community. CHAT emphasises the role of activity or the work that individuals do within a community as the driving force behind innovation. It also highlights the importance of historical and cultural factors in shaping activity and innovation in community settings.

Several studies in professional education development have combined the perspectives of CoP and CHAT to analyse cultural and historical factors shaping communities of practice. For example, Trust (2017) studied teacher knowledge-seeking and sharing in a peer-to-peer professional development network through CHAT, while Meyers (2007) used CHAT to model school library programs and practices and show how activity transforms into learning. Additionally, Saka et al. (2009) took a CHAT perspective to examine teacher induction and its impact on science education reform, investigating cultural and historical factors that shape teacher integration into a school community.

Furthermore, some studies have explored and extended the intersection of CoP *and* DCog within CHAT. Nicolini et al. (2003) used CHAT and DCog to analyse a community of business and economics practitioners, showing how historical and cultural factors shape their activity and influence innovation through experimentation and transformation of existing practices. Engeström’s study of activity in a hospital setting (2001) proposed the concept of "expansive learning," that is, how

collective processes construct interacting activity systems that involve the use of shared practice, tools and meanings, aligning with CoP and DCog. Through their argument for CHAT as a theoretical lens, Silvennoinen and Pirhonen (2015) identified challenges in surgical skills training, viewing it as a CoP within its own activity system, highlighting the importance of distributed cognition in individuals' acquisition of skills.

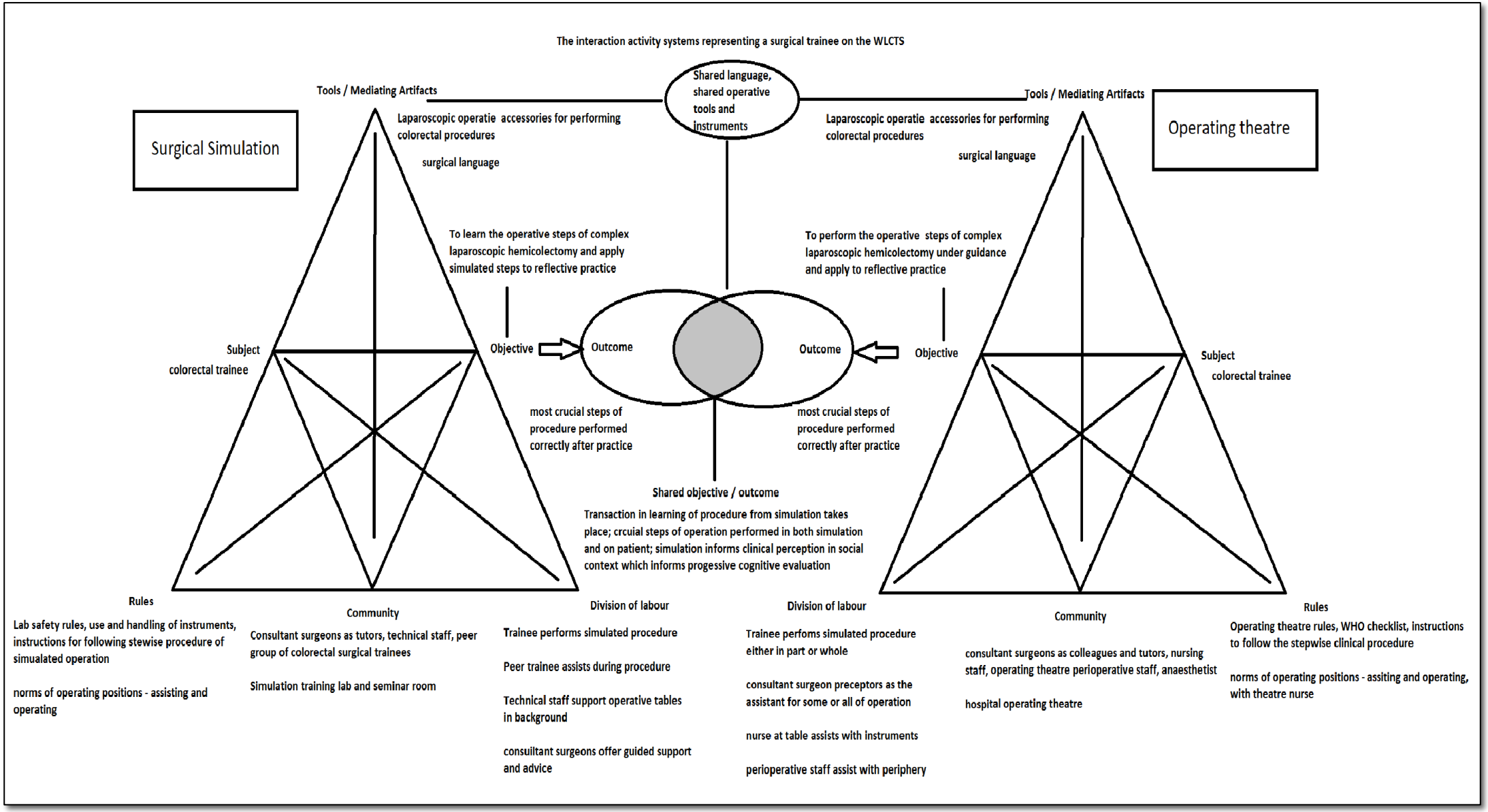


Figure 6. Third generation model of activity system (Engeström 2005) adapted from interactional model of Engeström (2001) representing a colorectal trainee transferring between simulation as a unit of activity and the OT as a separate unit of activity.

2.10 How DCog and CoP integrate into surgical activities

Through CHAT as an organising framework for analysis of surgical SBT, the components of the activity are conceivably the conduits of semiotic, cognitively distributed knowledge. CoP and DCog are the theoretical mechanisms by which the an individual's goal-directed learning may be negotiated between the SBT and OT activity systems (Elster 1989; Hoppitt and Laland 2013). They are also the mechanisms by which expertise is gradually acquired. Seen through the lens of CoP, declarative and procedural skills are linked further and further with the tacit, dynamic knowledge of the colorectal domain. To clarify this gradual acquisition of expertise, the consolidation of unit skills learned in surgical simulation is facilitated by transfer to the clinical surgical environment; knowledge of surgical skills and use of instruments is extended and distributed, which facilitates retention and fine-tuning of motor skills such as subtle cues that are only made known through expertise that comes through preceptorship with the expert. As an example, the more effective placing of a laparoscopic port may improve a retractor position, which in return improves a field of operative view. Examples such as this demonstrate the development of anticipation which comes from the negotiation of individual objectives that are shared by the same activity, i.e., the operation. Instruments both carry and exchange embedded knowledge and therefore reinforce the understood rules of the procedure to the community participating in it. Viewed in this way, it is reasonable to argue that the sociocognitive cultures of the OT and SBT are critical for the development of expertise and more, because they both share and depend on the same CoP which comprises the most expert colorectal surgeons at the centre. Collins and Evans (2007) support this notion in their book on redefining expertise; they argue that it is located within the social group rather than in an individual. That is to say, individual expertise develops out of negotiating socioculturally organised activities. Further to this then, surgical expertise can be described as the way a surgeon responds fluently to the events that take place during an operation in real-time, by utilising a complex body of knowledge that is maintained and backed by the community of surgeons.

2.11 Importance of reflection in reinforcing expertise

SBT links to OT clinical practice. It is in this sense part of a binary activity system. One further important cognitive mechanism of learning which was briefly touched on earlier, which facilitates both goal-directed motor acquisition and negotiation of surgical work as a social system, is reflection. Again, revisiting some of the history of surgical training, the gradual accumulation of operative experience might have been viewed as an accrual of expertise (Rolfe 1997). However, experience does not necessarily lead to expertise (Benner 1984). In the light of time constraints required to achieve levels of proficiency, reflective practice and mindfulness have been widely linked to

promoting effective management and clinical practice with a reduced rate of error (Bleakley 1999; Jordan et al. 2009; Sibinga and Wu 2010; Pezzolesi et al. 2013; Husebø et al. 2015; Taylor et al. 2015).

The three different parts of reflective thinking, reflection-after-action, reflection-in-action and pre-reflection (Hays and Gay 2011) all help the surgical trainee to imagine working through the operation from a different spatial perspective and have been shown to improve several aspects of the procedure, including objective decision-making (Edwards 2017), safety and reduced error (Ahmed et al. 2013) and more meaningful skills-learning experiences (Dreifuerst 2009; Helyer 2015; Husebø et al. 2015). Exactly how this is achieved has been the domain of recent research mapping neuronal pathways linked to cognitive processing, cognitive load and response to emotionally involved and complex scenarios (Huotilainen et al. 2018). It is not difficult to grasp that surgery is an emotionally invested activity and there is scope for understanding how reflection and mindfulness activities facilitate decision-making thought processes particularly linked to objective rationales (Anderson 2007), such as might be distinguished in an expert (Rock and Schwartz 2006; Dixon et al. 2017; Leszkowicz et al. 2017). Taking this thought further, emotions are a central part of cognition, being inseparable from learning by interacting with the environment (Damasio 1994; Huotilainen et al. 2018). By contention, the binary experience of emotions which form during motor learning is also engaged in social cohesion, especially in uncertain situations. But importantly, emotions are central to making sense of both social and individual interaction with the environment (Johnson 2007). This particular discussion is at this point beyond the limits of the present thesis, but some aspects from this lens are interesting to note because of the way individual learning is given meaning within the sociocultural.

2.12 Summary

My literature review contends that while surgical SBT activity focuses on goal-directed, individualistic learning, it must be negotiated and consolidated through social and material contexts (provided by CoP and DCog) to be understood and transferred to the OT. The simulation component of the WLCTS has been designed to contend with some of the issues that occur in the real clinical setting, to promote fidelity and aid retention. The WLCTS framework bridges simulation and clinical practice via preceptored instruction. Surgical trainees are members of the colorectal surgery CoP and this community embeds within the activity-theory framework as skills are acquired and the trainees gradually take on the identity and role of a colorectal surgeon. How trainees move from a context-free position of skills acquisition to a position where each psychomotor action takes on a meaning based on the situation, is a fundamental aspect of social learning. Therefore, the acquisition of skills that follow the “learning curve” can also be embedded within the sociocognitive narrative. Several

artefacts or boundary objects also facilitate the movement of learning and identity formation within the perspective of CHAT. This suggests that SBT can contribute to the steady development of expertise since it becomes extended knowledge through the various common objects that are shared between simulation and clinical activities.

To evaluate training through the lens of this social construct requires observation of the simulation part of the WLCTS as a unit of activity, followed by exploration of the views of the surgical trainees participating in the scheme.

This literature review gives rise to several considerations, of which three can be specifically addressed by observing the right and left-side courses of the WLCTS and the trainees attending them. These considerations are operationalised below with the following questions.

2.13 Research purpose and questions

I set out my research questions (RQ) in consideration of my available resources, observation timeframe and the limited simulation setting. These constraints help me to set specific problems, as recommended by O'Leary (2004). I have embedded my research objectives and indicated some of the assumptions underlying their construction (Gilbert 2008).

RQ1. Through what social mechanisms are the complex clinical skills of surgery which, being learnt through the WLCTS, translated to the operating theatre context?

This question directed me to examine how the social interactions and dynamics within a CoP influence the development of expertise in surgical trainees and how the principles of DCog and CoP could be applied to improve the design and implementation of simulation-based training for surgical trainees. My literature review contends that the complex laparoscopic colorectal skills acquired within SBT become understood both implicitly and explicitly through the negotiation of a social system. It makes sense therefore, to observe the social interactions which occur in the SBT setting against the parameter of task complexity, which is designated by the gradient of the learning curve. Increasing task complexities carry longer learning curves with associated cognitive loads (Bann et al. 2003; Carswell et al. 2005; Hopper et al. 2007; Tseng 2020). I premise that socially constructed learning is linked to increasing task complexity since it may place a higher cognitive load on the trainees. Apart from increasing the procedure length, this may cause a change in the learning interactions seen between trainees and tutors, through social and material exhanges where new knowledge becomes both embedded and distributed. Additionally, trainees work through the surgical tasks in pairs. It is reasonable to assume that each trainee will negotiate the tasks out of their prior knowledge, reflective capacity and existing sense of professional identity. I therefore consider

how prior trainee experience affects the exchange of these social interactions which may embed and carry learning.

RQ2. How do laparoscopic colorectal trainees perceive the value of and make their training meaningful?

This question directed me to examine the trainees' subjective experiences and perspectives and how they interpret and respond to different situations in their SBT, and how they make sense of these experiences in the OT. A further objective of this question is to explore the professional language which the trainees use to describe their training and how they see it embedded into their surgical practice. Answering this question might also reveal the extent to which trainees see their knowledge and skills transferring to the OT through negotiated activity and development of agency through participation. Analysis of participants' accounts of their SBT experience and its contribution to their OT practice may provide insight into exploring their perceptions.

RQ3. How could the learning theories discussed, inform a framework which can both acknowledge the social experience of simulation in facilitating the negotiation of learning and enable the professional development of the trainees?

Learning in simulation may be mediated through shared activity, where task completion is dependent on partnership and the negotiation of roles at the table. Through this, semiotic and external cognitive signals may be exchanged between trainees where the development and agency of both is extended. Interpretation of findings to sociocognitive theories could help shape a learning model which makes the social significance of simulation more explicit and intentional. In answering the first question there will be an emphasis on observation data; in answering the second question the emphasis will be on discussion with trainees. Answering the third question will link findings to the theoretical perspectives detailed in his chapter. My methodological approach is set out in the next chapter.

3 Methodology

3.1 Overview

This chapter details my methodological approach adopted to address my research questions. I will be following a conceptual format as advocated by Crotty (1998). I first outline the ontological and epistemological assumptions that underpin my methodological approach. I include reflection on my position in relation to my research and further, the choice of available approaches within the constraints of the SBT setting. I then describe the SBT research setting and available resources that shaped the direction of my research design before detailing my strategy and expanding on my methods. I bring the chapter to a close with a discussion on ethical issues which arose during my data acquisition.

3.2 Foundations of my research approach

The development of my research questions (section 2.13) was informed by my literature review. My research approach encompasses both interpretive and pragmatist ontologies, as these two approaches are not mutually exclusive (Hesse-Biber and Leavy 2010) and can be used together in research (Morgan 2007; Creswell and Plano Clark 2011).

In ontological terms, my view of the nature of reality is both interpretive and pragmatic, reflecting a relativist stance. The trainees' experiences of their training are subjective (Guba and Lincoln 1994) and my research questions reflect both empirical (Ansell 2016) and contextual characteristics (Morgan 2014b).

Crotty (1998) supports the intrinsic link between ontology and epistemology. My constructivist epistemology both informs and is informed by my interpretive and pragmatic ontology. Through an interpretive approach, my objective is to understand the social process and experiences of colorectal surgical trainees in the SBT setting and to model the contribution of social learning to expertise in the OT. By doing so, I seek to advance the understanding of how social learning contributes to expertise in the OT.

A constructivist epistemological perspective aligns with my research goals because it both allows for an understanding of the subjective experiences and meaning-making of the trainees (Mann and MacLeod 2015) and seeks an insight into the social mechanisms and processes that may be involved in SBT (Weinberg 2015). This foundation foments my philosophical stance in relation to my research

approach, which is important to acknowledge as it informs the decisions I made in relation to my design, strategy, analysis and subsequent explanation (Crotty 1998; Creswell and Poth 2016).

3.3 Researcher philosophical position and background

In this section I outline the philosophical assumptions that inform my research, of which there are three which merit inclusion. I then discuss how my insider background and positionality as an educationalist and expert in surgical simulation align with these perspectives, since they are intertwined in shaping my research design approach.

3.3.1 Post-positivism

A post-positivist stance considers that it is not possible to observe the world objectively and completely value-free. As research combines both experience and reasoning to create knowledge, as stated by Cohen et al. (2017), it follows that my perspective and interpretation will influence this process. It is worth noting that post-positivism is a view with a legacy in positivism, which briefly, maintains an objective view of the world where I as an observer could be detached from it (Illing 2013). Taking a post-positivist perspective means I am investigating my own epistemological research position in recognition that my observations and interpretations are fallible and further, capable of revising my theoretical underpinnings (Cleland 2015). In alignment with a post-positivist view, RQ1 particularly acknowledges the complexity and subjectivity of the learning process and seeks to understand the social mechanisms at play in the translation of skills learnt in SBT to the OT.

3.3.2 Social constructionism

A social constructionist perspective acknowledges the construction of reality through social interactions and language; knowledge is constructed through social interactions (Berger and Luckmann 1966). Understanding how surgical trainees as a CoP, construct their own meaning of their simulation experience in relation to their operative practice, is an interpretive process and relates to RQ2. My own interpretation of the data will be informed by the cultural and historical context surrounding the shift in surgical training and may offer new perspectives or challenge current understandings in the field (Burr 2015; Burr and Dick 2017). This social constructionist perspective informs an interpretive approach to data analysis. Implicitly, my social constructionist position infers that a qualitative, interpersonal research approach is appropriate for addressing the RQs I pose.

3.3.3 Pragmatism

If positivism sits on one end of a continuum with constructivism at the other, the pragmatic assumption moves between the two (Teddlie and Tashakkori 2006; Brierley 2017). Pragmatism, as put forward by Morgan (2014a), emphasises the nature of experience over the nature of reality. It holds that actions are linked to unique human experiences, leading to warranted beliefs developed

through repeated experiences of predictable outcomes. These beliefs are provisional and subject to change based on the context of the action. Additionally, actions depend on socially shared worldviews, which can vary among individuals but lead to similar actions in similar situations based on the extent of shared beliefs (Morgan 2014a). Pragmatism as a research paradigm acknowledges that there can be various realities, both objective and subjective, that are open to investigation through empirical methods (Tashakkori et al. 1998). Pragmatism moves from the 'traditional' dualism of objectivity and subjectivity and allows a researcher to abandon forced dichotomy (Kaushik and Walsh 2019). Furthermore, pragmatism holds that knowledge is socially constructed and also unique to individual experience, but also shared (Morgan 2014a). Collectively, these tenets make pragmatism particularly suited to the collection of multiple perspectives through the use of various methods and allows the integration of different forms of data.

3.3.4 My positionality

As an educationalist and facilitator of surgical simulation with 18 years of experience, I have gained valuable knowledge and understanding of the challenges faced by trainees in their professional development, in the face of reduction in training time and opportunities to practice. This, combined with my experience in designing and preparing course materials for SBT, puts me explicitly in an insider position (Fleming 2018), which is important to consider in qualitative research (Holmes 2020). I value SBT as a legitimate approach to improving surgical performance, which is a value-bias I bring to my analysis (Creswell 2014). Linked to this, in developing the hands-on element of the WLCTS, I was able to combine my practical experience with my educationalist knowledge to consider factors such as decision-making, communication and teamwork, as additional elements alongside the traditional task-based learning objectives.

As an insider, my acculturation to the surgical language and milieu enabled me to communicate and collaborate with trainees. I have participated in prior research collaborations with surgeons which have resulted in publications on task fidelity and simulation performance. Taken together, my experience influenced my philosophical position and approach to research, as well as guided the questions I chose to investigate.

In summary, my insider position as a practitioner and educator in surgical SBT has shaped my philosophical stance, approach to research and understanding of the field. Being an educationalist and facilitator of surgical simulation gave me a valuable perspective on the training process and the trainees' experiences, which informed my analysis. I chose to pursue this research because I had the unique opportunity to observe and interview surgical trainees in the WLCTS.

I recognise however, that my emic perspective could be in tension with my etic as a researcher seeking to understand the broader sociocultural context of surgical training. The need to promote distance and objectivity influenced my methodological design. For example, my emic perspective allowed me to identify and interpret social cues of interaction within this colorectal surgical culture. However, as an etic researcher, I needed to be aware of my intrinsic cultural biases and avoid assuming that what I recognised as meaningful social cues were universal or generalisable. To clarify, although I identify certain signals through the semiotics of belonging to the culture of surgical training, I take measures to verify whether what I observe is unique to this culture or has broader applicability.

When engaging the trainees in conversation, my shared professional surgical language gave me an intuitive understanding of their experiences and perspectives, which helped me ask relevant questions. That said, I acknowledge that I might have overlooked important differences or nuances that an outsider perspective could have identified. To address this, I reflected on my own biases before engaging in intentional conversation, seeking to remain open to perspectives that could challenge my assumptions with the additional intent of obtaining member-checking[5] feedback to enhance the accuracy of the interpretations I drew.

3.3.5 Mixed Methodology

Given my position, the complexity and theoretical breadth of my exploration, I chose to adopt a mixed methods (MM) approach, which allowed me to integrate multiple perspectives and different forms of data. MM comprise distinct components aimed at a pluralistic approach, that allows for the combination and possible integration of theory (Salkind 2010; Tashakkori and Teddlie 2010). My choice and order of data collection methods were determined by the research questions (Creswell and Plano Clark 2011) in context of the research setting (the SBT lab) and the subject of the research (the colorectal trainees) (Greene et al. 1989; Tashakkori and Teddlie 2010).

Supported by Creswell and Plano Clark (2011), there are multiple justifications for mixing methods: I identified that one type of data is not sufficient (p. 8) to address my research questions and suggested that my findings are enhanced through nesting quantitative data within qualitative analysis (p. 10); my theoretical organising framework intersects objective social activity with subjective trainee experiences (p. 10). Using MM allowed me to consider multiple perspectives and integrate different forms of data, which can increase the confidence in my interpretation of findings (Creswell and Plano Clark 2011).

[5] Member-checking was eventually not possible and the reasons are detailed further in sections 3.4.5.2 and 3.6.4.

In addition to this, Greene et al. (1989) contend the use of triangulation[6] and complementarity as functional concepts of MM used to enhance research validity. I collected two distinct categories of data aligned to my RQs and use CoP and DCog as theoretical frameworks to understand the social learning mechanisms and their capacity to bring meaning to the trainees as they move towards the OT. Therefore, methodological triangulation and conceptual triangulation are appropriate (Denzin 1978) along with complementarity, since my use of different methods sought to obtain unique insights that are limited to *those methods* specifically used. That is, where a method is limited, it can be overcome by the possible insights and strengths of the other (Greene et al. 1989). This approach also allowed me to move beyond the dualist view of objectivity and subjectivity discussed above, in keeping with the pragmatic philosophical assumption underpinned by the ontology of my research enquiry.

In aligning with complementarity (Morgan 1998; Creswell and Plano Clark 2011) I identify my main method of data collection as qualitative, since it forms the major portion of my subsequent abductive thematic analysis. Linked to this abduction, a portion of my quantitative data is nested with my thematic findings. That said, according to Morgan (1998), my MM approach fits a 'convergent parallel design' in which both my qualitative and quantitative data were collected and analysed simultaneously but separately. The findings from each approach were then integrated and compared to identify corroborating patterns or highlight divergences (Morgan 1998; Creswell and Plano Clark 2011).

I employed a qualitative, abductive thematic analysis of interview material (considered to be pragmatic in its assumption (Morgan 2007)) and a quantitative analysis of videographic data treated with inferential partial regression analysis. This approach may be considered unusual and deserves some justification. Visual data is qualitatively complex and Maxwell (2010) points out that there is a risk that this complexity can be oversimplified when reduced to numerical data. Furthermore, interpretation of results can be difficult if the context surrounding the number generation is removed. Moreover, there is an additional potential for bias when selecting which quantitative information is included and excluded from the analysis (Maxwell 2010). However, Maxwell advocates using numerical data in qualitative-oriented research for a number of reasons. First, numbers can be used in qualitative research to strengthen the trustworthiness of the findings by providing a more complete picture of the studied activity. Second, numerical data can increase the generalisability of

[6] The term, 'triangulation' is a metaphor borrowed from surveying and navigation (Turner and Turner 2009) where an unknown point in space is determined by the convergence of measurements taken from two known and distinct points. (Cohen et al. 2017, p. 265) define triangulation in social sciences, as "an attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint."

the findings by providing a more detailed and precise understanding of the activity. Third, numbers can increase the objectivity of findings by checking the validity of the qualitative data (Maxwell 2010). A quantitative analysis of video footage strengthens the trustworthiness of my findings by providing a more complete picture of the social mechanisms and trainee experiences being studied. Furthermore, the quantitative data allowed for a more detailed and precise understanding of the phenomena under study, which in turn increases the potential transferability of my findings. The numerical data could also support verification of the qualitative data collected through interviews.

3.4 Observation protocol and interview characteristics

A protocol outlined by Frechtling et al. (1997) informs (either qualitative or quantitative) observation-based research and data collection. I use this to describe the research setting and participants; the simulation setting is the location of the SBT activity for which I outline the resources, equipment and set-up of the simulation table used for surgical tasks. Additionally, I detail participant characteristics and sample size. Subsequently, I address the rigour of the analysis (quantitative content analysis and qualitative thematic analysis of guided conversation) (Cleland 2015). I then detail the data acquisition (video and interviews).

3.4.1 The simulation training setting

For the two courses of the WLCTS teaching surgical skills, first on the right-side of the lower intestinal tract and later (usually after about a year) on the left-side, there are three main 'operating' stations around which trainees work in pairs. Each station is a table on which different instruments and surgical devices have been distributed and made available by surgical supply companies who also widely supply their devices within hospital OTs. Because part of the learning approach also emphasises the trainee gaining familiarity with these devices, the pairs rotate around the stations. Within a single surgical procedure there are also several key learning steps that have been modularised in animal-based models (using animal tissues re-shaped and pathologised to represent human anatomical landmarks). Therefore, when trainee pairs complete one step of a procedure, they rotate to another station to undertake the subsequent step using other surgical devices and accessories with which it is possible to do the surgery. In their pairs they alternate roles; one trainee must be the primary operator while the other must be the laparoscopic camera operator who will also assist by holding secondary devices such as laparoscopic graspers or retractors. There are also separate stations set up for individual use. There, tutors act as the camera-operative for one procedure. The purpose is to familiarise the trainee with issuing instructions to their assisting camera operative. Separately, camera support 'arms' are available for laparoscopic anastomosis procedure

and for this, the trainees also practice individually (the right and left-side course learning plans are given in Appendix 2).

3.4.2 Data gathering strategy

The SBT lab in which the WLCTS courses ran, was set up with 10 surgical practice tables with a capacity for up to 20 trainees. *Figure 7* is a schematic of the training lab and shows the positions of the trainees and operating stations, along with the positioning of the cameras set up to face the trainees. *Figure 8* is an image of the typical set-up of a simulation operating station at the start of an activity. Their most common mode of clinical working across a table is in pairs and in the WLCTS their simulated tasks are designed to be undertaken likewise. The surrounding area supporting the training tables is also spacious and allows the movement of multiple tutors and technicians.

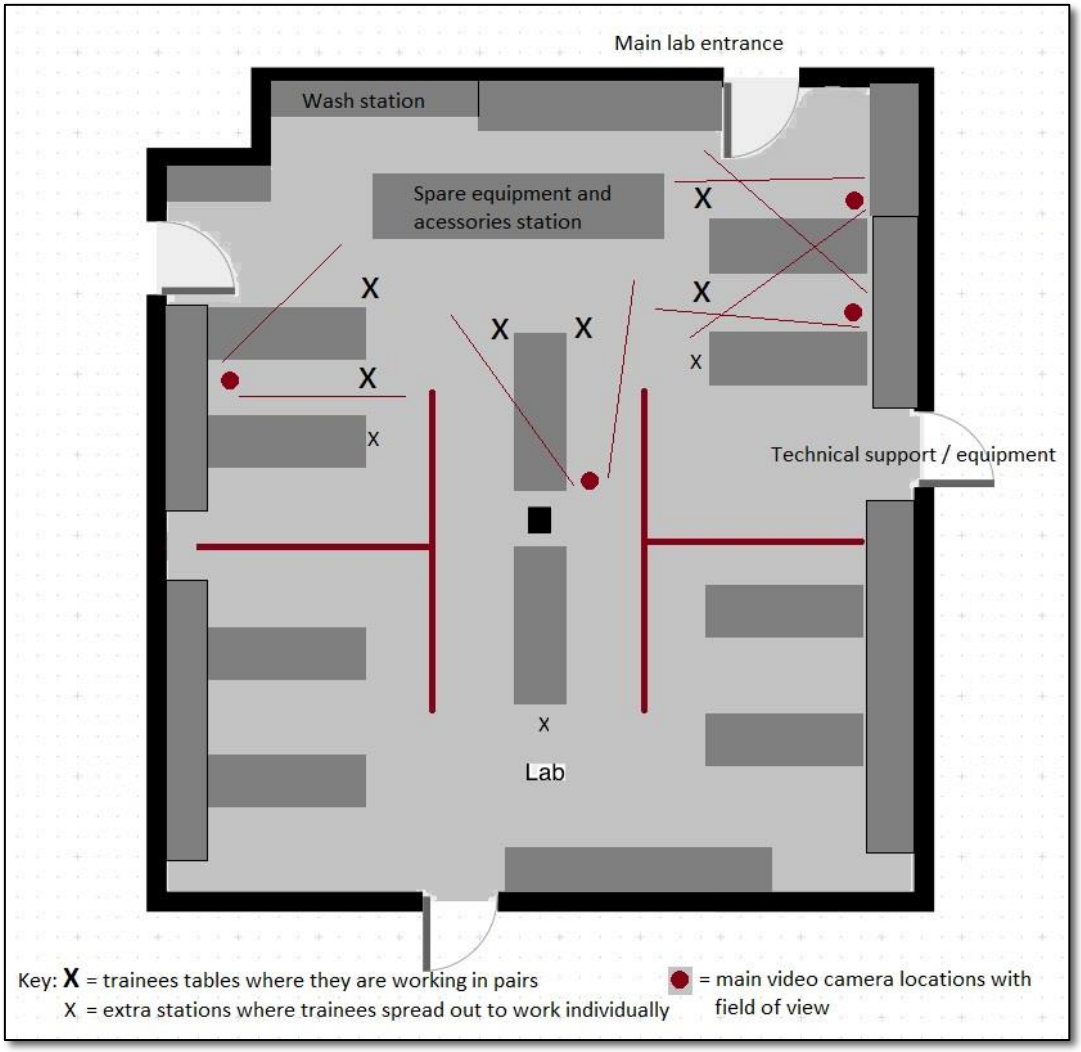


Figure 7. Schematic showing layout of SBT lab with trainee positions denoted by X around operating tables.

Figure 8. Image shows simulation station set-up for laparoscopic appendix by way of example. All accessories shown are identical to that provided in the OT. Trainees perform one appendix each, alternating between assistant and main.

The following materials were used to resource the WLCTS courses.

- Surgical accessories and instruments for undertaking surgical procedures.
    - Surgical laparoscopic instruments are integral to the WLCTS simulation procedures as much as at the operating table and serve as extensions of the trainees' bodies. A major background concept in my thesis is the embedded knowledge contained in them and exchanged between tutors and trainees and moreover, as a conduit through which knowledge is extended and transferred from simulation to operation.
- Animal-based models modified for training in colorectal procedures.
    - Such models contain anatomically representative features of the human digestive tract which can be therapeutically manipulated in haptically comparable approach, position and surgical actions to that of a real patient at the operating table. This is important given the premise that realistic approximation to the zone of activity will aid in retention and quality of knowledge which will be embedded and exchanged in the instruments, and between trainees and tutors via social mechanisms. This again is aimed at reinforcing 'social reality', that is, of objects whose function categorises

them as similar in meaning by the context and activity with which [surgical trainees] are going to interact (Feldman-Barrett 2021).

- Access to colorectal surgical consultants as tutors for the WLCTS.
- Access to colorectal surgical trainees of all grades relevant for the WLCTS and attending the associated courses. This is the cohort I recruited, both for observation and interview.
- Access to hospital OTs and staff undertaking colorectal surgery. This access was important as it helped me to appreciate the way the simulations should try to match the real events as much as possible.

The following materials were available with which to intentionally record specific cues of surgical activity.

- Digital video recording equipment for recording interactions and procedures in the lab for up to three surgical practice tables.
    - Having video recording equipment to hand, enabled me to undertake video analysis of trainees' social interactions while working through the learning steps of tasks.

3.4.3 Research strategy

The WLCTS comprised two short courses suitable for observation with follow-up interviews. Over an annual interval, the initial right-side course took place in July 2018 over two days, with the left-side course taking place in June 2019 over one day. For the right-side course there were a total of six trainees and for the left-side, a total of three. Pairings in the latter worked by rotation around the separated steps of a procedure with a tutor or industry representative fulfilling the role of assistant for the odd trainee. Viable video data only included recordings of trainees paired together. One of the trainees attended both observed courses during the annual interval, making a total cohort of eight who for anonymity, were labelled simply Trainee 1 through to Trainee 8 (T1-T8). To obtain consent to observe the trainees and follow them up with an interview, I gave them an information sheet with a consent[7] request form attached (Appendix 4). All trainees consented. It should be noted however, that the other two left-side trainees had also attended the right-side course previously.

Trainee observation by video recording also included their interaction with surgical tutors, all at consultant level and all preceptors in colorectal surgery. Six consultants were available for the right-side course and two for the left-side. Also contributing to the course and equipment support were surgical product specialists from three supply companies and circulating mainly on the training

[7] As part of consent I also added a provision for the possibility that an online questionnaire might be generated to follow-up the interviews and add to the generation of data. Because of both the word and time constraints of this thesis I felt this was eventually unnecessary.

stations about the use of their devices. Additionally, three educational staff were present (of which I was one) to support the set-up, training and sequential delivery of each stage of the courses.

3.4.4 Sample size criteria justification

Post-course interviewing was constrained by the availability, the distance and time-convenience of the trainees. For this reason I conducted the interviews in various locations; one trainee residence, four hospital coffee shops, one surgical staff room and the remainder over Skype. Face-to-face interviews were audio-recorded with participant permission. Although my sample size was constrained to eight trainees, I conducted 14 interviews in total. Unfortunately, I was unable to conduct follow-up interviews with two of the trainees due to the outbreak of coronavirus (Covid-19), which additionally severely limited my ability to connect with the trainees who had been redeployed. (One of those interviews would have been to follow-up with the single trainee who had attended both courses). To overcome these difficulties and to apply this sample size usefully, I employed the concept of information power rather than the notion of reaching saturation (Glaser and Strauss 1968; Morse et al. 2002); that is, the more relevant information held by the sample, the lower the number of participants required (Malterud et al. 2016). Five key items influence the sample power: i), whether the study aims are narrow or broad; narrow aims yield greater information value, ii), whether the sample is highly specific; where experience, knowledge and background are similar, the sample is likely to be information-rich, iii), whether the study is supported by limited theoretical perspectives or applies specific theory; if limited then a larger sample may be required, Iv), whether the interview dialogue is clear and focused and v), whether the analysis aims at revealing patterns or in-depth discourse detail. These five characteristics determining the information power range were used to justify the sample size and the extent of data with which to make verifiable and reproducible interpretations (Malterud et al. 2016). In terms of these criteria, my aims were specific, my cohort all shared common experiences, terminology and knowledge, and were broadly in the same stage of professional career. I also had a focused dialogue with all my interviewees. I considered my literature review to present an argument for the specific role of sociocultural learning theory. My subsequent data analysis revealed in-depth themes. I therefore believe that my sample size was sufficient for addressing my research questions.

3.4.5 Evaluation criteria for quantitative and qualitative rigour

To establish the validity and reliability of the research findings, my quantitative and qualitative design, approach and execution are assessed against their evaluation criteria. These are specific to each method in the study. Internal validity, external validity, reliability and objectivity summarise the quantitative evaluation criteria, while credibility, transferability, dependability and confirmability

have been given as respective equivalents for qualitative evaluation (Lincoln et al. 1985). Their equivalence is well summarised by Cleland (2015).

3.4.5.1 Quantitative content analysis

An evaluation of my video analysis method is shown in *Table 1*. It details the criteria definitions and their aspects. I address each aspect and provide explicit links to locations within my thesis where applicable. As a study, it matches a quasi-experimental type (Trochim and Donnelly 2001; Maxwell 2013) with some relational elements, as I am looking at the relationships of multiple identifiable (dependent) training interactions to two independent variables of task complexity and trainee experience within the cohort, which have been manipulated to establish causality. This manipulation removes the random assignment and acknowledges the lack of a control for comparison. Because of this, it is important to mention the construct validity exercise as part of the internal validity (Trochim and Donnelly 2001; Shadish et al. 2002).

It should be noted that, while the results of this study provide valuable insight, there are several limitations. One of the main limitations is the small sample size, although the number of pairs and procedures treated was higher (n=17), which can limit the generalisability of the findings. Additionally, the absence of a control group and the use of self-reported measures may also impact the internal validity of the study. Finally, the use of partial regression analysis, while appropriate for the research design, may also introduce limitations in terms of the interpretation of the results.

3.4.5.2 Qualitative thematic analysis

An evaluation of my qualitative method in line with its evaluation criteria is shown in *Table 2*. My approach used guided conversation for my interviews which were then analysed iteratively by abductive thematic analysis (detailed later). This iterative approach is rooted in observations made on the context of what is said and for this reason it follows a grounded theory perspective (Glaser and Strauss 1968; Ryan and Bernard 2000).

There are two main limitations associated with my qualitative criteria evaluation. Credibility is promoted with member-checking (Guba and Lincoln 1994; Trochim and Donnelly 2001). However, due to the restrictions imposed by Covid-19, I was unable to conduct in-person member-checking to verify the accuracy of participants' responses. While it may have been possible to send transcripts for them to check, I made the decision not to do so out of respect for the extensive demands on their time during the pandemic. I was also the only researcher interpreting the qualitative data. Despite this, I used a systematic approach to interview analysis and subsequent coding and categorising to ensure the dependability and credibility of my study. Further, an abductive cyclical process, the use of partial regression data and theoretical frameworks to structure themes, and the

provision of context on the setting and characteristics of participants through *Table 5* in the initial findings chapter contribute to the transferability and confirmability of my results.

Table 1. Evaluation criteria for test of quantitative rigour.

Criteria	Explanation	Evidence	Thesis section
Construct validity **Internal validity**	The extent to which a designed measure is appropriate for what the construct is supposed to measure. The degree to which the study design and data collection methods are free from systematic error and bias, therefore, whether the results of the study can be attributed to the specific variables being studied.	Initial content validity steps (concurrent evaluation of the following construct) (Trochim and Donnelly 2001; Bhandari 2022; Nikolopoulou 2022a) to identify existing measures for task complexity and experience characteristics of trainees by pairing (experience differential and experience combined): i) Collective recognition of arbitrary scores for task complexity by consultant surgeons as trainers. ii) The existing literature for guidance identifies some indices that could be considered useful to generate scores for experience in particular. iii) Identification of suitable score method for rank assignment self-reporting. iv) Multiple criteria analysis to assign numerical values to complexity and trainee experience. v) Identification and categorisation of observed social interactions. vi) Establishing clear coding criteria for dependent variables and use of prior training to identify and tag variables. vii) Use of content analysis software to orient coding and criteria for concise categorical definitions. viii) Inclusion criteria set up to define video code, tagging and reporting parameters.	3.5.5.1, 3.5.5.2 3.5.5.1, 3.5.5.2 Table 3, Table 4 3.5.2 3.5.3 3.5.2 3.5.4
External Validity	The extent to which the results of a study can be generalised to other populations, settings and time periods beyond the specific sample and context of the study.	Nonparametric correlations run to support the predictive validity of self-measured independent variable scores for task complexity and trainee experience (Nikolopoulou 2022b): i) Nonparametric Spearman correlation to test the likelihood of predictive validity and construct validity on task complexity rank score and trainee experience scores. - Complexity score vs. task completion time **0.485*** (*this shows significance <**0.05** 2 tailed). - Rank differential experience of paired trainees **0.128** - Rank combined experience of paired trainees **-0.302** These results demonstrate moderate correlations between rank score method and task completion time supporting predictive and construct strength of self-measure independent variables. - study context, which is similar to other laparoscopic surgical training settings, correlates with recent research showing that increased task complexity and cognitive load are correlated with longer completion times. - Representativeness of the participant sample i.e., colorectal surgeons at ST level is equivalent to demographics of UK ST colorectal population (e.g., M:F = 5:3 gender equivalence (Newman et al. 2022)). - Triangulation and complementary convergent use of thematic interview analysis corroborates with partial regression correlations to raise confidence in findings.	2.13, 4.3 5.4.3–5.5.2
Reliability	The consistency and stability of a measure or study and whether the results of a study can be replicated if the study is repeated using the same methods and procedures.	To demonstrate the reliability of independent variables to coded categories, i) Spearman-Brown split half reliability tests were conducted for data that would be used in regression correlation. - For complexity rank scores for task completion (**0.793**). - Experience differential between pairs (**0.241**). - Combined experience between pairs (**0.675**). Scores above 0.7 indicate good internal reliability, while scores just below 0.7 indicate moderate consistency, while scores below 0.3 indicate inconsistent reliability. ii) Partial linear regressions were used to inference the quantitative findings. The results of partial linear regression can support reliability if the data and methods meet the validity and reliability criteria. iii) Sample size, = 17 coded videos iv) Stable regression coefficients over multiple samples. Outliers were removed for observational consistency.	3.5.6, 3.5.6.1, 3.5.6.2 3.5.4 4.3, 4.4, 5.4.3–5.5.2

Objectivity	The extent to which a study is free from bias and whether the results of the study are based on facts and evidence rather than personal opinions or subjective interpretations.	i) ii) iii) iv) v) .	Data Collection: Used video data to collect data on the trainees' interactions and the video coding software helped in calculating the content length and frequency of occurrences. Data Analysis: Used partial linear regression to draw inferential correlations between trainee experience, task complexity and their interactions. The regression graphs and thematic analysis help to present the results objectively. Qualitative Reinterpretation: Visually reinterpreted video-tagged data as interacting threads of specific social cues, which helped in providing a qualitative analysis of quantitative data. Supervision: Received loose supervision from supervisors, which helped ensure the objectivity of the study. Limitations: Small cohort size and trainee selection bias (trainees attend the WLCTS under their own volition).	3.5.2, 3.5.4 3.5.6, 3.5.6.1, 3.5.6.2 3.5.6.3 6.1, 6.1.2 3.4.3 3.4.4, 9.2

Table 2. Evaluation criteria for test of qualitative rigour.

Criteria	Explanation	Evidence		Thesis section
Credibility	The trustworthiness and authenticity of the research findings. It is concerned with establishing the legitimacy and accuracy of the researcher's interpretations and conclusions. Complemented by ethical considerations and use of secondary data sources.	i) ii) iii) iv) v)	Used a systematic approach to the guided interview method, using a digital recording of interview accounts. Anonymised transcription through outsourcing. Correction of transcript errors and clarification of medical terminology by following audio recordings as part of data familiarisation process. Adoption of the abductive thematic analysis approach and use of a cyclical process, with consideration of supporting theoretical frameworks. Convergent parallel approach with methodological triangulation of content data to compare frequency and volume of social cues to frequency of referral in transcripts.	3.6.5 3.6.5, Appendix 4 3.6.5 3.3.5, 3.6.3, 3.6.5 3.3.5, 3.6.5, 4.6
Transferability	The generalisability of the research findings. This involves ensuring that the findings can be applied to other settings and populations beyond the specific context in which the research was conducted.	i) ii) iii)	Provision of context on the setting and characteristics of participants. Generated seven description rich, contextual themes from guided interview content with selection of the three most relevant to thesis. Although small, the cohort of colorectal surgical trainees is reflective of the UK colorectal trainee cohort.	Table 5, 4.2 3.6.5, Table 6, 4.6 Appendix 7 3.4.4
Dependability	The stability and consistency of the research findings over time. This involves ensuring that the data collected and the subsequent analysis are reliable, that is, replicable by others in different settings.	i) ii) iii)	Used a systematic process for coding and categorising data using NVivo software. Used audio recordings to check and familiarise with data and context and establish medical terminology in the transcript to ensure accuracy of data and correction of errors. Assigned classifications to trainee data to compare thematic data with gender and experience.	3.6.5 3.6.5 3.6.5
Confirmability	The objectivity of the research findings. This involves ensuring that the findings are not biased or influenced by the personal opinions, values or beliefs of the researcher. This can be achieved using a systematic and transparent data analysis process.	i) ii) iii)	Adopted a cyclical, iterative approach to generate themes informed by the theoretical backdrop and by the data itself according to abductive method. Used content analysis data on social and theoretical frameworks to structure themes. Used criteria to establish themes and categories relevant to the study and further fit with convergent quantitative analysis.	3.6.3, 3.6.5 3.6.5 3.6.5

3.5 The Video data

3.5.1 Recording Sociocognitive activity by video

Because my intention was to understand the social interaction of the trainees working in pairs, I set up an observation at each training station with a video recording device. The video camera was set up outside the margins of the activity and it was therefore unobtrusive. My rationale for video-recording social interactions was based on the assertion that visual images provide an information-rich source of data (Alexander 2008) and their creation affords the possibility for both quantitative *and* qualitative analysis of the activity timeline. Additionally, because visualisation can both magnify and reduce aspects of sociocultural practice (MacDougall 2006; Carroll et al. 2008), choosing to film the activity helped me to take the perspective of a (de-familiarised) outside observer and make embedded meaning explicit.[8]

Initially, I considered the rich addition of a qualitative content analysis of video data to extract meaning and understanding from participant interactions through accurate transcription of the conversation. However, upon examination of the video data, it became apparent that the sound quality was poor, making accurate evaluation and interpretation of the audio difficult. Since the audio component would be a crucial aspect of my qualitative video content analysis, I decided that this method would not be useful.

Instead, I focussed on a quantitative content analysis of the video data. This method centres on counting and identifying patterns and trends within the data (Neuendorf 2017; Krippendorff 2018). This approach has precedent in surgical training as an argument for quantifying and measuring movement economy (Glarner et al. 2014; Dimick and Varban 2015; Goldenberg and Grantcharov 2016) and allowed me to extract relevant data from the video, despite the poor sound quality, by focussing on visual cues and non-verbal communication.

3.5.2 Content analysis

To analyse video footage content I used V-Note Pro (V-Note 2014) for its ability to tag and label multiple facets of activity, which could in turn create time-in-action and action-occurrence frequency data for export and statistical analysis. Several visually recognisable social interactions between trainee pairs in the video footage were identifiable and subsequently tracked for analysis following observation of SBT, to see if increasing task complexity or increasing trainee experience affected these exchanges. The frequency of these interactions was counted and subsequently analysed for

[8] I reflect that in actuality, this approach did not remove all familiarity, but it did force me to look at the surgical activity through a more objective and narrower lens than I would have had as a partial and involved actor.

potential relationship variables. Five social interactions were assigned through categorical coding (expounded below). I attached descriptive labels to the observed social interaction categories across all recorded footage. In doing such, I adhered to the guidance set out by Rose (2016) in aiming to describe (with a clear definition in each category) what is observable, that is, to record and code actions which cannot be interpreted widely (Lutz et al. 1993).

3.5.3 Coding categories

In creating category codes to analyse, I postulated that social and cognitive learning would occur and embed through interactions between pairs via the simulations, interactions with tutors and interactions with objects such as surgical devices and instruments, since these activities and artefacts cross boundaries into the OT. Such interactions were observable in the video data and in my view, they form social elements of the professional learning culture of the surgeon which were extracted from the activity being recorded, in the hope that they could reveal something about the sociocultural dynamics they reflect (Sayers 1983; Alexander 2008).

The codes were assigned to all videos, which I subsequently used to 'tag' segments when such activity was observed. Both the number of tags and the accumulated time for them in an observed category generated two sets of data which were turned into the frequency of occurrence per 30 minutes of procedure across all recorded task footages, and the total percentage of occurrence per recorded procedure, respectively. Units of time for tagging were designated by hours, minutes and seconds.

The codes assigned to all tagged procedures were:

1. Trainee-trainee verbal exchange directly related to the procedure.

   This category was selected for every verbal interaction between pairs that I was confidently able to relate directly to the task.

2. Trainee-tutor verbal exchange directly related to the procedure.

   This category was selected for every verbal interaction involving the instruction and guidance of the tutors.

3. Trainee-instrument-trainee interaction (both verbal and non-verbal).

   This category was selected for every interaction and exchange between pairs of unfamiliar instruments or instruments specific to a procedure.

4. Trainee and tutor use of non-verbal communication and cues during the procedure.

This category was selected for every non-verbal exchange between trainees and tutors during a procedure since non-verbal communication was also used to convey or emphasise coordination of tasks and therefore an important channel in distributing meaning.

5. Trainee conversation that was unrelated to the task.

Casual verbal exchange unrelated to the task was also occasionally observed and I elected to tag this for possible correlation to complexity or trainee experience.

The background noise made it difficult to transcribe conversations accurately, but it was useable in providing context to the specific activity taking place and in tagging when exchanges were casual or task-related. The presence of noise interference is a design constraint which is discussed in the final sections of this thesis.

3.5.4 Videographic data rendering process

To prepare for task footage content analysis, I set up the training room to accommodate laparoscopic colorectal simulation. Videos capturing trainee interactions during procedures were recorded in multiple camera formats using a Sony HD Handy Cam, iPhone XR, iPad and Surface-Pro laptop. They were set to capture trainees working in pairs, their faces, upper torso and hand movements (see *Figure 7, Figure 9*). Rendering [9] and analysis of video content took place in stages and is described sequentially below. In *Figure 9*, the trainees' faces have been deliberately obscured to maintain anonymity.

Stage 1. All raw footage was transferred to Windows Movie Maker (Microsoft 2010) for editing as this software can run, edit and combine video segments from multiple formats. I applied systematic inclusion criteria to the footage; first editing out superfluous content mainly appearing before and after procedures. Useable content was further edited to comprise only that with trainees working in pairs. Trainees rotated in pairs from table to table during their linear tasking through the procedures. Due to this, video footage showing their paired practise of those tasks was sometimes composed of contiguous segments, being captured on separate devices. When this occurred, I sequentially combined and spliced the separate segments of these specific procedures together to form a complete procedure in full linear sequence for subsequent content analysis and matched to specific trainee pairs. (Notably, several videos contained footage in which trainees did not work in pairs. Content analysis was still applied to these videos but only for relevant coding categories in case it might have future use). In total, 25 videos were generated for 10 separate procedures and of these,

[9] Rendering is the process of creating the final version of the visual content. To create analysable content for V-Note, this was necessary to undertake to remove superfluous content, and unify the format.

17 met the full inclusion criteria. The footage was saved in one unified format which could then be 'read' in content analysis software.

Stage 2. 17 videos were generated for content analysis using the predesignated codes in V-Note Pro. *Figure 9* shows how the video data capture is aligned. Codes and tag labels are added underneath the video. Tracking explicit segments of information created data within the tagged coding streams. As previously detailed above, the number and frequency of each of the segments provided the source of the key data.

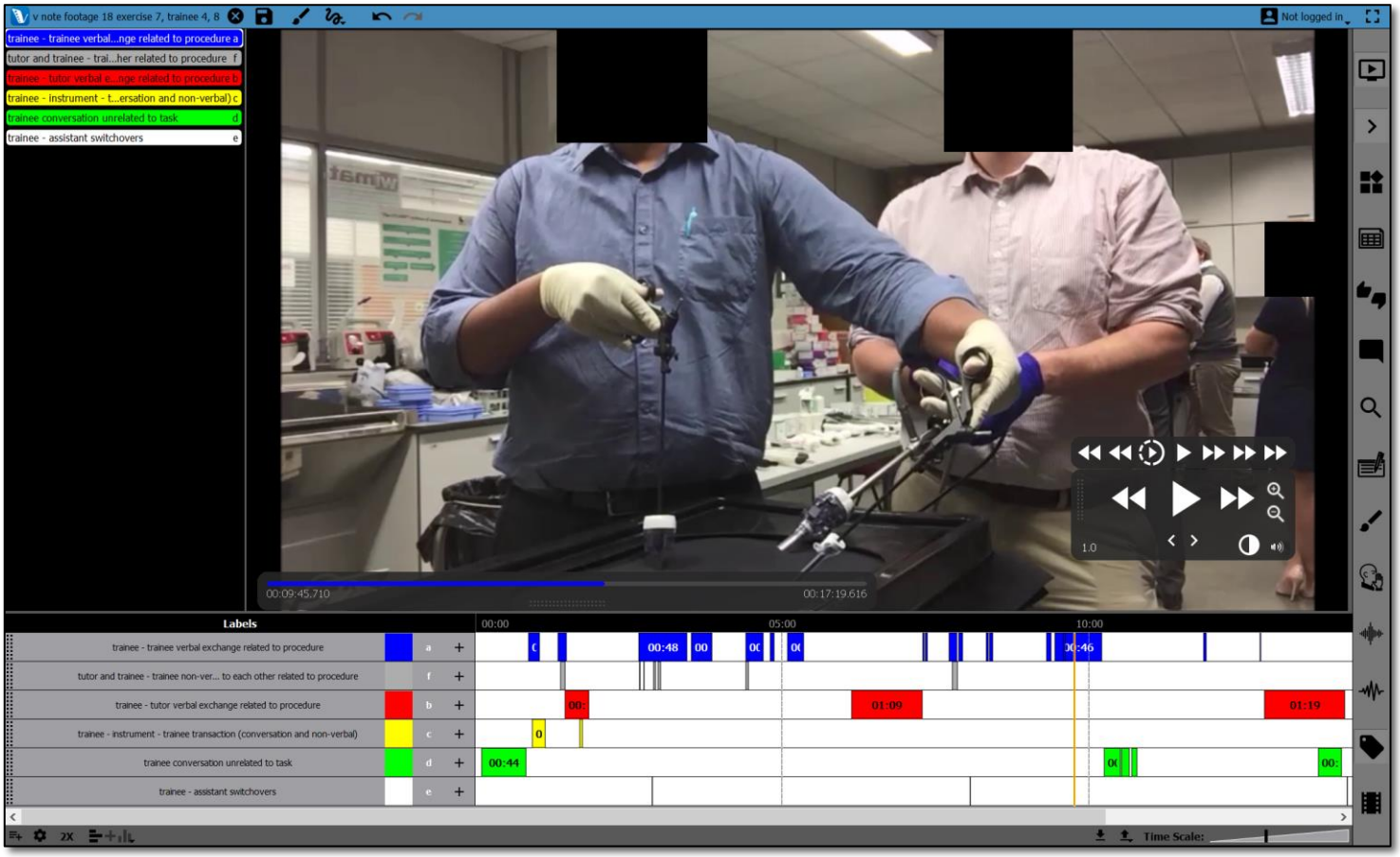


Figure 9. Screenshot of V-Note Pro, video coding software. The capture shows the typical set-up and direction of the camera angle.

Key features that can be seen in this representative view are the trainees working in pairs, their hands, their faces (obscured here) and their shared interaction with the instruments. There is enough space in the camera view to show interaction with the tutors when they come alongside the trainees.

Stage 3. Videos were analysed according to trainees anonymised through numbers T1 to T8. Procedures were categorised as exercises from 1 to 10 ascending, according to a score for complexity, which is discussed below. An iterative process of coding and tagging took place by blending two approaches; first observing and tagging all interactions of interest, which I

subsequently followed up by scrutinising the video sequences of these interactions for up to two specific activities at a time; tagging interactions according to their definitive category.

Stage 4. Due to its export format, tagged social interaction category data was first moved to MS Excel, then to IBM SPSS Statistics 25 (IBM Corp 2017) for manipulation of numerical and categorical variables.

Because I contend that social transactions foment and mediate socially constructed learning, both the cognitive burden of training task complexity and relative limitations in trainee experience (as an indicator of social competence and confidence) may have impacted social interactions which convey learning and consequently shed light on what social mechanisms link to the embedding of skills. As such, procedure complexity and trainee experience became my independent variables.

3.5.5 Establishing procedure complexity and trainee experience by rank

3.5.5.1 Complexity

In aiming to establish a possible relationship between SBT complexity and social interaction, I needed to set numerical criteria for the procedural difficulty. It is not enough to tacitly acknowledge the difficulty gradient in the SBT tasks. I first determined a criterion to enable me to categorise the SBT procedure levels into *basic, intermediate, or advanced* based on the point at which trainees are usually exposed to component dexterity skills in their surgical training pathway from their initial basic skills course onwards, which has also been informatively agreed by course design and collective judgement of colorectal surgical trainers. I further define these criteria below.

Basic – defined by the set of hands-on skills trainees will have used in the OT and have exercised in prior basic and intermediate simulation courses.

Intermediate – defined by the set of hands-on skills that trainees have likely used in either prior SBT or in the OT in limited intervals, with increasing refinement in dexterity.

Advanced – defined by a set of hands-on skills that are specific to the laparoscopic colorectal procedure being simulated and built on existing collective dexterity skills.

I assigned a level to each one of the 10 procedural SBT exercises comprising the right and left-side hands-on SBT. On further noting the *minimal* number of psychomotor manoeuvres required to complete one whole step, I was able to consider compiling a numerical ranking for complexity. To do this, I adopted a simple mark-based scoring method (Borgulya 1997) as an approach to analyse a combination of multiple criteria assigned to give a ranking to evaluated groups in a category (Sureeyatanapas 2016). *Table 3* details the names of the procedures with their designated complexity

and the mark-based ranking applied to them to score their complexity level.[10] Establishing a numerical score (shown in the far-right column) allows analysis of the correlation of social observations against an informed calculation for complexity.

[10] See the learning and teaching plan in Appendix 2 which details the procedures listed in *Table 3*, and their objectives. These procedures comprise either an individual technical skill, or they form one part of a larger number of sections to learn that would be required to complete an operation.

Table 3. Multiple Criteria mark-based score analysis to assign complexity scores to the SBT procedures of the right and left-side courses of WLCTS.

Procedure complexity calculation	Qualitatively understood level of difficulty	Categorical, Basic = 1 Intermediate = 2 Advanced = 3	Number of laparoscopic movements in exercise	Categorical based on movements, 4 = 1, 5 = 2, 6 = 3, 7 = 4, 8 = 5	Total for categorical calculation of complexity score
exercise 1 - practical session using 30^{O} scope	Basic	1	4	1	**2**
exercise 2 - roeder knot and lap appendix	Basic	1	5	2	**3**
exercise 3 - basic intracorporeal suturing and knotting	Intermediate	2	5	2	**4**
exercise 4 - SBT	Intermediate	2	5	2	**4**
exercise 5 - vascular pedicle and mobilise	Advanced	3	6	3	**6**
exercise 6 - bowel intracorporeal anastomosis	Advanced	3	8	5	**8**
exercise 7 - left side course SBT	Basic	1	5	2	**3**
exercise 8 - left side course steps 3 – 7 right ureter medial dissection at promontory left ureter gonadals IMA pedicle	Advanced	3	6	3	**6**
exercise 9 - left side course splenic flexure mobilise	Advanced	3	4	1	**4**
exercise 10 - left side course isolation and cross stapling of rectum	Advanced	3	5	2	**5**

3.5.5.2 Experience

Similarly, I explored the possibility of any emergent relationship between trainee experience or job grade to the level of their social learning transactions using the coded data. This is because the frequency or length of interaction, whether verbal or with instruments, may also be linked to relative trainee experience, (or how much a trainee may have already embedded into the surgical community of practice). To do this, I also needed to establish trainee experience criteria. Hopper (2007) has collated literature figures on the number of cases a trainee will have done in specific surgical procedures to achieve an acceptable standard of measured outcomes. In the case of laparoscopic colorectal surgery, a margin of 55 to 80 cases has been indicated as the level for competency (Tekkis et al. 2005).

Trainee responses for measures of training years, professional training grade, procedures performed and assisted conversions from laparoscopic to open and prior simulation-based course attendance indicate scoring and ranking experience levels. To combine the values for these multiple criteria into a score for trainee experience I used the same multiple criteria decision analysis method as above, to generate a model for relative ranking between multiple criteria (Borgulya 1997). Here, an incremental score point was applied to each rank of the multimodal measures, without undertaking an exhaustive comparison. *Table 4* shows the experience scores for the trainees which were assigned by mark-based ranking.

Table 4. Mark-based score analysis to assign experience scores to trainees.

Code	Grade	category points for training grade CT -> ST6 = 0 -> 4	No. clinical procedures performed / assisted	procedures >50 = 2, procedures <50>25 = 1, procedures <25 = 0	No. prior Sim based courses attended	category points for familiarity with simulation, 0 -> 3 = 0 -> 3	total points for assigning category score
Trainee 1 (T1)	senior clinical fellow	3	3 /15	0	0	0	3
Trainee 2 (T2)	ST 6	4			0	0	4
Trainee 3 (T3)	ST 4	2	35	1	3	3	5
Trainee 4 (T4)	ST 5	3	2, 35	0 RS, 1 LS	2, 2	2	5 RS, 6 LS*
Trainee 5 (T5)	SpR	3	20	0	1	1	4
Trainee 6 (T6)	ST 3	1	6	0	0	0	1
Trainee 7 (T7)	ST 6	4	50	2	3	3	7
Trainee 8 (T8)	senior clinical fellow	3	2 /14	0	1	1	4

**Because T4 attended both the right and left-side they have two experience scores.*

3.5.6 Representation of videographic data

Video analysis produced quantitative data for the frequency and volume percentage of trainee social interactions tagged in task activity. These data were used to augment sociocultural and sociocognitive findings of qualitative analysis. Trainee experience and task complexity were two determining variables, which my literature review predicted would issue differences in the way social interactions occur. By inference, these differences were used to indicate cognitive distribution and semiotic development in action. Video observation therefore presented an opportunity to add quantitative data to sociocultural findings which were mainly qualitatively led.

To draw inferences about patterns in emerging data, I elected to use descriptive statistics because the volume of data allowed for this. Task complexity and trainee experience were interacting independent variables that might predict the level of socially negotiated behaviour. A way of representing this can be seen in the following Venn diagram (*Figure 10*). Analysis of correlation with social cues due to one of the determining variables needs to take account for the impact of the other. Therefore, a linear regression tool known as partial linear regression was used. The use and interpretation of this requires some explanation (discussed below). The relevance of such analysis is linked to RQ 1, which explores the impact of trainee experience, cognitive load of tasks and semiotic acquisition during socially transacted learning. The postulation is that these activities that are negotiated in simulation are cognitively distributed through social mechanisms to be understood in their negotiated work of the OT.

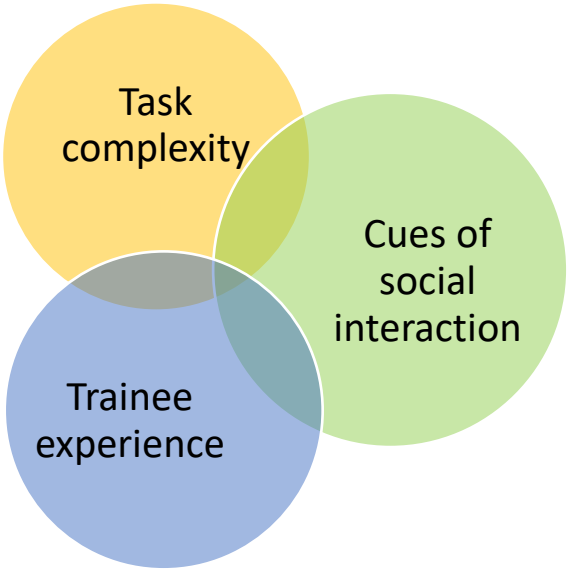


Figure 10. Venn diagram showing that trainee experience and task complexity both influence the observed threads of sociocognitive activity.

3.5.6.1 Partial linear regression

Linear regression R^2 was considered because of its ability to indicate potential social cue patterns in observations against changes in task complexity (Lewis-Beck 2011). As a graph, R^2, that is the regression coefficient, represents the proportion of variation in 'Y' which may be explained by 'X' and attempts to establish a cause-effect relationship while testing correlation. Because correlation analysis of trainee experience and vice versa, could not be isolated without accounting for the possible influence of the other, the descriptive method of *partial linear regression* was selected as it accounts and corrects for the presence of more than one independent variable (Ryan 1997).

3.5.6.2 Interpreting partial linear regression

The key element of linear regression remains R^2. Taking the definition of correlation strength from Rumsey (2021), R^2 of $>\pm0.7$ = strong relationship; $>\pm0.5$ = moderate relationship; $>\pm0.3$ = weak relationship, noting that the relationship can be positive or inverse. Integer values along the X and Y axes are not the actual observed values taken directly from the data (such as time or experience ranking, etc). Each plot on the graph has a value calculated through the condition of an extra independent variable. The significance of this is that the graphs can potentially (and in fact do) show the X and Y values according to the conditions of their partial regression treatment. That is, they can both show *negative to positive scale values*.

One caveat in this descriptive method is that the sample sizes both for complexity and trainee cohort, are not large enough to test the probability of any correlations observed occurring by chance but can only indicate trends for which further study is recommended. However, correlation trends indicated by regression may both support and be supported by the thematic analysis of trainee interview data. Two distinctive sets of experience information arose from its analysis through paired interaction. First, the difference in ranked experience between individuals in a pair was selected to quantify effects on procedure time and observed social cues due to possible differences in *individual* agency. Second, the combined rank experience of pairs was selected to account for the possible augmentation of effects due to *combined or shared* agency.

3.5.6.3 By organisation of social activity as seen on video timelines

Observation of multiple, simultaneously interacting threads of activity within the videos also provides a rich text from which to interpret social interaction. The contentions from my literature review help me organise this activity through the negotiated knotworking narrative of CHAT. Re-drawing the frequency and volume of the observed social interactions is a way of imagining and illustrating their interplay. Through this illustration, I aimed to demonstrate that social interactions provide the point at which meaning and cognition is made for the trainee, and therefore this may help towards

exploring RQ1 and RQ2. I note the observed and tagged social interactions and re-illustrate them as threads of co-constructed activity, interacting to exchange semiotic cognition toward a common goal.

3.6 Interviews

3.6.1 Undertaking interviews as a guided conversation

While the quantitative content of my video regression analysis was useful in identifying specific social activities, I believed it was important to prioritise a qualitative investigation of the sociocultural aspects specific to the relationship between SBT and the changes in clinical practice facilitated by the WLCTS. In my study, I specifically aimed to explore the learning experiences of colorectal surgeons and therefore, interviewing the trainees involved was essential. These interviews created rich descriptions, which were analysed for patterns and themes (Warren 2001).

In order to draw out how the trainees make sense of their training in the real world of operating, I decided to adopt a guided conversation approach for the interview strategy. There are several reasons for this. Guided conversations are a type of semi-structured interview. Conventionally, this approach involves asking a set of predetermined questions to participants with room for flexibility and additional probe questions (Ritchie et al. 2013; Braun and Clarke 2021). The flow of conversation in a guided approach is more reflexive, underpinned by the overarching topic and less constrained to a predetermined route of fixed questions compared to a traditional semi-structured interview (Kvale and Brinkmann 2009). However, questions still serve as signposts for the discussion, and the approach has some structure around which the interview discussion develops (Roulston 2008). Guided conversation allows for a degree of standardisation in the interview process while still permitting for some openness and exploration of the participants' experiences. Furthermore, a guided conversation-style interview lets the interviewer actively participate and share their own knowledge and views on the topic while still maintaining a structured conversation that would enable identification of common patterns of thinking or meaning among the interviewees (Fielding and Thomas 2008). It has been demonstrated as a good strategy for discovery (Fielding and Thomas 2008) with room for flexibility in subsequent analysis (Lofland and Lofland 1995).

This approach facilitates the inclusion of predetermined themes or areas of exploration, including ideas shaped by my observations in the training setting. Additionally, it conforms with my aim to understand the trainees' collective, professional, meaning-making context and further, in aiming to identify their particular common and recurring patterns of thinking (Kvale 1996) while providing a structure for the discussion with a defined cognitive objective (Corbetta 2003). Additionally, this approach flowed naturally into an abductive thematic analysis with the intent to draw common

sociocultural and cognitive experiences together (Warren 2001; Ritchie et al. 2013; Braun and Clarke 2021).

In-depth and unstructured interviews without predetermined themes (Ritchie et al. 2013) present an alternative approach and are used in phenomenology where the focus is on understanding the subjective experience of individuals with the aim of uncovering the underlying meaning and essence of individual experiences rather than identifying common patterns in the dialogue or recurring themes, the latter of which (in the context of clinical practice facilitated by the WLCTS) was the aim of my study. For this reason I did not consider an unstructured approach further.

3.6.2 The thematic approach to analysis

I used *abductive* analysis for my thematic development. Thematic analysis has been traditionally characterised as a tool to use across different qualitative analytic methods (Boyatzis 1998), with its coding process located around mainstream analytic activities, for example, grounded theory (Ryan and Bernard 2000) and interpretive phenomenological analysis. The process involves identifying segments of text that are linked by a common "theme" or notion (Gibbs and Flick 2018). By its own merit, it is a systematic method (Braun and Clarke 2006) for identification, analysis and reporting of patterns in the interview data, but moreover, allowing a pathway for the interpretation of social constructs found within. It is possible to interpret into codes, patterns and contextual notions that might be implied, if not explicitly stated within the narrative.

Conventionally, themes have been identified in one of two main ways: inductive or deductive (Braun and Clarke 2006). A rationale for these approaches is expounded in Appendix 6. Abduction, although a less mainstream mode of reasoning, is proposed in the social methodology literature as an analysis which acknowledges the existence of pre-existing hypothetical positions, but also where a theoretical position is not known. It is not without criticism for its validity. However, it is worth consideration. Propounded by Peirce (1935), Kennedy and Thornberg (2018, p. 52) understand this mode as the creation of a "provisional hypothesis to explain particular empirical data and pursuing this hypothesis with further investigation" (Douven 2011; Charmaz et al. 2018). In this lens, qualitative research involves a selective process to examine how data may support existing hypotheses or rather, how it may infer modification of models of understanding. Abductive reasoning acknowledges that data is shaped by prior knowledge (Kelle 1995), yet also acknowledges that data might be shaped by the synthesis of other ideas. The process is iterative and involves moving between data and theory, and data and analysis (Kelle 2014) to make comparisons and interpretations of patterns that infer plausible explanations (Bryant 2009; Thornberg 2012). I take the definition from Kennedy and Thornburg (2018) as my understanding of abduction. This mode of reasoning is therefore situated between deduction and induction and allows the possibility of analysis through a synthesis of prior

ideas while being open to purporting other unconsidered paradigms at play. Therefore, it is an attractive approach for me. However, abduction has been criticised for its permissibility of inferences which could be drawn from many emergent hypotheses (Paavola 2004). Constraints can be added by using strategic rules such as requiring a plausible hypothesis to be consistent with the clues in the data and employing critical scrutiny to both emerging conventional and 'wild' hypotheses (Paavola 2004). Another challenge to abduction is that analysis may yield interpretations leading to multiple legitimate explanations, which might render my research findings too complex and lack validity or strength. This issue can be mitigated to some extent by a process of examining and contrast exercise, which may allow both rejection of a hypothesis or strengthening of a synthesis of ideas. Three further points give strength to abductive reasoning: First, the approach enabled me to treat my theoretical framework and conceptual models as both provisional and modifiable (Thornberg 2012; Charmaz 2014); Second, it encouraged mental conversation between different emergent ideas, since learning is after all, a dynamic social construct (Thayer-Bacon 2003; Tavory and Timmermans 2014); and third, while knowing that I have assumed prior knowledge, I also intended to be open-minded (Kennedy and Thornberg 2018).

Different approaches represent a variety of ways data are thematically coded. What is common is the intention to collate evidence into themes and capture something important about the data concerning the research question. One of the main reasons I chose thematic analysis is this very flexibility; I approached my interview data mainly abductively.

In conducting my qualitative study, I evaluated several methods of analysis that could potentially provide rich and detailed information. I initially considered the use of case studies and narrative approaches (Bruner 1986), but ultimately determined that they would not fully meet the objectives of my research question, which aimed to link the meaning made through collective patterns with the social interactions of trainees. Narrative analysis (Riessman 2008) could be useful in exploring the stories and experiences of individuals, but would not fully inform the cultural aspect of my social study which explores the meaningful experiences of the trainees in relation to the underlying theories of DCog and CoP embedded in CHAT. I subsequently evaluated the use of conversation analysis (Hutchby and Wooffitt 1998) to look at the structure and organisation of talk-in-interaction, which might uncover underlying social structures but I determined this would create an interesting but separate line of study. Additionally, when I considered phenomenology (Moustakas 1994; Smith and Osborne 2008) as mentioned in 3.6.1, I acknowledge that while it could reductively deliver in-depth meaning and structure to the trainees' lived experiences (Ritchie et al. 2013), I decided that thematic analysis would fit more appropriately for its ability to identify and focus on common experiences and ideas, particularly in my abductive pragmatic approach (Murray 2008) in which I was

aiming to link findings from two types of data together. Tashakkori and Teddlie (2010) support the use of thematic analysis as a suitable method for this type of research.

3.6.3 From interview to thematic data: planning process

I aimed at a systematic approach to the interview method similar to that proposed by Kvale (1996) in seven stages; thematising, designing, interviewing, transcribing, analysing, verifying and reporting.

Thematising: I determined that my research questions required a direct address of trainees' perceptions of SBT. The thematic framework for interviewing arose from constructs provided by the research questions and the theoretical position of my literature review. A guided interview approach was suited to uncovering their perceptions and to contextualise simulated activity that was translated into clinical practice.

Designing: My interview guides for the left and right courses and follow-ups comprised of a set of broad interview questions that were shaped by my reflective experiences of the WLCTS as an educator and by the social-orientated contentions set out in *ch.2*. I intentionally set out the questions to serve as topic pointers, hoping to limit the standardisation of interviewees' responses. I judged it unnecessary to keep to the exact language of the questions. Furthermore, neither was linear conformity to the questions between interviews crucial to subsequent analysis. The interview format was a guided approach which is a form of semi-structured interviewing. The interview question guides are given in Appendix 5.

Interviewing: Across both the right and left-side courses, I interviewed all trainees attending the course; first, within a two-week window following the course and second, around eight months following the course, to allow opportunities for preceptored laparoscopic colorectal experience to frame their thought processes and add extra insight into the transfer of sociocultural and sociocognitive-mediated learning (Pimmer et al. 2013; Markauskaite and Goodyear 2016) to the OT. Guides for both the first interview and second interview followed similar lines of inquiry with some slight modifications in the eight-month follow-up to explore trainee reflections from the OT environment. Interview times ranged from 16 minutes to 59 minutes. Two trainees gave shorter accounts in comparison to the rest of the cohort.

Transcribing: I outsourced the transcribing to a recommended company (Virtutype Ltd), with instructions to copy to 99% accuracy, excluding 'ums and ahs', repeated words, emotions, background noises and meaningless prompts. Anonymity was maintained with the transcriber; trainee numbers T1 – T8 were substituted in place of names. Subsequently, I screened all transcripts with interview playback to immerse myself, correct minor errors and verify medical terminology.

Analysing: This was a systematic, iterative and cyclical process, and towards developing themes I became increasingly familiar with the interview narratives. Based on a constructionist approach, my abductive thematic analysis comprised three elements: coding, categorising and theme development. I managed this process with NVivo-12 (QSR International Pty Ltd. 2020), which is an organising platform to facilitate coding and data categorisation.

Coding – In order to extract meaningful insights from the data, my search was guided by my research questions arising out of my literature review contentions and further, through understanding that trainees must interpret their own learning process. My initial step was a search for specific words, terms and phrases using criteria of content frequency and context. In tagging this data I assigned labels to both link and identify their content and context across all transcripts.

Categorising – This raw layer of coded conversation was subsequently categorised abductively; that is, my emerging categories were informed by the coded data but also guided by my organising theoretical framework and overarching research questions. This approach was flexible and enabled me to identify patterns and connections in the transcript while keeping my theoretical research position in mind. As a first category step, I collated these codes into common semantic and syntactic meanings. I then contextualised these categories according to the conversation and then consolidated them further based on their fit with my existing theoretical contentions and RQs. This exercise raised initial categories such as learning transfer, communication in simulation, or where meaning or understanding was connected to the use of instruments, for example.

Theme development – Through subsequent collation and synthesis of categories into a cohesive and meaningful interpretation of the data, I distilled the categories into overarching themes and subthemes that were closely aligned to the direction of my research questions and background literature. This process overlaps with my verification stage.

Verifying: I critically evaluated relationships between themes and subthemes, with the aim of establishing connections between the data, the theoretical perspective and content observations from my quantitative analysis (to compare frequency and volume of recorded social cues to frequency of referral to these as implicit ideas in the interview transcript). That is, I systematically checked the fit of the data against its interpretation (Morse et al. 2002). Screenshots of the iterative process within NVivo-12 can be found in Appendix 7. Member-checking was not undertaken due to Covid-19 restrictions and duty reassignment of the participants.

Trainee classification data such as rank experience and gender were assigned as cases to analyse themes, informing for any possible patterns according to these categorical units. The interview data

was assigned to four folders in the NVivo-12 file section according to the right and left-side initial and subsequent eight-month follow-up interviews for coding.

Reporting: I generated several meaningful themes to consider as potential subjects of interest to the place and impact of surgical simulation. In the interests of the research focus I applied exclusion boundary criteria to these. They were, i), to focus on those themes and subthemes which fit most explicitly to the exploration of my RQs, ii), to consider themes and categories with the highest frequency of mention across the transcripts and iii), by using NVivo's capability to explore the distribution of codes against trainee categories such as experience, designation (T1-T8) and gender, it indicated which themes provided richer links through cluster density. The result of the application of these criteria gave three themes.

3.7 Ethical considerations

The premises of my thesis are underwritten by the notion that the surgical simulation environment is rich in socially organised activity from which it should be possible to gain systematic insight into learning practices and transfer. My questions are therefore physically bounded to the SBT lab and require the voluntary involvement of the surgical trainees involved in the training programme. As noted in section 3.4, all trainees consented to take part in my study. Appendix 4 shows the consent form, which also detailed their freedom to opt out at any time.

I received ethical approval to undertake video-recorded research observations and interviews outside of the clinical setting, in the surgical SBT situation. This was granted on 21st June 2018 by the School of Social Sciences Research Ethics Committee of Cardiff University (Reference SREC/2791). The ethical approval is noted in Appendix 3. I maintained confidentiality in any presentation of visual footage from the video analysis by digitally obscuring the faces of the trainees and tutors. Trainee identification in both video footage and interviews has been designated by numbers (T1-T8), which I generated in order of the trainees' first interview schedule following the right and left-side courses.

There are two notable ethical challenges within the context of the SBT lab. First, in my professional situation, I was involved in the set-up, delivery and management of the course, as well as providing some teaching. As a tutor and course facilitator, I recognise the power relationship between trainees and tutors. I have knowledge and experience that, aligning with a Foucauldian view (Foucault and Gordon 1980) may have introduced conscious self-regulation into the activity being observed (Foucault 1978; Sergiu 2010). No matter how much I aimed to maintain the neutral position of an observer, there must be some bias implicit in the activity of the trainees toward me. To minimise my presence in field observation, I used non-invasive cameras to record the surgical practice activity. This meant my facilitator input was also recorded and although conscious that I was an actor in my

study, I undertook my activities as naturally as possible. Further, I discounted through video editing, any interactions between myself and the trainees, as a way of mitigating any possible biased observance due to the Hawthorne effect (Thompson et al. 2003). Direct interaction such as interviews with trainees, may have provided a more equal power relationship because the context was outside of the training situation. However, in perceiving me as a non-clinical interviewer, trainees' might have been hesitant to representing some of their experiences to me. Second, in belonging to the culture and activity of SBT I was an "insider" (Saidin 2016; Fleming 2018), the significance of which has been discussed at length. My awareness of this helped address my own potential bias for potential subjectivity toward data findings and also, the possibility that I might find some insights insignificant, which might deserve to be made explicit to an outsider. I was also overtly familiar with the surgical environment both in the simulation and clinical practice context, which is a well-documented phenomenon of social research (Delamont and Atkinson 1995; Hammersley and Atkinson 2007). I shared a common medical and scientific language with my surgical colleagues and I did not want to inadvertently overlook its rich narrative textures. Thematic analysis of interviews by design, facilitated engagement in the narrative with some objective, which may have helped counter the severity of any familiarity. Nevertheless, I acknowledge the difficulty in suspending the presumptions that derive from my shared knowledge which would render me blind to the significance of some of the words and actions of the trainees I wanted to observe. However, I mitigated some familiarity by using the difference in the way the trainees as qualified clinicians, belong to a group which transcends SBT and moves with agency beyond my own. They engaged with their own shared knowledge and commonalities in language. I also counteracted familiarity in the research design by intentionally using a mixed methods approach to the data collection. This has been argued to improve the level of confidence in data findings (Denzin 1978; Kelle 2005) and further, I attempted to employ strategies for reducing familiarity (Allan 2018) by the intentional use of non-clinical terminology where possible and cultivating a reflexive habit of questioning the activities which appeared obvious to me; both of which have been proposed by Delamont et al. (2010). Additionally, I drew on the attempts of previous qualitative research using visual methods of gathering data (Mannay 2010) to inform an impartial approach to analysis. These approaches went some way to addressing my own sociocultural bias.

3.8 Summary

My methodological approach was based on contextual observation of real simulation course settings. These presented the opportunity to capture and categorise social and material interactions between trainees through quantitative content analysis of SBT video footage, with subsequent guided conversation-styled interviews to yield qualitative insights. The coded video data was scrutinised for

correlation by task complexity and by existing trainee experience levels. Interviews were treated to abductive analysis where trainee insights were organised into key themes. Some thematic findings were supplemented by the video analysis through methodological triangulation and complementarity. Furthermore, the coded categorical video interactions were treated to illustration according to the social theories as my organising framework. The final iteration of the thematic analysis of the interviews through the coding process in NVivo-12 (QSR International Pty Ltd. 2020) yielded three distinct themes (shown in *Table 6*) linked directly to the RQs informed by the literature review. There was contextual overlap within the thematic narrative, indicative of the underlying richness of the text. Other themes and subthemes of relevance to how trainees transition from simulation to operation arose; however, their focus is not within the remit of the present thesis. The complete list of themes and subthemes can be found in Appendix 7.

4 Findings: An overview

4.1 Introduction and Overview

This short chapter is the first of four, detailing the findings from my analyses and presents initial characteristics contained within the data collection. It aims to provide a contextual outline. Through analysis of task completion times, I then subsequently demonstrate construct and predictive validity (Trochim and Donnelly 2001; Bhandari 2022; Nikolopoulou 2022b) in my criteria ranking calculations for task complexity and trainee experience through the video observations (*Tables 3 and 4, p.55, p.57*); since any correlation may reveal the extent to which task completion is both influenced by complexity and the prior experience level of the trainees. Following a summary, I outline the themes raised through my interview abductive analysis which go on to title the following three chapters.

4.2 Initial interview, video observation and trainee characteristics

Table 5 presents all eight trainees involved in the WLCTS right and left-side courses, who formed the interview cohort, yielding 16 transcripts from initial and follow-up interviews. Trainee 4 attended both courses and was subsequently interviewed after both of them. Two of the cohort did not complete follow-up interviews; trainee 4 (in the left-side follow-up) and trainee 6 (in the right-side follow-up). Interview length ranged from 16 to 59 minutes, with an average duration of 39 minutes. The two shortest interview dialogues were given by trainees of non-European cultural backgrounds. Three of the interviewees were female. *Table 5* here and *Table 4* in the previous chapter show that the cohort attending the courses had a broad range of experiences as defined by their years in training, previous procedures performed and prior course attendance, and this range fits within the normal criteria for acceptance to attend the WLCTS courses. Although analysis of thematic feedback by gender is not the focus of this thesis, a cursory comparison of responses between both genders revealed similar ratios of thematic content and word usage.

Table 5. Overview of Trainee Cohort.

Code	Specialty at course attendance	Years in training at course attendance	Training grade
Trainee 1 (T1)	General surgery	5	Senior Clinical Fellow
Trainee 2 (T2)	General Surgery	>5	ST6
Trainee 3 (T3)	General Surgery	6	ST4
Trainee 4 (T4)	Colorectal	3,5	ST5
Trainee 5 (T5)	General Surgery	7	SpR
Trainee 6 (T6)	General Surgery	1	ST3
Trainee 7 (T7)	Colorectal	4	ST6
Trainee 8 (T8)	General Surgery	3	Senior Clinical Fellow

Seventeen videos recorded the interactions of trainees working in pairs. One out of the pair worked as the main operator while the other held the camera and retracted instruments. Once certain operating steps in the exercises were completed, the pairs switched roles. The duration of the recorded footage for paired trainees ranged from 10 minutes to 1 hour and 26 minutes, with an average duration of 41 minutes.

4.3 Longer exercise completion times correlate with increasing task complexity

The partial regression (*Figure 11*) for the time taken for trainee pairings to complete the simulated procedures shows a rising and correlating trend with increments in ranked procedure complexity. The linear correlation coefficient (R^2) is 0.51. This is a moderate and positive correlation (Rumsey 2021), which suggests increasing complexity has some influence on the time taken for trainees to complete the task. Recent findings of researchers (Nadolski et al. 2005; Haji et al. 2016; Papachristofi et al. 2016) show that it takes longer for trainees to perform a complex, cognitively demanding task than a relatively simple one. The verification of my rank scoring method by assigning a complexity value to tasks is indicated by a positive correlation with the completion time, with further predictive and construct validity test scores (see *Table 1, ch.3*) demonstrating the likelihood that self-measures for complexity (and prior trainee experience) have internal and external reliability.

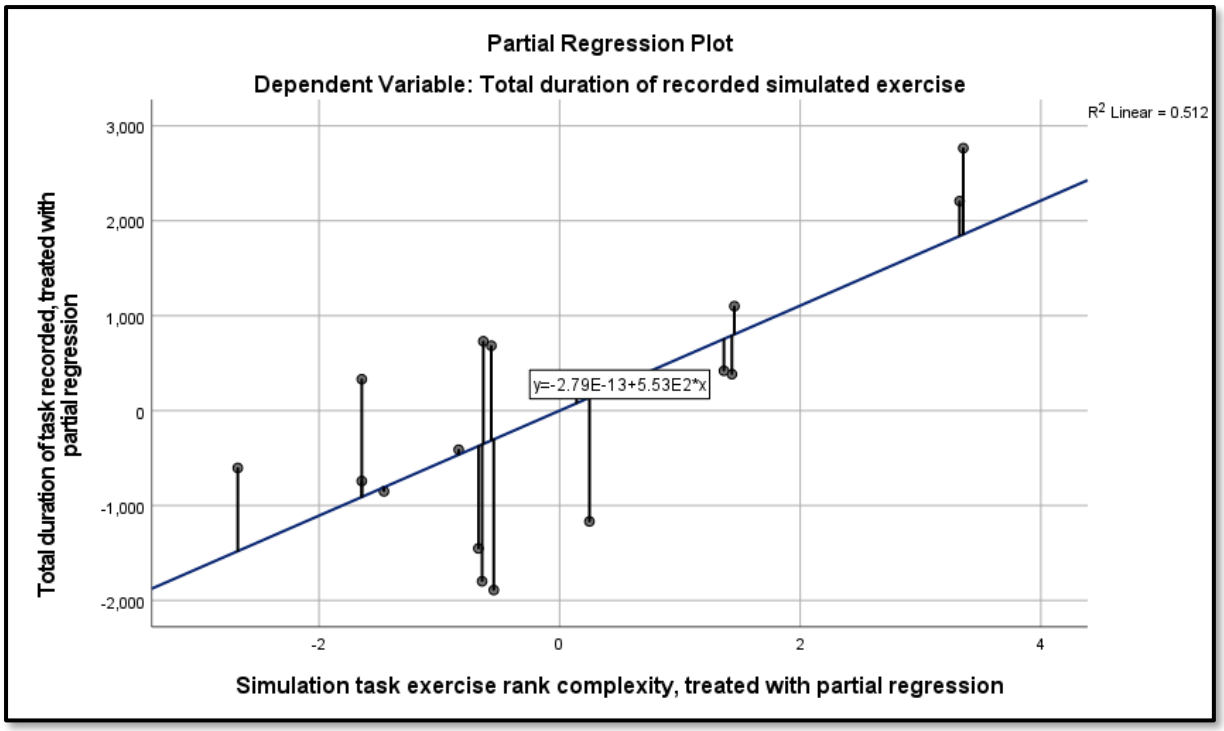


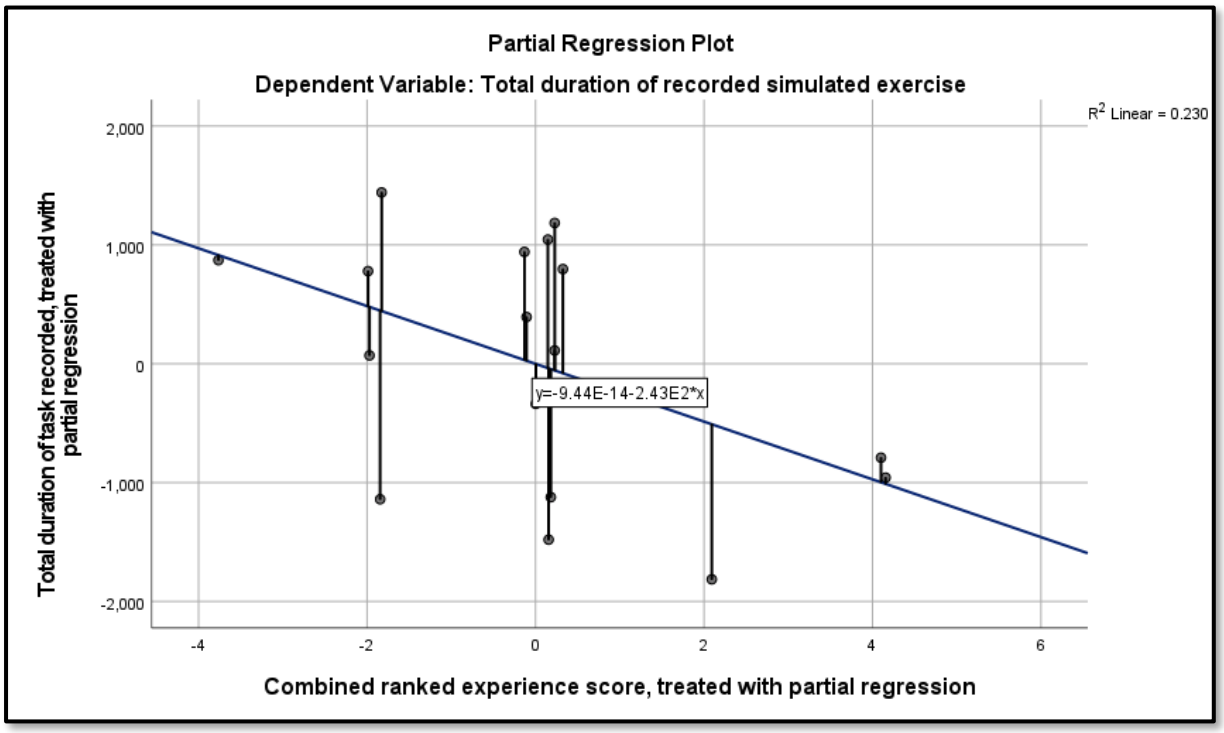
Figure 11. A partial regression plot indicates procedure duration is moderately affected by increasing complexity of the exercise.

4.4 Shorter task completion times correlate with increasing paired experience, but not an individual experience

The partial regression correlation (i.e., accounting for complexity as an irreducible independent variable) shown below in *Figure 12a*, infers that as the paired experience of trainees increases, task completion times reduce. R^2, that is the linear correlation coefficient of this relationship, is -0.23 (weak and inverse (Rumsey 2021)). Insofar as the data provided shows, the coefficient value suggests that the combined agency indicated by the interacting experience of trainees has a small but visible effect on procedure completion time, where the increasing ability of trainees working together leads to a quicker finish. Simultaneously, partial regression exploring how procedure time correlates with the differences in experience between trainees working in pairs *(Figure 12b)* gave a negligible R^2 value of 0.06. This suggests that the individual (experience-based) contribution of trainees in their pairing did not impact procedure time.

The difference in these regression values importantly suggests that the improvement in task completion time is more related to shared experience rather than to the individual performance of experienced trainees. This therefore provides quantitative support for a social mechanism of learning between pairs, indicating that task learning occurred through the involvement of social-cognitive cues; those being transactions of learning exchange during exercise completion. Literature evidence substantiates the perception that greater experience (capacity for cognitive load, relatively improved

economy of task moves, etc.), reduces task completion time (Shingler et al. 2013; Tobin and Grondin 2015; Modi et al. 2020).



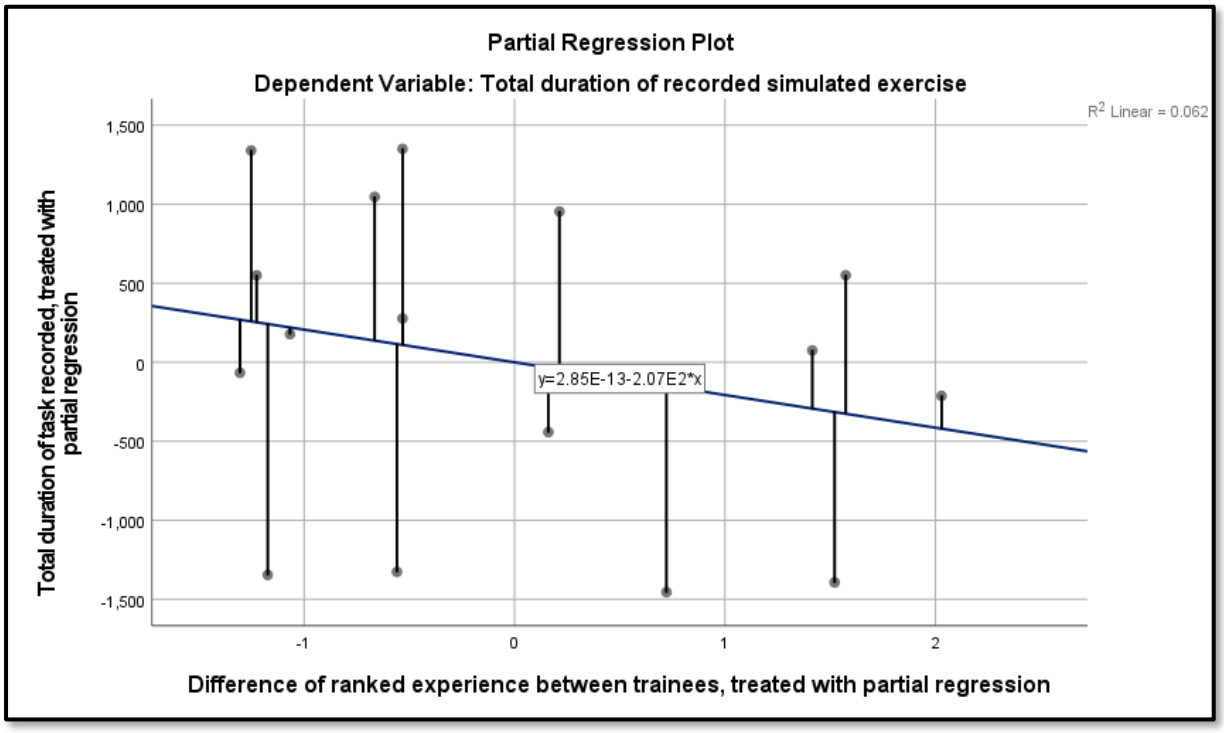


Figure 12. The partial regression plot (12a, top) suggests that procedure completion times decrease with an increase in the combined experience of trainees, whereas the plot (12b, bottom) infers procedure completion is not affected by individual differences of experience seen in the pairs.

4.5 Summary

Interview and trainee demographics highlight the range of experience and broad differences in the length of time trainees reflected on their simulation activity. Initial task completion analysis (supported by the contention of the current literature) demonstrates that more complex, cognitively demanding tasks take longer to complete. The increasing level of combined experience of trainees working in their pairs links to progressively shorter task completion times rather than by the efforts of individuals, regardless of ability. This significant insight may lend quantitative support for social transaction through a shared, combined experience leading to task completion.

4.6 Introducing the analysis themes

The findings that follow in the next three chapters are organised by the themes emerging from the interviews (*Table 6*). In keeping with my convergent parallel approach, a complementary analysis of patterns in the SBT recorded video footage supplements and supports the thematic narratives where they are specifically linked, namely, social and material interactions, which are semiotic. Because semiotic narrative and activity has been observed from two standpoints, triangulation forms part of this convergence.

Table 6. Themes emerging by abductive reasoning of perspectives described in the literature review, with the frequency of occurrence across all interview data.

Themes	Frequency in interview data
Semiotics of simulation	**378**
Learning through negotiating activity between SBT and OT	**254**
Reflection, mental rehearsal and developing decision-making	**237**

5 Surgical skills take on meaning through shared activity

5.1 Introduction

Of the key themes, this most frequently occurring one of the semiotics relates to the way trainees viewed their participation in simulation and their post-simulation clinical (preceptored) work through a cognitive semiotic lens. To recap from the concept and definition found in the literature review (*ch.2*), semiotics (sign processes) (Scott 2014) is an adjective to describe how people make meaning from 'signs' such as activities, gestures, images and objects, manifested through physically tangible (material) socially organised settings.

While only one of the trainees explicitly mentioned semiotics as part of their conversation, contextual responses showed that there was a pre-existing tacit understanding of this concept across various areas. Because of this, the semiotic nature of simulation is comprised of the subthemes shown in *Table 7* below. These describe some ways through which meaning was made during SBT and subsequently manifested in the trainees' operative environment.

Table 7. The theme of semiotics with its subthemes.

Semiotics of simulation subthemes	Frequency in interview data
Scaffold creation to build understanding of operation	**161**
Simulation fidelity aligns with operative steps	**88**
Surgical knowledge is embedded and extended in surgical instruments	**77**
Surgical transfer between simulation and the OT is socially negotiated	**55**

In the WLCTS courses, simulations are set up in such a way as to represent the processes and goals of the OT as much as possible. These processes might be the moments where the learning curves of individualised cognitive and motor skills are embedded into objects and other cues. In other words, it makes sense for new information to be embedded into previously unfamiliar surgical artefacts, (either as instruments, anatomical landmarks, or process steps) by cognitive distribution (DCog) and then subsequently understood by the trainee. Simulation must represent a process of turning such artefacts into signs to be understood in the OT, since extrapolating simulated conditions into the OT is always the intended goal of the learning objectives. Any meaning made by trainees, particularly

regarding how simulation is set up, is intended to be interpreted by them into behaviour in the OT, specifically related to how knowledge was constructed both internally and externally in the simulation.

For example, when discussing the possibility that knowledge is transferred to OT procedures due to the use of surgical devices previously introduced in simulation, T4 commented:

> *"In terms of ... semiotics, ... when you come to set up and do a procedure, obviously the patient and the pathologies [are] the primary factor[s] in determining your behaviour, but also the equipment that you have will determine how you behave and what you do as well. Whether it's one piece of laparoscopic kit, whether it's a stapler or whatever else is [available], it'll determine how you go about something, and certainly if you can become familiar and comfortable with the technology in a simulation setting [you can] then transfer that into the operating theatre. It's then beneficial because [they are not skills you're having to acquire] in a real setting when you're operating on a patient."*
>
> *Excerpt 1. T4 (left-side initial interview).*

The comment by T4 implies that learning to handle unfamiliar devices in a procedure may not just be a cognitive load reduction process, but also one of embedding socially agreed signals for them to become knowledge transfer objects (because T4 talks directly about semiotics). That is, the meaning of the objects and their actions has become socially agreed upon in the learning situation, which are then understood concerning the other elements of the operative system. It is important that these signals are socially agreed upon between all participants involved in surgical simulation for learning exchanges to take place between tutors and trainees and between trainees and trainees.

5.2 Scaffolding

Many participants mentioned how well the simulation creates a scaffold to understand the steps of the right-side and left-side hemicolectomy procedures. Conceptually, a scaffolded learning approach is the provision by the preceptor, of intentional and graduated, controlled support while building competence, with such support being removed in stages as particular competencies are achieved. When asked whether the simulation courses were useful to them in the first set of interviews, all the trainees gave an answer reflecting how the content helped them to organise their surgical working knowledge into a coherent series of procedures.

T2 represented this notion by indicating that the learning steps of laparoscopic surgery provide a basis for being permitted to receive support in the OT.

> *"You learn [the steps of laparoscopic surgery] as you go on, and it's nice to have a basis. It's nice to learn… in a bit more detail before you do it. …It's like a coordinated programme as a starting point..."*

Excerpt 2. T2 (right-side initial interview).

While SBT may have been seen as providing a framework to start with, it also exposed the trainees to alternative approaches outside of their current experience. For example, T3 (*excerpt 3*) reflected that their previously learnt surgical approach for a specific procedure was just one of several approaches. While this was potentially overwhelming for them, simulation provided a scaffolded and organised way of doing the procedure. This organising approach helped T3 identify the common elements that built for them, a greater understanding of the operation. Their perspective supports the idea that simulation provided a structured approach to help T3 develop a mental construct through shared knowledge.

> *"In simulation you see different [approaches]… When I first went on hernias I only ever did it the way that my Registrar at the time taught me how to do it ... [Through working with other people in simulation] you see differently to that. I felt very uncomfortable, [but] then, you see the common steps that are important, [and so] you have a greater understanding of the operation."*

Excerpt 3. T3 (right-side initial interview).

Both the right and left-side courses delivered hands-on practice in specific techniques and procedural steps. Although every trainee found specific skills useful to them as individuals, their reflections were not unanimous in the favour of any one particular technique or procedure. Experiencing simulated laparoscopic appendicectomy was felt to provide a common benefit, more notably among trainees of lower training grades. However, the challenge presented by laparoscopic suturing in bowel anastomosis was found useful through all training grades, particularly in the context of developing a laparoscopic right hemicolectomy skill-set. It is worth noting that this latter technique carries a relatively high cognitive load (holding a rank complexity score of 8) (see *Table 1*) That is, this 'learning curve' needs to combine a series of steps which will eventually become consolidated into one act.

There exists a prescriptive nature in SBT where the task models tend to be exclusively designed for the practise of few, or even only one set of procedural techniques. This prescriptive nature can adequately describe the WLCTS. Trainees acknowledged that reality diverges from this 'prescriptive nature'. This could give them a cognitive dissonance in viewing SBT toward clinical reality. However, trainees also acknowledged that SBT has strength through a scaffolding lens. T4 (*excerpt 4*) was explicit in viewing the simulation approach as a framework from which to extrapolate into reality.

"…To a scaffolding perspective, I think the basic model is valid because… it gives you a framework to bridge the gap… To achieve a basic level of performance from zero level and then from there extrapolate [again], to something… more challenging, to take those skills that you've learnt and apply them differently…"

Excerpt 4. T4 (right-side follow-up interview).

In this view, scaffolding occurs in SBT and it validates the learning experiences, because it provides a learning structure through which skills can be transferred and adapted into clinical reality. The hidden notion here is the activity of the preceptor, since preceptorship provides a controlled method of operative teaching to aid the extrapolation of that knowledge into scenarios as yet unfamiliar to the trainee, but familiar to the consultant doing the precepting. Trainees acknowledged guidance of preceptorship through their negotiated activity and excerpts in this chapter point to this implicit presence.

5.3 Simulation fidelity

A faithful representation of surgical simulation to operating activity is difficult to quantify. Full simulation fidelity of the live OT setting in reality is only achieved with a full interprofessional team participating in the simulation, mimicking the communication and collaboration that occurs during real-life surgeries with trainees. Importantly though, some fidelity is recognisable by the actors for whom it is aimed who negotiate the activity systems. The experience of fidelity is highly subjective, yet made credible by its socially involved design, which also qualifies the activity as a semiotic process. In other words, those who set up the simulation system aim to imbue meaning into the components which would be seen and used by the trainees in the OT, with the implicit intention of providing a situation in which trainees will take that meaning and understand it. This is important since previous research indicates that greater retention of situational knowledge comes with a closer approximation to realism (Finn et al. 2010). Therefore, through a semiotic lens, deeper, richer, textured layers of meaning can be embedded into the simulation scenario as a whole and the better this is done, the better the fidelity. T2 and T4 support this notion in their language in the following excerpts.

"When I was doing the vessels, [in] the one I was doing, the 'planing'[11] was brilliant. It was just like how it was meant to be ... and I was like, crikey, this almost feels like I'm actually doing it on a real person. I think that side of the simulation, and really this

[11] A tissue plane is a surgical anatomy term which could be understood as the point or space at which structures such as organs, vessels, nerves, muscles and visceral tissues potentially separate and become distinct (Cornish and Leaper 2006).

goes with any kind of simulation training, you've got to throw yourself into it and pretend that it is real. Take it as it is because then you get more from it."

Excerpt 5. T2 (right-side initial interview).

"The right-sided models that we used that were supposed to be simulating the right colon and structures around it were actually very good. Particularly the tissue planes worked nicely because simulating a structure is much easier than simulating the space between structures and that's often why these things fall down."

Excerpt 6. T4 (right-side initial interview).

These excerpts demonstrate that viability in simulation requires more than constructing an anatomically accurate model for individual stepwise learning. The fidelity of the activity also lies in accurately representing peripheral tissues, tissue planes and space which support retention and cognitive re-creation for the trainee. T2 made a further point here that there is a certain level of pretence involved on their part. This pretence might help their visualisation and mental rehearsal if the elements of simulation that are the important parts, that is, those at the zone of focus (Kneebone 2010) have the best degree of realism. In other words, T2 indicated that their pretence was an attempt at constructing a meaning or narrative of the operation, while T4 added to this that more accurate representations of reality support a more meaningful transaction of embedded knowledge.

5.4 Surgical knowledge is embedded in surgical instruments through their process-handling

All eight members of the trainee cohort referred to knowledge building through the use of instruments. SBT included a mix of using familiar and unfamiliar surgical instruments as part of the process. New devices and surgical tools were provided because they are functionally the same as those used in the OT. Essentially, the integration of the various separate simulated aspects of the procedures all contribute to the recognition of the other related parts, which emphasises the importance of providing faithful representation in SBT where possible. However, the use of unfamiliar instruments along with familiar sequences with familiar instruments would mean simultaneously embedding new knowledge into the unfamiliar instruments. T7, who scored highest in rank experience level, revealed a useful analogy (*excerpt 7*) during a dialogue on handling unfamiliar devices in simulation. The use of a pencil was compared with the use of a fountain pen. This analogy indicated what T7 perceived was a cognitive distraction to the purpose of the exercise. Nonetheless, part of simulation involved encountering unfamiliarity which required a transfer of meaning and cognition from trainees' previous existing knowledge.

I: *"If something becomes an extension of your own hand, like this pencil. I'm just writing like that (using a pencil in hand at the time).*

T7: *It's only because your fountain pen (pointing to my fountain pen)…*

I: *Yes… I don't have to think about the pressure that I'm using to write and actually I prefer writing with a pencil … but if someone was to come now and say right, you've got to use something else. This is how you hold it...*

T7 *...You concentrate on using it, rather than concentrating on writing your name."*

Excerpt 7. T7 (left-side initial interview).

Interpretively here, familiarity with the use of one instrument may already provide a pre-determined knowledge template which transfers over to another instrument. Therefore, there is a pre-existing social agreement over what kind of use the instrument will have because it relates to something similar which already has pre-agreed meaning. T7 indicated a learning curve may be associated with an unfamiliar instrument because there is a need to cognitively attach it to a specific operating task. T7 pointed out in yet another insight (*excerpt 8*) that, with further progress in the training pathway they were less inclined to familiarise with new devices that do a similar job to those already being used by them in the OT.

"I was seeing instruments [on the left-side course] that I'd never even seen in practice, let alone knew much about… Ultimately, for the next six months I'm still going to use what my boss uses…. I found actually even here on the demonstration and the models using a device I'd never used before, ergonomically didn't feel right in my hand. [Using a familiar device is] like riding a bike. I know what I'm doing. So it takes away part of your mental concentration on the task at hand when you're trying to learn how to use a new instrument at the same time."

Excerpt 8. T7 (left-side initial interview).

It is plausible that providing novel instruments to more experienced trainees in SBT may detract from their actual personal learning goals, which may supersede the stage of needing to embed psychomotor and process knowledge into analogous devices. T7 indicated that novel instruments, at least in the left-side course, provide an unnecessary mental load. T4 also had accumulated more experience at the time of attending the left-side course, whose comments (*excerpt 9*) corroborated with T7 above.

"…one thing that was actually good on the left-side course was having a go with the different laparoscopic instruments. So the lotus[12] and the other devices, and I suppose staplers to a degree, because they do essentially the same sort of thing, they have their subtle differences, but you become accustomed to one bit of technology over another. [However] I have to say I wouldn't necessarily rush to pick up something different clinically at the moment anyway while I'm learning. That would be an additional level of complexity."

Excerpt 9. T4 (left-side initial interview).

While T4 noted that the course was a suitable place for handling unfamiliar instruments, practice with them may not be worthwhile in relation to their immediate experience or opportunities in the OT, citing an unnecessary cognitive load distraction to the task at hand. Additionally, T7 acknowledged that a certain dissonance comes from knowing and accepting the devices are often provided *pro bono* for training by industry and further, a SBT setting rather than the OT, is the most suitable place to learn on unfamiliar devices.

It should be noted that these views differed from the cohort with lower rank experience scores. For example, T1 acknowledged that they found learning to handle unfamiliar devices on the right-side course allowed them to make informed comparisons to incorporate into their tasks (*excerpt 10*), while T6 added that SBT is suited to handling unfamiliar devices and being allowed to fail while learning to use them (*excerpt 11*).

"… In having three successive [instruments] you have a proper comparison of the differences."

Excerpt 10. T1 (right-side initial interview).

"As I mentioned the energy devices, it's just getting a chance to use different ones, because sometimes you go into theatre and somebody hands you one or the boss uses a different thing and suddenly you're like, I'm not really sure, how does it work? [While in SBT you know] nothing bad can happen."

Excerpt 11. T6 (right-side initial interview).

Here, T6 emphasised the SBT setting, rather than the OT, as the natural place to figure out how to work with novel and specific surgical devices, since simulation's objectives are different to those in the clinical setting and by its nature, failure is allowed. T6 also revealed tacitly that SBT may help avoid anxiety which might come through exposure to new devices for the first time in the OT setting.

[12] The Lotus is the name of a surgical company which supplies a surgical device that cuts and coagulates tissue through mechanical vibration energy.

This supports the notion that SBT is the appropriate setting for the cognitive demands which come from learning new devices.

5.4.1 Evidence that instrument embedding was socially constructed

Evidence from the interviews infers that new knowledge embedded in unfamiliar instruments was socially constructed during the courses.

1. New surgical devices have names that already begin to become synonymous with the meaning of their use. Trainees adopt the commercial names into their language of colorectal surgery. Trainees get exposed to the passive reference of surgical devices in the OT and then they use them subsequently for the first time in SBT. The right and left-side courses of the WLCTS also refer to surgical devices through their commercial names, which indicate an unwritten social agreement on what those names mean within the surgical community. For example, T4 referred to the Lotus device in *excerpt 9*, while in the following, *excerpt 12*, T1 explicitly mentioned the harmonic scalpel, of which both perform a very similar function and purpose. However, contextually, T1 referred to the skill, function and purpose of the device by the term 'Harmonic', which was not the only device available. Reference to 'harmonic scalpel' in place of other devices that perform a similar function is common. Similarly, T1's use of 'Ligasure' as a term (in *excerpt 14*) is understood by trainees to mean a device that coagulates blood vessels using electrical energy in a bipolar way. In this sense, some commercial names take on a general understanding for a set of devices in which their function is analogous.

> *"Technically [the course] provides very important skills, [like using] the harmonic[13] [scalpel] and so on."*
>
> *Excerpt 12. T1 (right-side follow-up interview).*

This phenomenon of using devices' names to recognise the function of all devices in a similar category is also synonymised with the companies who supply the devices, such as T7's reference to Ethicon in place of the harmonic scalpel in *excerpt 13*. Therefore, the language of colorectal surgery (which identifies a colorectal surgeon) adopts the names of these devices as synonymous with their intended use.

> *"[We] 'walk' the small bowel, divide the mesentery with the Lotus [or] divide it with the Ethicon. Get a feel of the different instruments there, then and let the 'reps'[14] do*

[13] Like the Lotus, the Harmonic scalpel is a surgical device which cuts and coagulates tissue through mechanical vibration energy. The Harmonic Scalpel is manufactured and sold by Ethicon.
[14] Industry specialists.

their talking so that when you come to the actual task that you want to learn, you use what you're comfortable [learning to use]."

Excerpt 13. T7 (left-side initial interview).

"…At a certain point, you can [work as] fast at the pedicle [to the] same [level] as you go through the mesentery with [either] the harmonic or Ligasure[15]. I think it is [about acquiring] the knowledge [of what to use and when]."

Excerpt 14. T1 (right-side follow-up interview).

2. Via industry specialists (*excerpt 13*) and preceptors (*excerpt 11*) in the simulation setting, surgical knowledge was distributed to the trainees, through new and unfamiliar devices supplied for the right and left-side courses. T7 (*excerpt 13*), supported by the context of *excerpt 14* where T1 referred to functional knowledge being shared, indicated that this distribution of knowledge was part of their learning process. T4 referred to this knowledge distribution through devices which become facilitators of knowledge transfer in *excerpt 1*.
3. Trainees working in pairs reinforced and refined their process knowledge being understood and practised during the cognitive and associative phases of their task learning. This is contextually evidenced by T2 (*excerpt 15*) and T5 (*excerpt 16*) talking about the perceived benefit of working in pairs during SBT; sharing their knowledge of the task process was perceived to be useful.

"You learn a lot by watching someone else as well. How one person will do it. They're all quite different "

Excerpt 15. T2 (right-side initial interview).

"…Different colleagues have their own skill-set, [learned from] somewhere else … and they use those techniques differently [too]. [T1] taught me some other knots. It's a good idea to swap partners so that you can grab their techniques. And I can share what I know with them as well."

Excerpt 16. T5 (right-side initial interview).

T5 talked about how partnering with a specific trainee (T1) led to extending their own psychomotor knowledge by tying knots. To further contextualise the comment, knot tying in keyhole surgery normally requires a lot of practise in using laparoscopic needle holders. Laparoscopic knot tying and suturing is widely considered one of the most difficult techniques to master in a variety of operative situations. Conceptually, for T5 to recognise the actions of

[15] Ligasure is a device, marketed by a company called Medtronic, which uses electric energy to specifically coagulate blood vessels.

T1 as different and useful to their current knowledge, would only come first by observing and recognising a difference that they might perceive to have a benefit. Therefore, this is a clear example of how knowledge of surgical instrument use is socially constructed.

4. Cumulatively, *excerpt*s show that trainees tacitly recognised knowledge co-construction as an intrinsic part of SBT. *Excerpt 1* reveals T4's insight into how knowledge learnt in the SBT social system can be transferred into the social system of the OT. T4 went further (*excerpt 17*) in describing how they recognised this mechanism of knowledge transfer while talking about a specific example of applying what they experienced in the WLCTS, to their clinical work.

> *"…Interestingly if I think now for instance, I'm going to do a lap-right or a lap-left this afternoon or in the next hour. Not only am I thinking about how I'm going to do the procedure, but I can almost feel the instrument in my hand. You know, you subconsciously move, or you can feel that you move your hands as if to feel it in the hand, where the buttons are. Obviously there's nothing there, but you have an appreciation of the sensation of it. You're modelling it. You're constructing that in your mind which I hadn't really appreciated before."*
>
> *Excerpt 17. T4 (left-side initial interview).*

Interpretively, T4's proprioceptive rehearsal of the instrument within their mentally constructed environment reveals that knowledge is not only externally represented, but internally too, since they can appreciate the sensation of how 'things' are supposed to feel.

5.4.2 Findings indicate the role of surgical instruments in learning transactions between pairs

Trainees infer through *excerpts 12–17* that the simulation courses are the place where knowledge is embedded into novel surgical devices and they support the contention that this learning and meaning did not occur without social transaction; led by an implicit understanding that the sharing and use of these devices is socially conferred both by trainees working as a pair and by the guidance of their preceptors. Supplementary content analysis of the videographic data looked at how the exchange of novel devices between paired trainees changed when accounting for task complexity or trainee experience levels, since the introduction of cognitive load could be contentious. That is, how the exchange of knowledge or transfer of meaning on devices is impacted by the kind of task or the previous experience of the trainees. The linear partial regression shown in *Figure 13* shows how the rate of exchange of novel instruments between trainees in a pair changes with increasing complexity. There is a 'weak' inverse correlation (Rumsey 2021) with a coefficient $R^2 = -.029$. As task complexity increases, it follows that the cognitive load required to take on the tasks also rises, which has a small

but noticeable effect on instrument exchange. The rationale for this comprises a possible two-fold explanation. First, tasks with a smaller cognitive burden allow more opportunity for trainees to explore instrument handling, whereas at the higher end, the focus of the cognitive effort is less on the instruments and more on the task itself. This notion is supported by the findings illustrated in the above *excerpt*s on instrument handling. Second, exchange of instruments is less likely when individuals in the pairings need to give more cognitive effort to embedding more complex psychomotor processes into devices used in more complex tasks.

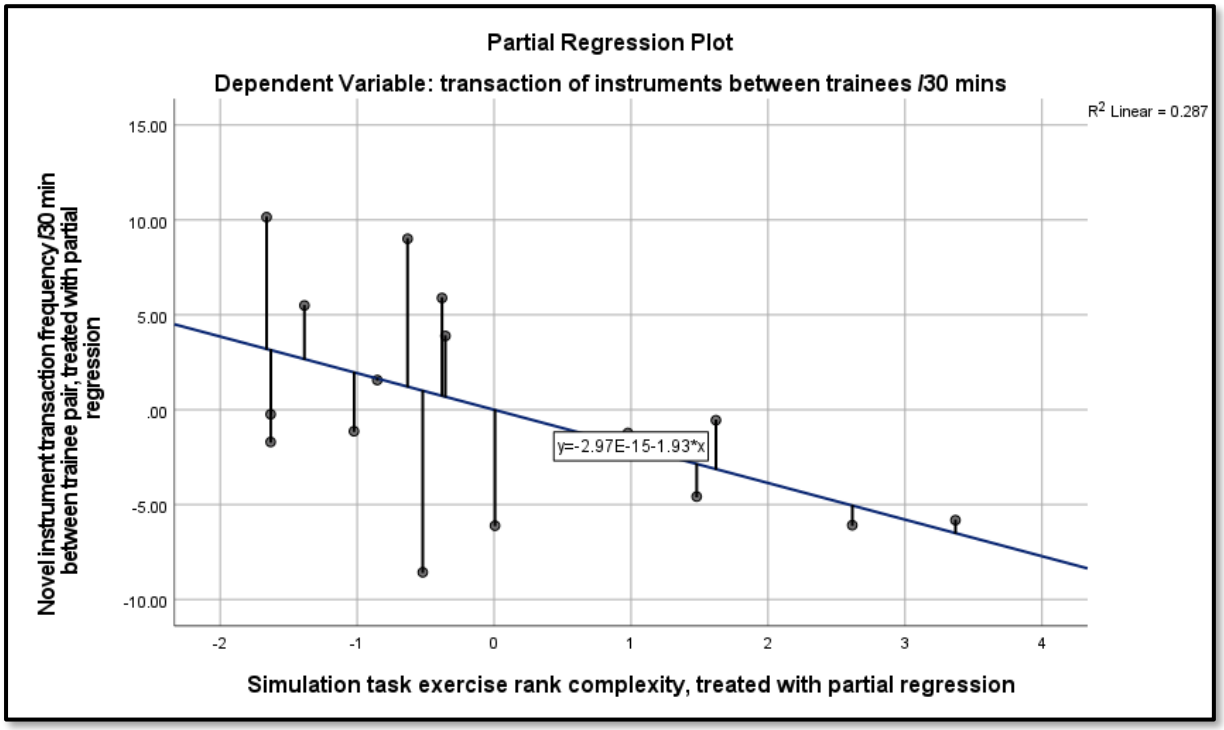


Figure 13. Partial linear regression graph indicating an inverse trend in the exchange of unfamiliar instruments between pairs at the simulation table as procedure complexity increases (outlier at complexity rank 2 removed because this value had no unfamiliar instruments).

Additional support to infer that increasing task complexity may also demand a further cognitive effort through more complex psychomotor skills comes through T4 (*excerpt 18*). During a part of the conversation about how skills learnt in SBT consolidate by the time they go into the OT, such as handling devices for the first time when performing a new surgical task, T4 commented:

> *"You see trainees … when they're using the laparoscopic hook and things like that, and they're searching around and looking on the floor for the foot pedal, and they're not used to co-ordinating those sorts of things… You have to develop that fluidity and be comfortable with it. As the technology gets more complex, having it as being second-nature, rather than additional cognitive burdens, is important."*

Excerpt 18. T4 (left-side initial interview).

This comment suggests the complexity of tasks is intrinsically linked to the coordination and handling of surgical devices and further, that the process around the acquisition of surgical fluency involves a *negotiated* consolidation of the technology with the tasks. That is, there is evidence of cognitive load through multiple streams of new information, which T4 argued may be reduced through the cognitive priming of simulation.

Linear partial regression correlations to assess if the rate of instrument exchange between pairs during tasks changed with trainee rank experience levels are shown below. *Figure 14* shows how trainee pairs cooperate and assimilate their instrument exchanges together based on their combined experience. *Figure 15* presents the analysis of instrument exchanges with changes in the difference in individual experience between pairings. Both show negligible correlation coefficient scores.

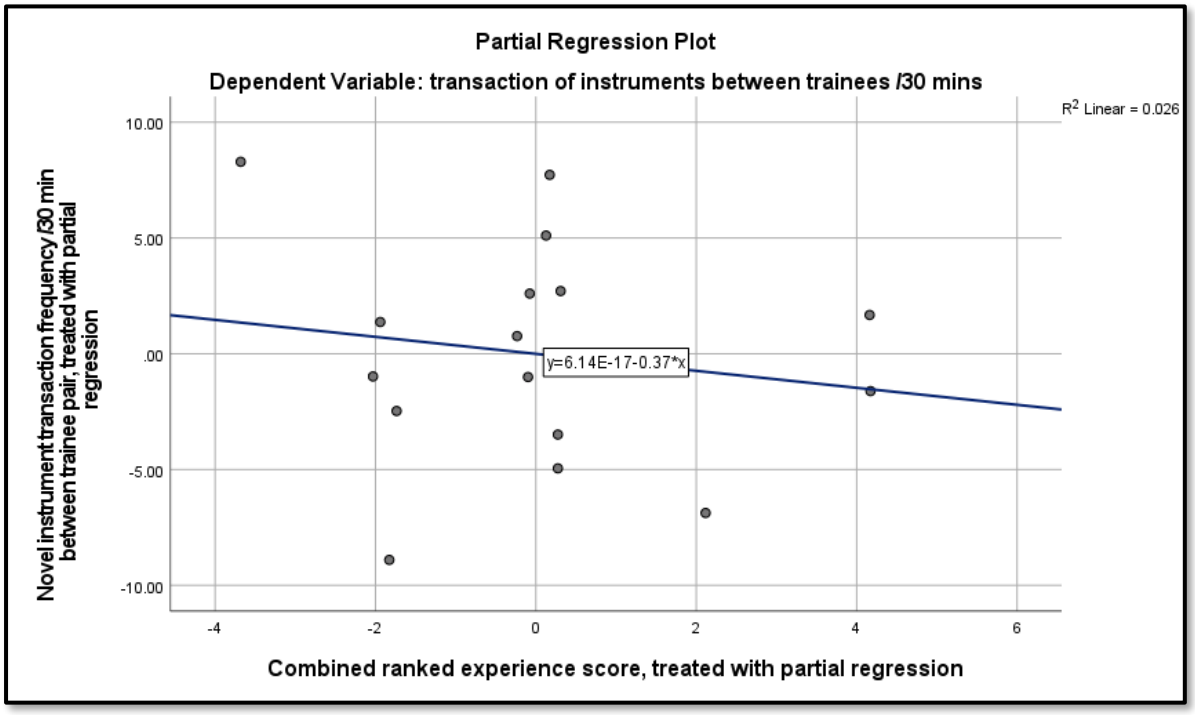


Figure 14. Partial regression to test the strength of correlation between exchange of surgical instruments with the combined experience of pairs.

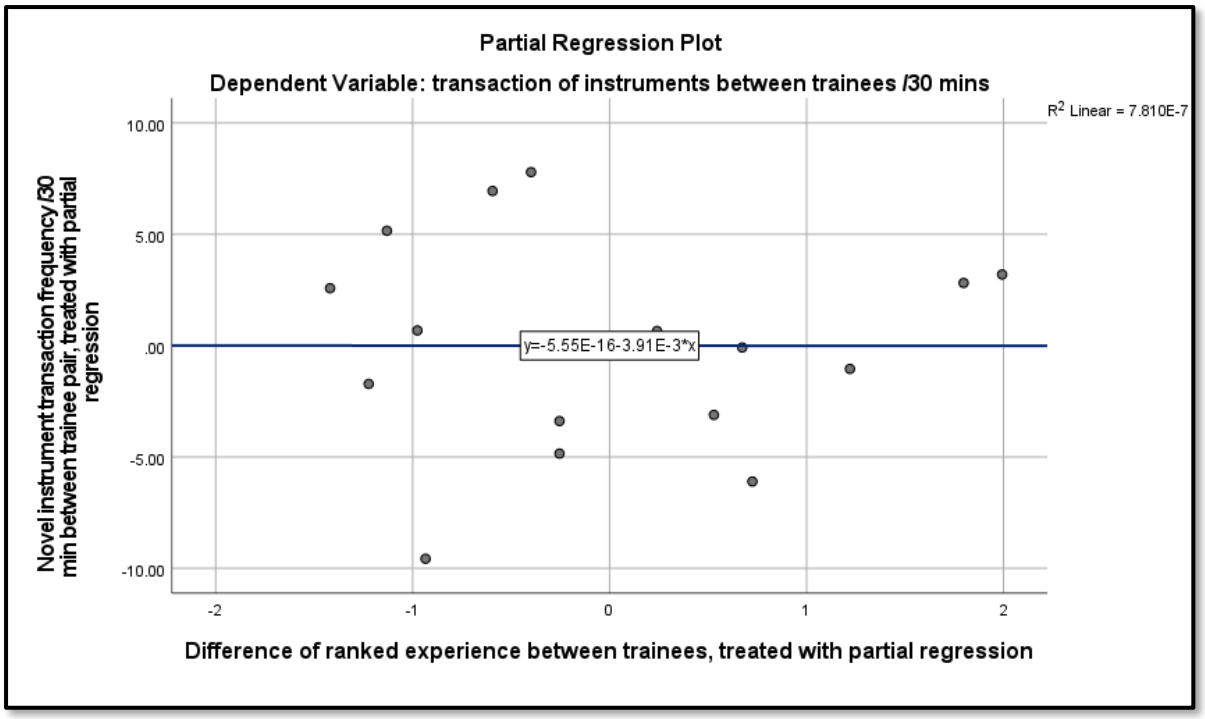


Figure 15. Partial regression to test the strength of correlation between the exchange of surgical instruments with the difference in experience levels between pairs.

These observations imply that prior experience designation did not affect the exchange of new embedded knowledge through novel devices; that is, the cognitive load is set by the starting position of the trainees attending the specific procedural training and not by their previous cognition. Thus, a similar prior level of exposure to novel instruments may be assumed for most trainees who decide they should attend the WLCTS.

5.5 Skills transfer to the OT experience is socially negotiated through verbal and non-verbal interactions

Three specific observations regarding social negotiation of skills through verbal and non-verbal communications are discussed in turn. They demonstrate that social negotiation of skills is a semiotic process since task learning and understanding align language, meaning and knowledge to the proprioceptive steps of the tasks. Verbal and non-verbal interactions abound in reinforcing socially agreed meanings for the trainees developing their specialist expertise and are therefore categorically semiotic. They are forms of knowledge transfer that are not explicitly didactic. Video observation data also recorded these interactions regardless of any subsequent correlations with experience or task complexity rank scores. Correlation analysis does, however, align with the trainee reflections below.

5.5.1 Learning is a by-product of shared negotiation of a task toward a common goal

Trainee commentaries infer that their skills acquisition was socially negotiated through their verbal and non-verbal interactions, however, importantly, this aspect was for them, a tacit process. For example, when asked whether learning in SBT came through conversations with their paired partners, T8 responded:

> *"[My partner] gave their own perspective about what the consultant taught us [both], and because we were working together, I was trying to work to that perspective. [My partner gave] me his opinion, 'oh my concern is to do that' (about part of a task). So he got some kind of point across. [I replied], 'oh yeah. I have to think about it. That's also a good way'. ... It was very helpful just to learn from different trainees from different hospitals, following some different things. Very, very small things but they did make a difference."*
>
> *Excerpt 19. T8 (left-side follow-up interview).*

T8 followed up on the operative input of these small social learning negotiations in SBT, particularly in helping to navigate the culture of changing partners across the table, remembering that the WLCTS courses were set up to emulate the OT by rotating operating partners.

> *"The [left-side course was] a good learning experience because when you change your partner … it's the same as changing a person whom you're operating with, in the theatre. Sometimes with a consultant. Sometimes with another Registrar. You get used to the new person and you tell them what you need to do and how they can help you while you're doing what you're doing. So I don't mind the partner changes."*
>
> *Excerpt 20. T8 (left-side initial interview).*

Indications from the interviews which followed a six-to-eight-month period of preceptored operative work also signal that skills negotiated socially in SBT are likewise negotiated in the OT. T1 had the advantage that the course convenor for their right-side course happened to be their consultant in the OT for preceptorship, that is, the negotiated partnership may have been the ideal trigger to apply the skills as learnt in the simulation. It could be argued that T1, knowing their existing consultant's prior activity and task preferences, may have limited their learning of new skills through negotiated activity because they might be following a familiar process.

> *"I'm supervised by Mr A_____ and he was the course faculty. [On one task for the course, which was basic skills with a 30^{O} scope camera], he was holding the camera for me. So it was almost exactly the same [as in the OT]. I know what he likes. What*

to do. …. So this was an advantage. … It was almost the same with the same steps and the same stepwise approach."

Excerpt 21. T1 (right-side follow-up interview).

While T1 reported that the familiarity of their consultant's negotiated activity reduced the cognitive load of their task goal, T7 offered that explicit near-peer skills transfer may not have occurred because of the relative equality with their partners on the learning curve. The contextual background is that T7 attended the left-side course with the notion that the other attendees all bought similar experiences and expectations aligned to the task (addressed in the prior section). Rather, T7 observed that the negotiated exchange point must come from the preceptors, who *conversationally* reinforced theoretical knowledge of a procedure by a stepwise approach, telling 'how' and 'why' the trainee needed to do something:

"I don't think there's much skills transfer between peers because… we're all on the same point in the learning curve. Definitely [there is] from the trainers to the trainees because they're breaking it down for you and how to tackle this in a stepwise fashion, and a lot of it is common-sense. A lot of it you probably already know but having somebody tell you why you're doing it helps to reinforce that. ... We know [for example] to watch out for the spleen… watch the small bowel and watch this, etc."

Excerpt 22. T7 (left-side initial interview).

T7's experience shaped their perceptions about whether socially negotiated learning took place between trainees at all. However, T8 countered this, reflecting that during an open discussion session involving preceptors and trainees, near-peer social interaction was useful to their learning.

"[The course] gave me an answer for all the things that I wanted to ask my teachers. The other participants also brought questions to my mind that I never thought about. It was a full open interaction, and that helped a lot."

Excerpt 23. T8 (left-side initial interview).

Both T7 and T8 attended the left-side course. There may be an emerging difference in the impact of socially negotiated learning between the right and left-side courses since T1 observed, following the right-side:

"[Trainees] have different levels of ability and surgical knowledge ... [T5] is better than me in colorectal dissection because his main [specialty] is colorectal, but I'm better than T5 in knotting and tying because I do it a lot. This is really different, but [we both] respect and [are] willing to teach and help each other."

Excerpt 24. T1 (right-side initial interview).

These *excerpt*s give evidence that the level of trainee experience may have had an impact on how they prioritised or perceived their near-peers and their preceptors as useful resources of socially negotiated surgical knowledge. However, importantly, they tacitly acknowledge that there has been skills transfer and knowledge co-construction. The contextual assumption in which this knowledge co-constructed, is that it has occurred as a consequence of multiple 'actors' involved in negotiating multiple interactions during a task process.

The importance of SBT as a place to recognise social cues specific to the culture of colorectal surgery is that they should be the same in both the lab and in the OT. Ascertaining (not just task fidelity but) the social fidelity of this colorectal SBT may be an important crux in the thesis. In the interviews, it was discussed whether trainees perceived similarities in how their communications flow at the operating table to their learning experience during the courses. This enquiry arose because trainees do not usually have a choice in their working partners from one operating list to another and this working characteristic was emulated in the WLCTS; trainees are swapped around for every task and paired up with different partners. To this extent the SBT environment did not challenge that of the OT; social fidelity was constructed which, besides the probability of supporting retention, would support the fluency of surgical language acquisition and task-focused exchange between colleagues at the table.

Excerpt 20 already indicated that T8 recognised the usefulness of the left-side course in emulating the rotation of working partners and this was further reflected by T5, who indicated that a change in partners requires recognising a change in the way the task process is navigated, both in context of the OT and SBT. T5's comment highlighted that there is negotiation towards a common goal.

> *"You don't always get the assistants you want; with a different assistant your experience may vary …. You need to find a way to work with, whoever the assistant [is, that] you are getting. [So] swapping the assistant [in SBT] also will make a big change actually, and you can think differently on how [you're] going to tackle that situation."*
>
> *Excerpt 25. T5 (right-side follow-up interview).*

Likewise, T6 observed that negotiating procedures in the right-side course emulated their experiences of real life. The most important aspect of the SBT for them was learning to work across the table with surgeons of all levels, of which all are valuable.

> *"I think [simulation very much emulates] real life. [In] doing something on CEPOD[16] for example, you could have [someone] … not interested in surgery and has never held a camera ... or [someone] who actually can do things themselves. Actually, spending some time with lots of different people at lots of different levels [of ability is important]."*
>
> *Excerpt 26. T6 (right-side initial interview).*

The common supporting tenet from these comments is that trainees are familiar with adapting their role to pursue the common goal of the shared task. Learning may not be explicitly recognised as a consequence of sharing roles; the object of SBT tasks was to learn the procedure, while in the OT it would always be to obtain a good outcome for the patient. Either way, the important common denominator (therefore social fidelity) is that the trainees recognised a social negotiation of activities while being task-focused. This was explicitly pointed out by T3 when asked about their experience of working in pairs during the course.

> *"You were more focussed on the tasks. You've got a common goal for them. We had to work together to do them and help each other. If you're with the same person the whole time, you'd be a bit more distracted. I'm not saying you'd be gossiping, but there would be less of a focus on doing the task together."*
>
> *Excerpt 27. T3 (right-side initial interview).*

This insight also reveals that the common goal of the simulation tasks came through the construct arising out of the partnership and switching partners helped T3 to maintain focus on the task rather than on being focused on the person they might be working with.

5.5.2 Shared negotiation of a surgical procedure through the social mechanisms indicated by verbal and non-verbal exchange may be dependent on trainee experience

5.5.2.1 Verbal exchanges

Video data supports the notion that verbal exchanges (whether surgical or casual/non-surgical) as well as shared non-verbal cues, were influenced by the rank experience of the trainees in the cohort. Interestingly, there was a greater level of casual (non-task or procedure-based) conversation among trainees of equivalent rank experience level compared to pairings comprised of trainees of relatively different experience rankings. This is illustrated in the following regression analysis (*Figure 16*) where the average length of measured casual conversation segments over 30 minutes of a procedure

[16] CEPOD is pseudonym for non-elective or emergency surgery in the NHS. It usually refers to an OT which is reserved for emergency surgery 24 hours a day, and the name derives from the NCEPOD classification which determines what constitutes a non-elective procedure.

indicates a moderate inverse correlation (R^2 = -0.39) to widening experience levels between pairs. That is, shorter exchanges of casual conversation moments occurred with a wider difference in trainee experience. Observing casual conversation as a facet of social interaction is useful because it corroborates with social organisation, tacitly informing the position of a trainee in the learning process with respect to their peers and tutors.

Verbal exchanges between trainee pairs relating directly to the procedure and those between the trainees and the tutors at the stations were also recorded. These were important to note because I contend that the language of surgery is constructed during these exchanges. I make the assumption here that in a negotiated multi-threaded process of constructs such as that of instrument handling (previously discussed) and non-verbal interactions (also recorded), meaning will be formed when these activities converge. This is the semiotic relevance of verbal and non-verbal exchange.

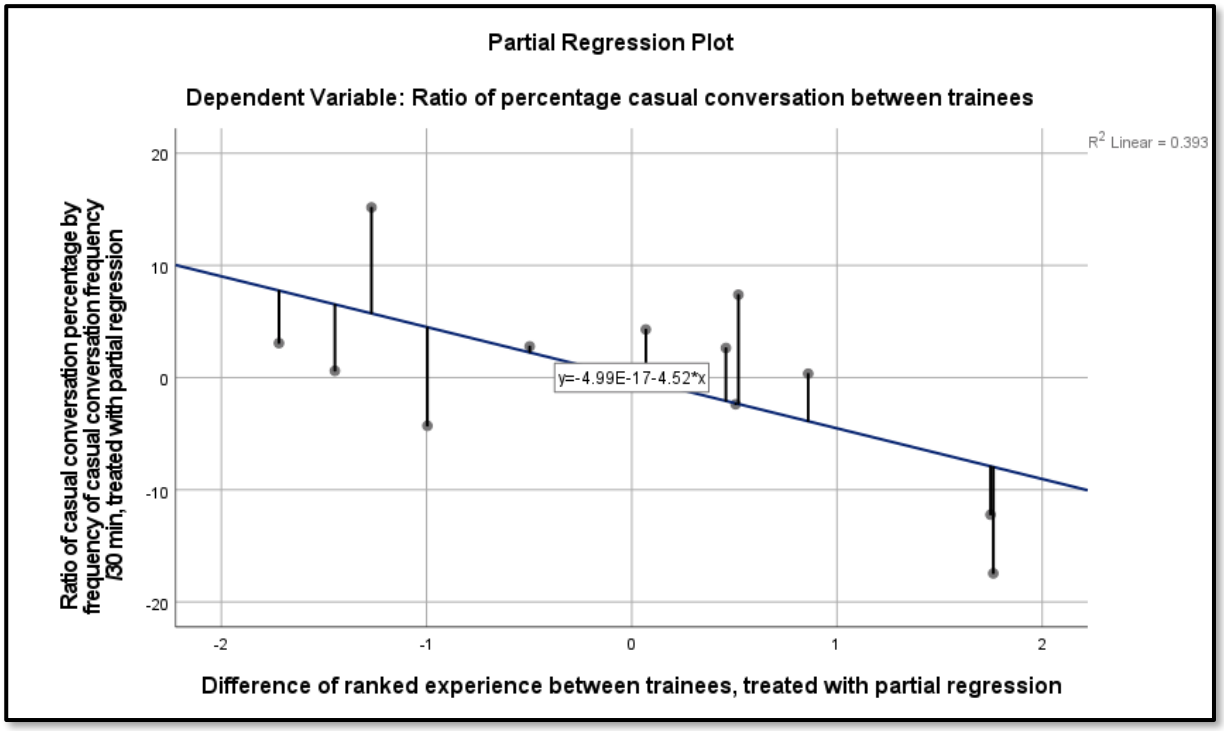


Figure 16. Partial regression line indicating a moderate inverse correlation that relates the levels of casual conversation to the differences in experience between paired trainees.

Conversely, the level of task-oriented conversation between pairs did not appear to correlate with increasing skills difference (see *Figure 17*). Taking the comments of T3 (*excerpt 27*) with the way casual exchanges decrease over the rank difference (*Figure 16*), these observations could indicate that the perceptions of goal-oriented focus depend on how much may have been unsaid during a task. However, a partial linear regression exploration (*Figure 18)* of the relationship of task-related conversation with the *combined* experience levels of the trainees shows that the length of the

observed moments of verbal exchange decreases with increasing combined experience, although weakly (R^2= -0.19).

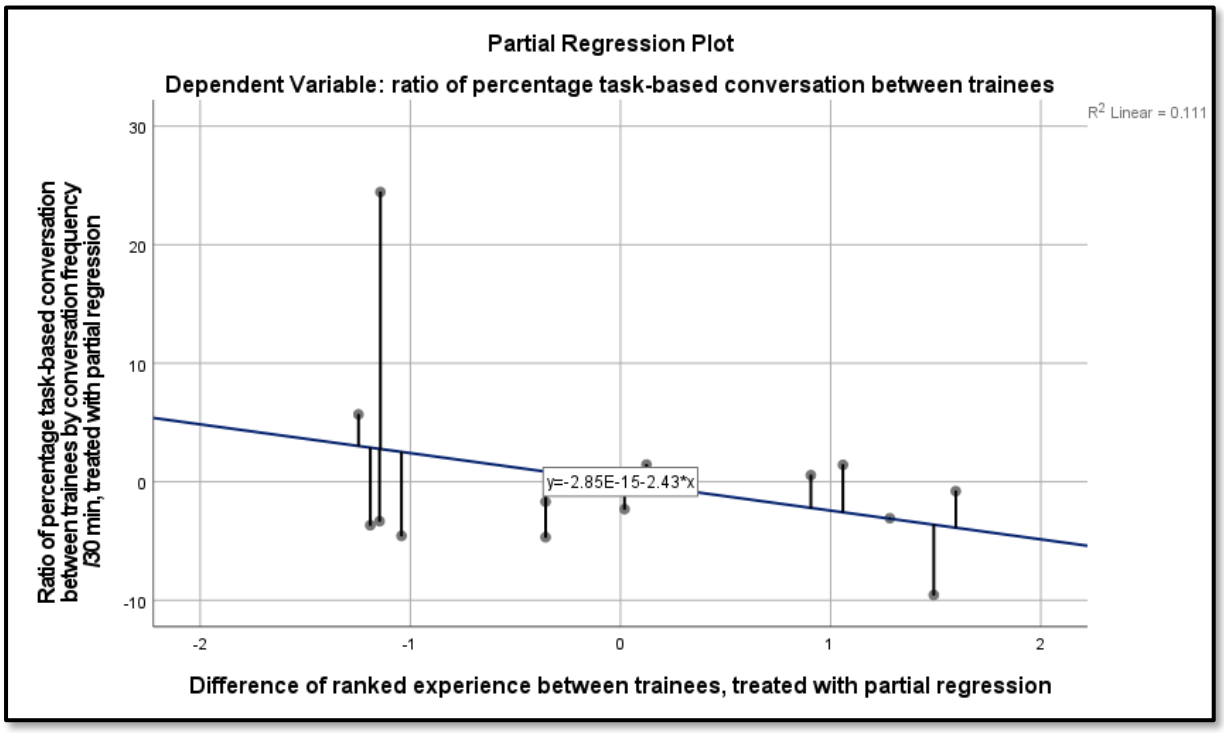


Figure 17. The ratio of conversation length by the frequency of exchanges does not correlate with the difference in experience between paired trainees.

The verbal exchanges of trainees between tutors were recognised by instruction, questions and the acknowledgement of instructions. These interactions were observed and recorded as occurring with the pairing, rather than to one individual in a pair, since tutors engaged through the task rather than with the individuals. Simultaneously, while the task-related conversation between trainees with greater combined experience decreased, there was a negligible change (R^2 = 0.13) in the time given during the procedure for tutor verbal engagement (*Figure 19*), but concurrently there was a weak positive relationship between tutor verbal exchange with trainees as the difference between paired experience increased (*Figure 20*) (R^2 = 0.24).

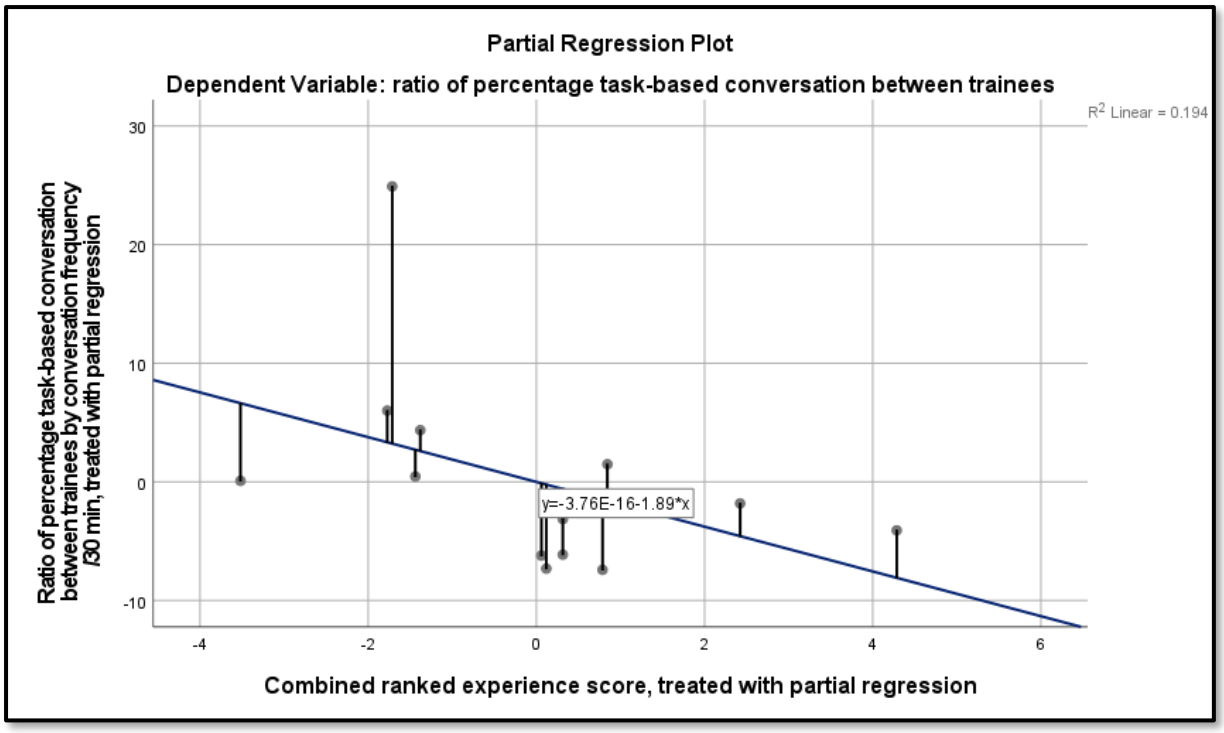


Figure 18. Procedure oriented conversation declines with increasing combined experience. The ratio shows frequencies at which conversation exchanges occur remain constant while lengths of those exchanges decrease.

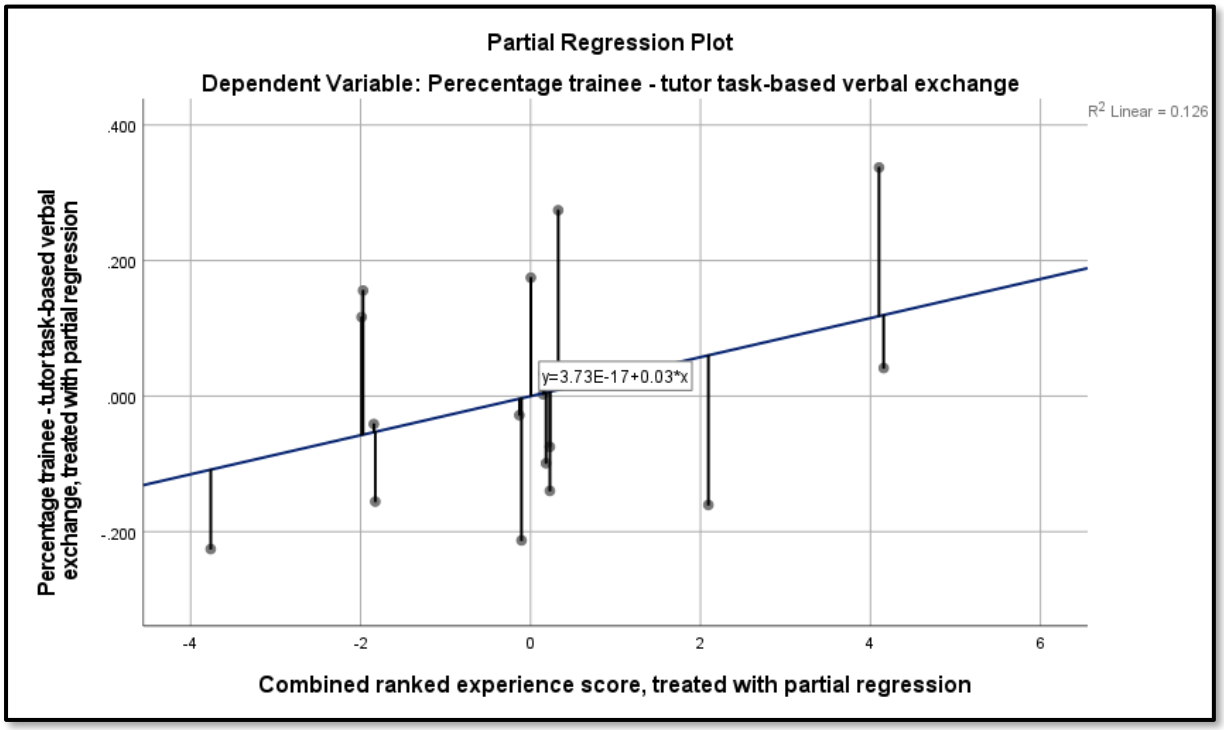


Figure 19. Tutor verbal exchange with trainee pairs increases negligibly as the combined experience of pairs increases.

In conversing about the tutor-trainee relationship during the course, T2 (*excerpt 28*) noted that tutor verbal engagement was important to guide them in the tasks, with further perceiving *(excerpt 29)*

that guidance in context of taking task steps from the course to the OT, as well as to promote the common language of colorectal surgery between the pairs. This notion may explain the trends seen in *Figures 19 and 20*.

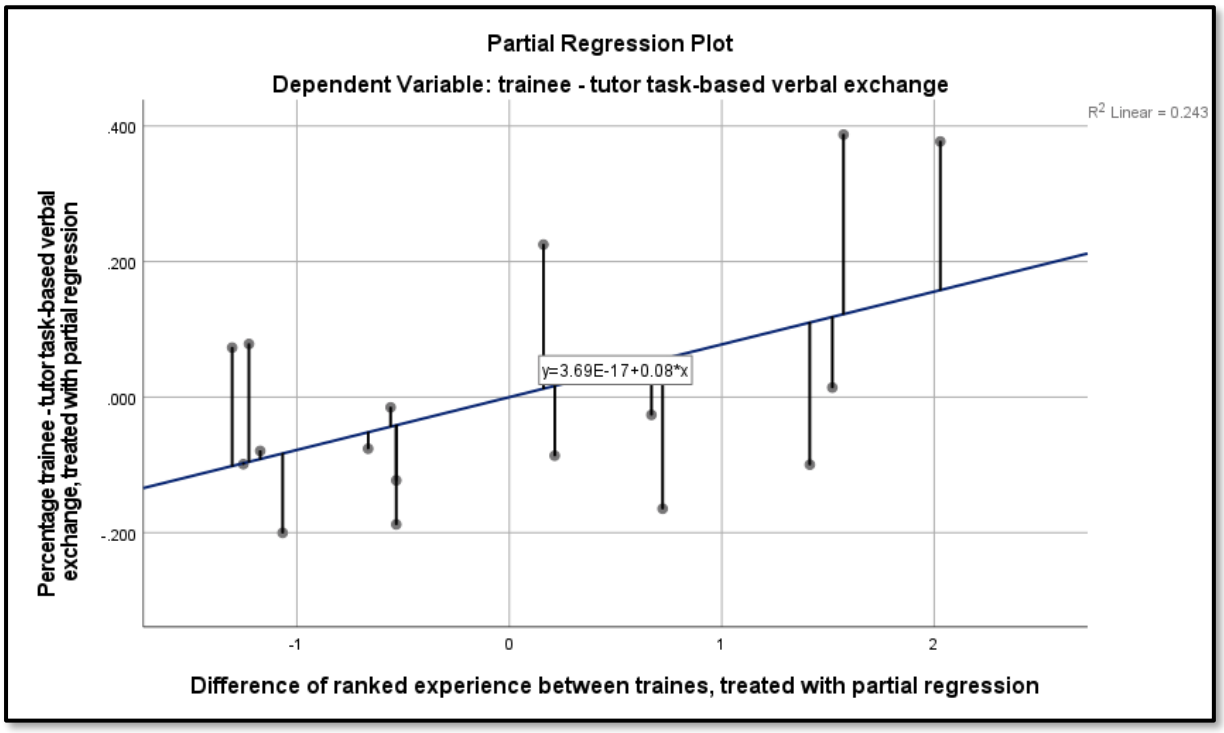


Figure 20. Tutor verbal exchange with trainee pairs increases as the experience difference between pairs increases.

That is, while tutors may have given more or less equal attention to all pairings, within those pairs, tutors may have spoken through the task more to individual trainees where a difference of agency was noticed. The trend seen in *Figure 18 may, however* imply paired trainees with more shared experience tacitly assume possession of existing embedded process knowledge of a procedure and are therefore less inclined to voice what they are doing; as they work together, knowledge acquisition through negotiation leads to a gradual decline in requirement to explicitly talk through their task.

> *"I think [the] perception from the tutors [is knowing] when someone needs that extra help and when someone just needs to be left alone because they'll figure it out for themselves … I think they're very good at that. You know, they probably are doing the right thing, leave you alone, or maybe try this … some trainees may need a lot more interactions and some may need a lot less."*
>
> *Excerpt 28. T2 (right-side initial interview).*

"The purposes of [the course] are to teach people how to… make sure everyone is talking a common language, that everyone knows the steps. That everyone knows what should be next…. There's expertise in the room."

Excerpt 29. T2 (right-side initial interview).

5.5.2.2 Non-verbal gestures

Common language is more than the verbal, surgical vocabulary and attaching understanding to a technical process; it is also shown in non-verbal cues, such as hand gestures which imitated the use of instruments and those indicating spatial movements or pointing locations at the screen for trainees to focus on. Trainees used non-verbal gestures to indicate their understanding of a concept to a tutor. T8 reflected on an example of non-verbal cues that provided an opportunity to embed further learning through instruction (*excerpt 30),* while T5 (*excerpt 31*) recalled how one of the preceptors instructed them on how to hold laparoscopic needle holders using their hands to gesture the surgical motion.

"Dr H____ asked me to show him where we place the port [for a particular procedure]. Then he gave me his own [port placement positions] (gesturing with hands), why we are keeping the ports here. And I actually don't even question when people tell you to do it 'that' way, but when somebody says, 'this is the way we're keeping it because it helps to do this', then you get like, 'oh yeah. I didn't even think about it'. That helps a lot."

Excerpt 30. T8 (left-side initial interview).

"Mr P____, he [showed] me, [which] I found very, very interesting and very convenient and said, 'hold the needle with your left hand, left instrument, [then] rotate it on the right-hand instrument'. It really was an easy way which I had not come across earlier on. It's also really helpful in thinking of the operation beforehand, especially when it comes to intracorporeal anastomosis."

Excerpt 31. T5 (right-side initial interview).

These examples show how knowledge transfer was socially negotiated through the use of non-verbal cues as a way of building meaning and understanding into the way instruments were handled, talked about and further, mentally rehearsed. They combined surgical language and experience, in that the preceptors' instructions were understood contextually.

Observations of non-verbal cues being used between the tutors and trainees in the WLCTS courses did not correlate with task complexity when subjected to partial linear regression analysis. However, trainee experience appeared to have a weak to moderate role; the regression in *Figure 21* indicates

that the frequency with which non-verbal cue moments were observed increased when the combined experience of pairs increased (R^2 = 0.26) and concurrently, this frequency also increased when observed for trainee pairs whose experience levels progressively differed (*Figure 22*, R^2 = 0.21). Simultaneously, an increasing percentage of the total operating time was also observed for non-verbal cues where combined experience and experience difference increased, albeit more weakly.

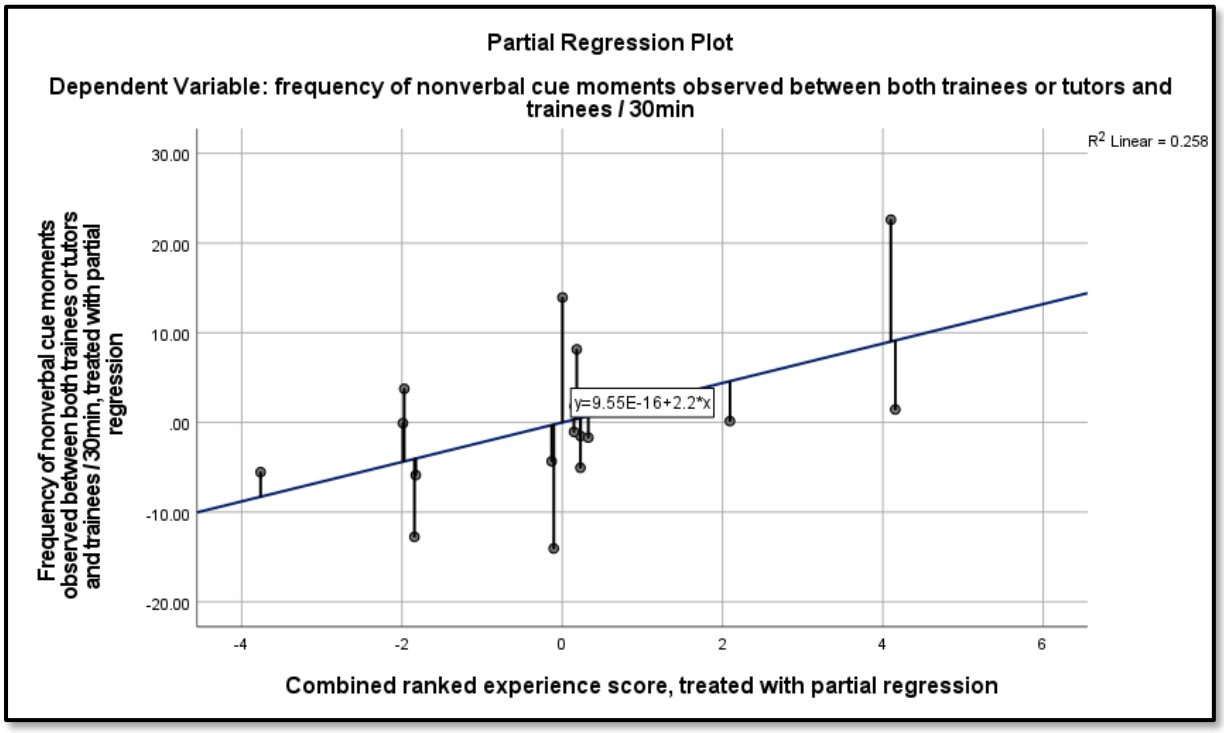


Figure 21. Partial regression showing recorded non-verbal cue moments correlate with increases in the combined experience of trainees.

Why more experience plays a role in the greater use of non-verbal cues, may be supported by the reflections of T1, T2 and T7 (*excerpts 32, 33, 34,* respectively). When explicitly discussing how a preceptor uses their non-verbal gestures, such as the laparoscopic camera when they assist during an operation to intuitively point to a progressive direction for the movements of a task, T1 observed:

> *"Sometimes I see the camera at some point [where my preceptor's gaze is going]. He may or may not be giving me attention, [indicating to me] 'look at this and see this.' So it may be some sort of blind guidance. I need to be intelligent enough to notice this. If he's getting me to this area, I'm just trying to reassess myself as I may have missed something."*

Excerpt 32. T1 (right-side follow-up interview).

This suggests that trainees rely on non-verbal gestures from surgeons with more experience to indicate where they need to focus in the progress of an operation. Further, reflecting on times in the OT where T2 was either the inexperienced surgeon or assisted by someone more junior, they said

that a consultant would use their instrument and camera to intuitively suggest the next steps, while a junior trainee might challenge them to take an explicit leadership role (which might involve more verbal instruction).

> *"When you're operating with your consultant, they know what you want to see. They know what the next step is. They can see what you're trying to do, and [for example] they'll put traction in, pull something out the way, or put the camera [further] in. Whereas if you're doing it with someone who's more junior than yourself or perhaps someone who is not capable of doing the operation, it's sometimes quite challenging to take that leadership role."*

Excerpt 33. T2 (right-side follow-up interview).

Similarly, T7 took non-verbal cues as a useful aspect of learning from their experience, observing that although preceptors may exchange operative knowledge when assisting, their gestures often reveal they are thinking too far ahead, whereas a near-peer is at the same operative place mentally.

> *"I think the best camera holding colleagues I've ever operated with are probably fellow registrars. With SHOs, they're perhaps too inexperienced or maybe they haven't done enough to sort of get to grips with it. And with consultants, it's probably the opposite, especially the more senior the consultant is, because they're not thinking from a camera point of view. They're thinking from an anatomical point of view and what they want to look at and where they want to be. And I often found the bosses will be two or three steps ahead of where you are in the operation and everybody looking at the other side and you're thinking, 'oh come back a second. I haven't finished this bit'. But the fellow registrar would know where you'd want the camera. It's not because the bosses can't hold the camera. It's because they're just not used to doing it regularly. They're used to just having the knife and fork in their hands basically."*

Excerpt 34. T7 (left-side follow-up interview).

T7 revealed through their language in *excerpt 34* that non-verbal gestures such as an assistant moving and pointing with the laparoscope are part of the normal exchange in the OT and further, that there is a level of their use which becomes more appropriate as the trainee grades sharing the task become more equal. Coupled with the downward trend in verbal exchange seen between trainees in *Figure 19, Figures 22 and 23* imply that as shared experience increases, there may be a move toward a tacit understanding of task processes through non-verbal cues, whereas explicit

verbal communication is more important to convey knowledge and meaning to a task between less experienced pairs.

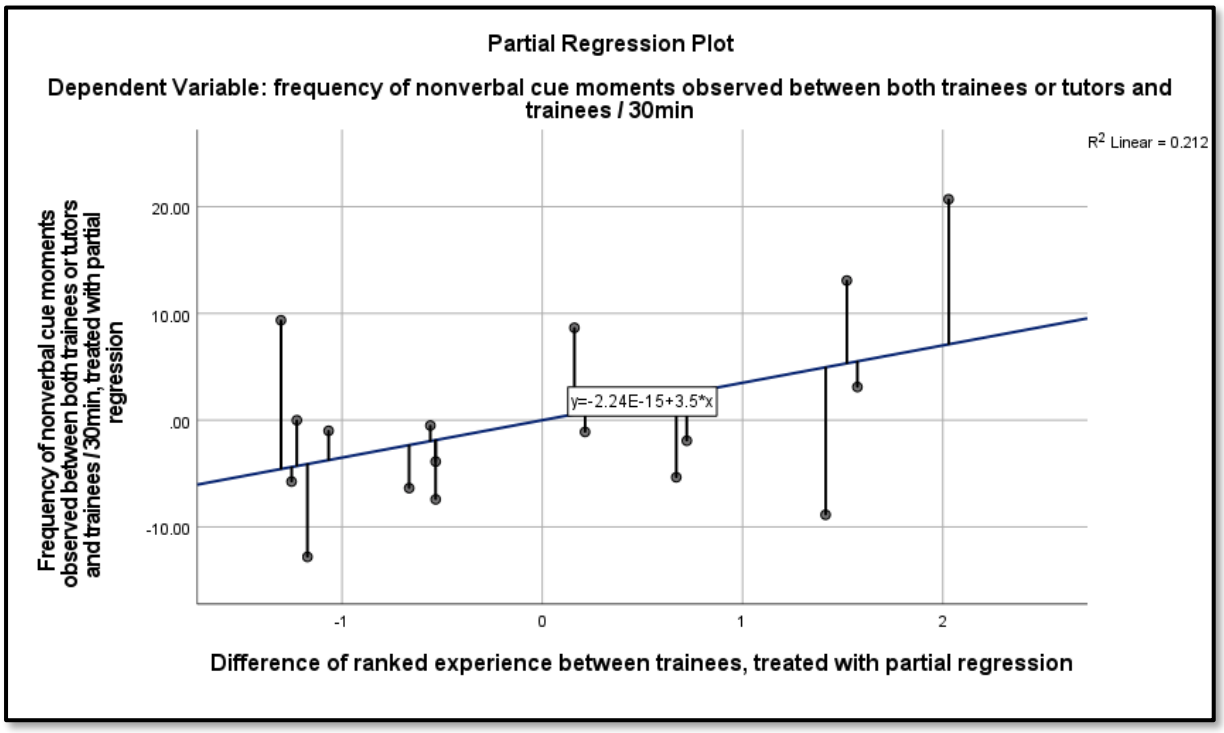


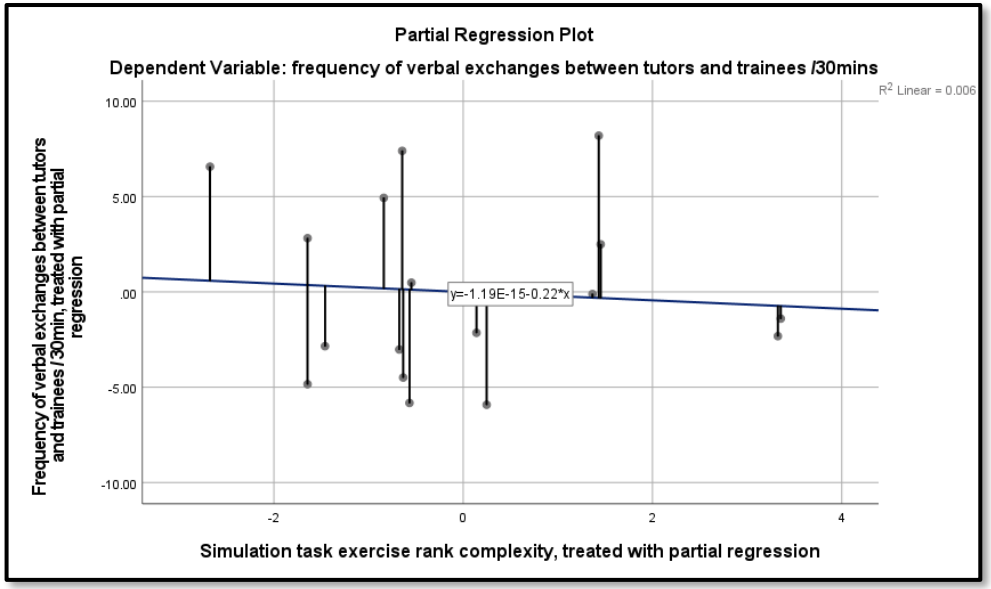
Figure 22. Partial regression shows how recorded non-verbal cue moments correlate with increases in experience difference between trainees.

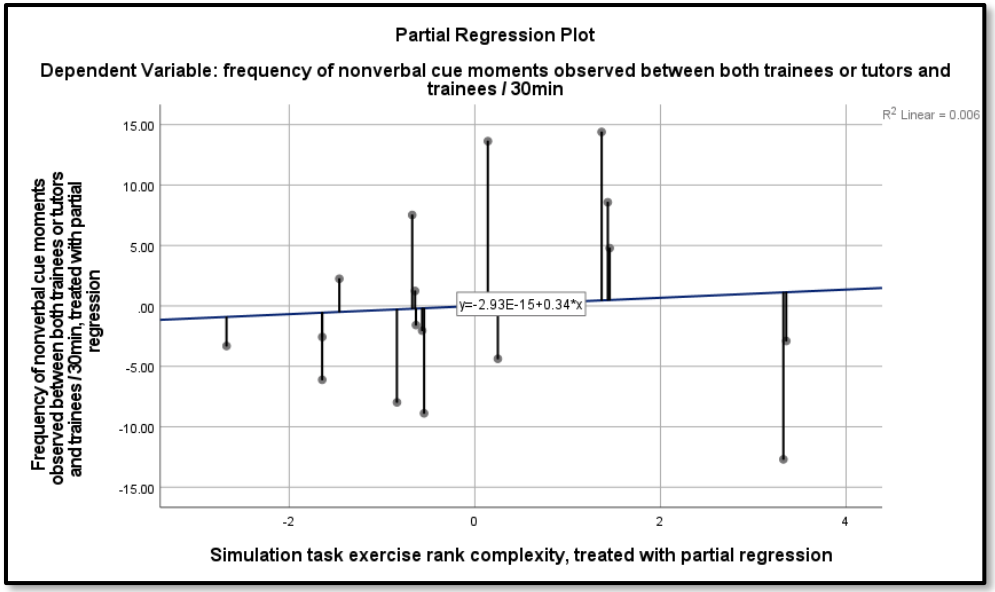
T2 and T7 (*excerpts 33-34*) also further indicate that the difference in experience between pairs may provide a gradient along which surgical knowledge may be transacted verbally and non-verbally, as supported by the trends in *Figures 20 and 22*. This verbal and non-verbal gradient of knowledge transfer could be an important component of socially organised learning seen in SBT but moreover, might serve as a mechanism for trainees to extend their shared knowledge into the OT.

5.5.3 Shared negotiation of a surgical procedure through the social mechanisms indicated by verbal and non-verbal exchange is not affected by increasing task complexity

Tests (shown in *Figure 23* below) to explore how increasing task complexity affected verbal and non-verbal exchanges revealed negligible correlations with tutor-trainee interactions (R^2 = -0.006, 0.006 respectively, top left and right graphs), while the procedure-oriented verbal exchange between trainees was only shown to decrease with an extremely weak (or negligible) correlation to increasing procedure complexity (R^2 = 0.08, bottom left). The distinction between trainee experience and task complexity in influencing social mechanisms of knowledge is important. While increasing task complexity might challenge the time or cognitive load required for procedural knowledge to be

established, the social mechanisms by which this learning occurs and is shared and further given meaning could be said to be consistent, regardless of the task given.





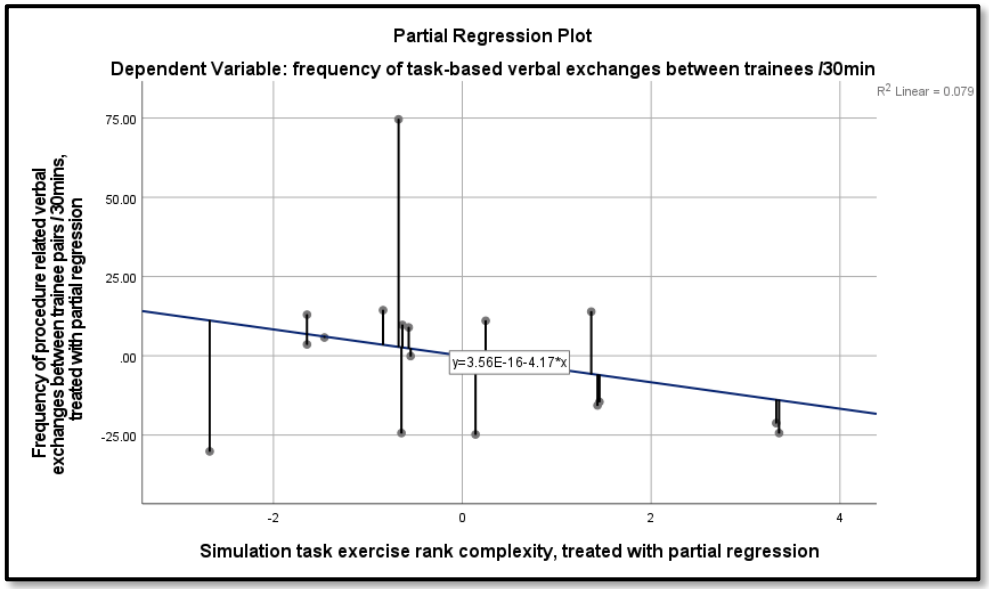


Figure 23. Partial regression graphs to explore correlations of verbal and non-verbal exchanges to increasing task complexity. Top left and right include tutors. Top left: procedure-related verbal exchanges do not appear to correlate to task complexity; top right: non-verbal cues do not appear to relate to increasing task complexity either. Bottom: Weak decrease in verbal exchange seen between pairs as task complexity increases is inconclusive.

5.6 Summary

This chapter highlights several observable aspects of SBT through which trainees experienced a semiotic process of social and technical knowledge acquisition. The strength of these interacting aspects was related to the experience of the trainees themselves and the relative cognitive complexity of the tasks. Task completion was achieved through co-constructed stages of shared task objectives. The process of embedding knowledge in external devices and operative activity seen through the exchanges between pairs is evidence of cognitively distributed and shared knowledge in action. There are several key findings. Trainees saw the benefit of course design in layering skills with guidance through scaffolded learning at each stage, which helped them extrapolate their learning into more challenging scenarios.

Course fidelity requires more than anatomical realism for the models; it requires realism of the anatomical space between the models. The language used by the trainees also suggested that tacit functional realism helped them in their pretence. This notion includes the possibility of accounting for social fidelity as an important factor in course activity.

Novel surgical tools associated with colorectal surgery take on external cognition and become artefacts through which both knowledge and meaning created in simulation can cross over into the OT. Furthermore, through a semiotic process, such knowledge is co-constructed between trainees working on a shared activity. When tasks increased in complexity, trainees found that having to learn new instruments was an unnecessary cognitive burden, regardless of prior experience.

Verbal and non-verbal cues are semiotic signals, mediating and reinforcing colorectal knowledge with activity between pairs sharing the learning task. Learning was a consequence of the shared co-constructed activity. Where the experience of trainees in a pair was unequal, verbal cues were less casual. As the shared experience of trainees paired on a task became greater, task-oriented conversation was given less priority over the use of non-verbal cues to signal between participants.

6 Learning occurs through the negotiated interaction of multiple social and cognitive cues

In this chapter, I explore the evidence within trainee accounts supporting the mediation of learning through the organising social learning perspectives of CHAT and CoP. Multiple social, material and cognitive cues interact in simulation and may be emulated in the OT. Interview responses indicated that learning was socially mediated between the right-side and left-side courses to the OT through several underlying mechanisms which could produce rich and deep learning.

Table 8 details the subthemes which emerged through recognition of trainee learning transactions taking place between simulation and clinical practice. This is important for exploring the interplay of learning theories and for informing a learning framework which recognises the social experience of simulation in negotiating professional development.

Table 8. The theme of modes of learning transfer between simulation and operating theatre, with its subthemes.

Learning through negotiating activity between SBT and OT Subthemes	Frequency in interview data
Evidence of negotiated knotworking as part of activity theory	**36**
Evidence of situated learning and CoP	**29**

6.1 Evidence of negotiated knotworking and activity theory

Signs that learning was negotiated through what can be seen as knotworking (see glossary) of different activities coming together as contended by the literature review, are embedded in the interview content. Significantly, video observation coding of semiotic cues in the simulated procedures revealed that simulated tasks were comprised of separate 'threads' of activity consisting of trainees, tutors, non-verbal and verbal productions, and instruments as objects. It is reasonable that where learning is the goal of the simulation task activity, to complete it requires the cooperation of all these components together. Importantly, it is reasonable that this task can also be extrapolated into the OT. In the following sections, trainee evidence suggests that learning activities negotiated in SBT align with those negotiated in the OT environment, where learning also took place. This idea is expounded to illustrate how activity was negotiated between the paired trainees during their SBT.

While preceptorship in the colorectal OT is supposed to encourage open and democratic communication, in an increasingly accountable and less deferential culture of team working (outlined in *ch.1*), it is important to note the historically hierarchical nature of surgical teams. While negotiated knotworking is observed in SBT, that it may 'boundary cross' to the OT setting is not guaranteed. Traditional vertical hierarchies tend not to allow room for negotiation. This presents SBT with both a challenge and an opportunity to shape the professional dynamics of the OT, fostering negotiated knotworking within it through emphasising learning through social transactions. Furthermore, possible future developments, such as the progress of digital collaboration, might bridge gaps between the two activities.

6.1.1 Negotiating roles at the 'table'

One of the main aspects of the hands-on structure of the course that was designed to mimic reality; that trainees will not always get the luxury of working with the same people across an operating table, was in prompting trainees to exchange partners for every change in procedure. In the culture of the OT, this requires a process of negotiating the distinct roles and agencies involved and can be seen as a knotworking process (which is not as stable as a traditional situation or apprenticeship or teamwork where the expectancies of all actors in their roles are known).

T2 had revealed an experience of working frequently with different colleagues in the OT (*excerpt 35*) during colorectal procedures. Through this experience, they reflected in their initial interview that exchanging operating partners gave them wider learning perspectives. This came through their observing the difference in approaches between surgical colleagues.

> *"You're working with a different boss every time [so] you're working with a different system every time. You're not working with the same consultant all the time. Also, one day you've got different SHOs helping, and you also learn different…you learn a lot by watching someone else as well. How one person will do it. They're all quite different."*
>
> *Excerpt 35. T2 (right-side initial interview).*

T2 equated their learning a variety of surgical approaches through working with different surgical colleagues. Learning through *negotiating* different systems of activity is implied because T2 was an active participant in each case. It was not a passive process. The implication is that learning was applied and adapted through a systematic and sequential input of multiple surgical partners. T2 went on to say that this change of partners needed to be balanced with consistency, which was provided by course faculty teaching standardised operating principles and further, all differences were negotiated through common surgical language.

"Having the faculty there telling you the stepwise, or saying the base teaching is [common] principles - that gives you consistency. Rather than one telling you 'Well I do it this way', and 'I do it that way', and 'I do it completely the other way', you need a common language for the purposes of the course … We should be talking a common language and have variations on that common language."

Excerpt 36. T2 (right-side initial interview).

T2 viewed the faculty's role during SBT as imparting a common language; a way of communicating the activity which is recognised as part of the tacit integration of skills into the colorectal surgical community. This implication is important because imparting a common language through teaching functions as a tool for negotiating their surgical activity, development and identity in the OT. There is a valid perspective that the common language alluded to by T2 (*excerpt 36*) is more readily recognised and understood between trainees at a similar level. That is to say, SBT may be driving a contemporary way of communicating, because partner rotation may generate and reinforce a particular communication strategy. While acknowledging that not all individuals communicate in the same way, T4 reflected on the value of moving between partners during simulation (*excerpt 37*), particularly those at a similar level, since they face comparable challenges which shape their perspective and the learning exchange occurring between them. Their comment also provides an account of the importance of effective communication which is a richer description of how the common language of surgery is negotiated.

"I think near-peer learning is important. You can learn a lot from working with other people who are at your own level, because you can teach each other things and you have perhaps a more up-to-date perspective on the challenges that are in front of you, as opposed to some of the tutors on the course who [have been doing it for years]… You're going to be operating with other people who some of them aren't very good communicators, and I guess you just have to find ways to overcome that and not let it get to you. There are some people you really like to work with because you like them and they're constructive and they're helpful, but it's not always going to be like that. So I guess it's a good thing to move around."

Excerpt 37. T4 (right-side initial interview).

This account also brings the implication that communicating with a common surgical language between near-peers who move from table to table may also impart socially agreed meanings to the tasks and objects in and through which the pairs are working. This is because there is a learning exchange which brings a semiotic process in.

Six to eight months after having attended the course (a period during which to accumulate operative experience), T4 further reflected on two contrasting socially organised operating set-ups that they experienced; one was from a community hospital in which they were located at the time of interview and the other was from their experience at a busy university hospital where they worked during their attendance at the right-side course.

> *"In theatre, where I'm working at the moment it's a DGH [District General Hospital], it's quite a tight community and people get on very well and they're very much, particularly in theatre, a community that is well established. There are all the things that go along with it being not just a sort of interwoven group of professionals who come together around activity points. There are the possibilities they've done it before. Not the fables, but they tell their own stories. There's a cultural currency that goes along with that department."*
>
> *Excerpt 38. T4 (right-side follow-up interview).*

In a DGH, there is less movement of operative staff and more opportunities for trainees to operate (Field et al. 2011; Kwok and Gordon 2016), although less likely in complex cases. It is possible to take the cultural currency to imply that the operating department had its own cultural capital; a socialised disposition to act, think, feel and communicate in a particular way as belonging to it (Bourdieu and Passeron 1990). The actors in this system communicate their goals with the common language of that system. There is peripheral participation then, which could be required every time a trainee moves from one operating department to another. In which case, having multiple tools with which to negotiate an activity is useful.

> *"In other places that I've been that are perhaps busier, there's a high turnover of staff. People have moved around between teams much more frequently. It's harder in that sort of sense to become part of a centralised part of the community and you'd have sort of, whether it was a negotiated knotworking model or an activity network, you just have to approach it differently and you have to be aware of it and how to exploit it for your own benefit and more importantly obviously to get what you need for the patient."*
>
> *Excerpt 39. T4 (right-side follow-up interview).*

In a busier operating department with higher patient turnover, opportunities to operate may be less abundant, although what *is* undertaken is usually more complex (Field et al. 2011; Kwok and Gordon 2016). T4 indicated the need to use separate strategies to negotiate the cultures of the DGH and university hospitals separately. If there was no sense of community because the actors in the

operative system were made up of transient colleagues, then there was a greater awareness of what could be termed knotworking in order to achieve the goal. In a similar account for their involvement in SBT, negotiating activity became more goal-oriented for T3 (*excerpt 27, ch.5*), since they were changing partners for tasks and forming transient connections with each other. Moreover, T3 mentioned they did not know the other trainees very well. This, coupled with the transient nature of attending a short course, may have encouraged a greater sense of negotiation around each task.

6.1.2 How negotiated knotworking was observed during simulation

The simulation course aligned more with a busy university hospital operating department. This focus on the simulation activity is valuable because it may emphasise the need for trainees to make use of all the multiple threads (those semiotic, observed categories of verbal and non-verbal transactions, instrument handling) available to make sense of the activity.

The following analysis shows how the social categories observed between pairs in the simulation videos have their own 'flow' during the simulation exercise tasks. At times, for example, verbal exchanges between the trainees may form the densest component of activity, in the sense that this may be the most prevalent of the sum total separate components of negotiated activity in a given moment. While it may be at times the most active, at another time or in another sample, the visibility of a combination of categories may rise and fall in length and/or frequency. Taking one of the tasks as an example, *Figure 24* shows how the social cues (through which learning can be exchanged) between two different trainee pairs undertaking the same exercise (3), are negotiated from start to finish. The 'negotiated knotworking' metaphor describes how seemingly separate (metaphorical) threads of activity come together during collaborative work towards a common goal involving different actors and tools in a system (Larsen et al. 2017). Moreover, the term 'knotworking' kindles an image of multiple threads being tied together loosely, only to be untied and re-tied in alternate ways. *Figure 25* shows how these components of social activity can run through like threads, which here, are aligned to 'rise' and 'fall' with the changes of social observations. They depict a collaboration in which there is no fixed centre of control (the unstable knot depicts a centre which does not hold) (Engeström 2008).

It is further possible to postulate that the mechanism of negotiating these social, surgical tasks may be irreducible in that all these social categories exist both in the OT, just as in simulation, even if the goals are not the same.

Appendix 8 contains figures for the social cues recorded from all other tasks observed with paired trainees, along with their concomitant 'thread' diagrams. The important point of the illustration is that it shows these threads as continuous phases, which are also seen to interconnect at the points

of the task during which they occur in simultaneously dense nodes. The aim is to convey an understanding of how the separate social components of shared activity are connected and form the way in which the exercise is negotiated.

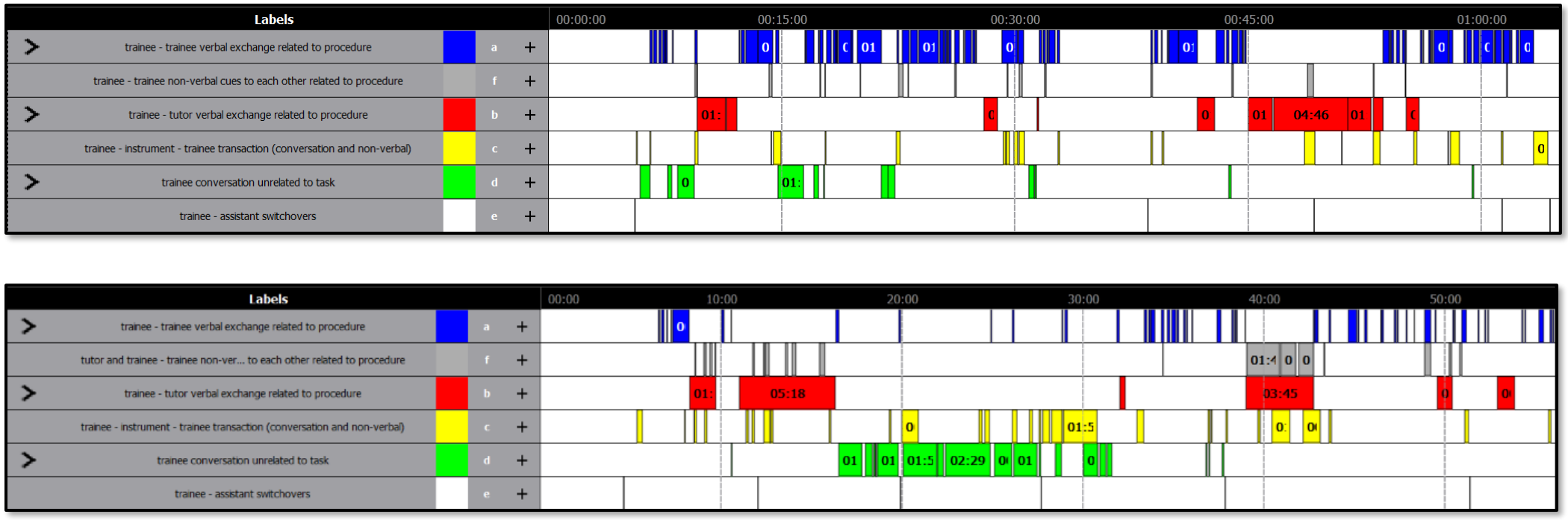


Figure 24. Labels of social cues could show points of learning exchange. These labels come from 2 separate recordings of exercise 3.

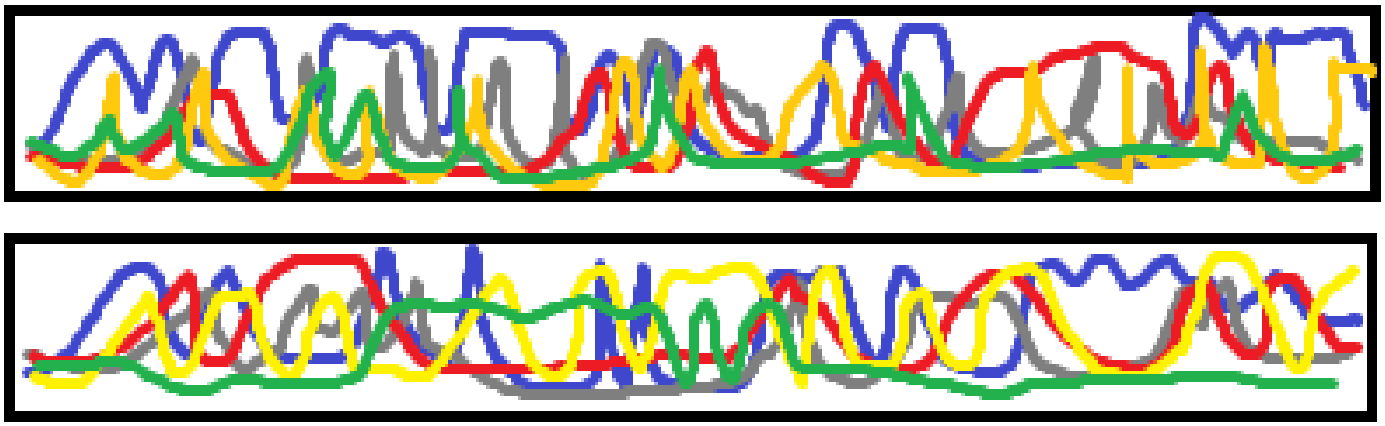


Figure 25. Illustration of social cues as labels of exercise 3 activity seen in Figure 24 depicted as individual threads that come together as a knotworked pattern.

6.2 Evidence of situated learning and communities of practice

Situated learning and communities of practice (CoP) are rooted in the same theoretical foundations as CHAT. One of the contentions of this thesis is that CoP is embedded within CHAT. They both acknowledge the need for social interaction for learning to occur. To recap, within the context of the WLCTS, colorectal trainees learn through a gradual process of becoming socialised to the professional community in which they are situated, taking on the language and tenets that form their (surgical) identity through a process of legitimate peripheral participation (Lave and Wenger 1991). That is, novices to a professional community begin at the periphery of it and become central to its activities as they undertake to learn the tasks and achieve the goals of that community.

Therefore, there is value in looking at how the language in the conversations with trainees may have shifted from the initial interviews following a period of surgical preceptorship, as evidence for the development of their surgical identity. Further, how trainees describe their gradual inclusion into more independent clinical practice may also be useful, as an indirect observation of effect due to situated learning by simulation.

From the initial guided conversations following the course, there were indications that trainees may recognise their position within the community in relation to the tutor who tacitly represents the centre, with their knowledge, language and 'fluency'. Implicit within the narratives of several trainees was the recognition of difference between themselves and the tutors, and further, between themselves over time. T3 pointed out in *excerpt 40*, that consultants assert their way of approaching a surgical task by implying strongly that things should be done in a certain way. In turn, this exerted on the trainee, the impression that a surgical task must be approached in a certain way.

> *"I have heard so many times now consultants saying, 'this is the way I do it. It's not the way you have to do it. It's the way that I prefer and you'll get your own way as to how you prefer doing it, but while you're with me I'd prefer you do it this way.' I think that's completely fair and valid if they say that, but there's a respect that you might not like it. You might think … you prefer doing your way and there's an openness to accept that, rather than you doing it this [consultant's] way and that's it."*
>
> *Excerpt 40. T3 (right-side initial interview).*

This comment tacitly impresses that while their consultant might give T3 permission to challenge an approach, even to offer a valid suggestion, it is not likely to be heeded. T3 supplemented this by saying they did not feel that they could challenge the instructions of the tutors even if they wanted to. The significance of this is that it reveals the implicit awareness of a difference in agency and power (both of which can be acquired as the trainee progresses toward the centre of their

profession). Moreover, T3 revealed that trainees compare themselves to each other in terms of perceived ability, which in this example may also have shaped their identity within the community strata:

> *"We all compare ourselves to each other. I was quite conscious I was the ST3, the baby, and there were some ST6s there. So actually, if I failed at something or felt I was struggling, I think I got quite a good get out of jail card..."*
>
> *Excerpt 41. T3 (right-side initial interview).*

This remark indicates that personal expectations for T3 on the periphery of the simulation community may not have been so urgent or high-pressured. However, this position is relative to the situated level of the trainee; in the OT acting in a more experienced position, T3's reflection on supervising a more junior doctor doing a more straightforward operation shows that they can 'measure' their development and position in relation to their agency and power over another.

> *"…obviously everyone has got their own preference by doing it and I know now when I've seen an SHO do an appendix and I'm supervising that, they're doing something right but it's not the way that I like and I would rather them do it my way because I feel more comfortable watching it because I would know if there was a problem."*
>
> *Excerpt 42. T3 (right-side initial interview).*

Another finding that arises from these two above *excerpt*s is that situated learning with legitimate peripheral participation in the simulation, certainly with respect to surgical identity, seems related to the trainees' specific learning goals. In the situated case of the colorectal trainees on the WLCTS, on learning the specific procedures and complex steps of right and left-side colorectal operations, they are at the periphery, while in cases such as performing 'straightforward' appendicectomy in the OT, they are already moving towards the centre.

T7 (a senior trainee and most experienced in the group), explained how they initially thought that skills transfer between trainees (paired up together) at the same point in the learning curve might not have been that strong compared to the tutors during the course (*excerpt 22*). T7 admitted subsequently that in the OT, the conversation between near-peers working alongside each other is more 'fluent', with no barrier to admitting their limitations, compared to how they will communicate with a "boss".

> *"When I do stuff like operating alongside [my fellow colorectal registrar], it's just the two of us in theatre. There's no language barrier. We can just be fluent in what we talk about and how we go about things, and then … you're not ashamed to admit your faults to each other because then you're sort of bouncing off each other."*
>
> *Excerpt 43. T7 (left-side follow-up interview).*

Both reflections support the view that for trainees at the same point in the colorectal CoP, their learning and progressive formation of identity may be shaped consciously by their position relative to the trainer/boss rather than each other. However, these observations also imply that there may be mutual reinforcement of surgical identity for experienced trainees at the same position within their CoP, which is consistent between the two systems of activity.

For one exercise during the right-side course, in which the objective was to encourage the trainees to communicate and guide them with clear instructions, tutors pretended to be the "most inexperienced F1" and paired up with the trainees, assisting them with the laparoscopic camera. T5 recalled this exercise during a discussion about how the participants in this 'surgical community' encourage their learning.

> *"Mr A____ [was] holding the camera, but he turned the light cable down and it was very difficult for me to follow. I thought that he's not concentrating on the operation. So I asked [him], can you show me that. Mr A____ told me 'I'm the most inexperienced F1, just think like that.' So that helped me a lot. Not just concentrating on what you're operating on; you have to have an idea who is holding the camera behind and what sort of training that person has got. You have to consider all those factors."*
>
> *Excerpt 44. T5 (right-side initial interview).*

T5 showed insight into how their situated learning was negotiated not just individually, but in how they learnt to communicate with the people assisting them and make assumptions about how their partners may think. In their follow-up interview in *excerpt 25*, T5 reflected back on their situated learning during the SBT, adding that a change of assistant required a change of thinking approach for each task. Negotiation of dynamic exchange with the assistant, with each attempt at a procedure, may also then develop with growing experience in that particular procedure; T5 in *excerpt 45*, went on to signify that comparatively greater self-confidence in their ability to perform a procedure equated with a reduced reliance on supporting dialogue with the assisting surgeon. Whereas for a task in which they had less self-confidence, the trainee relied on greater explicit negotiation of agency with their assistants.

"If I'm doing the right-side I'm pretty confident and I know what I'm doing and I know when I need to get some help if I fall into trouble, but usually it's a straightforward operation for me … If it's an anterior resection and we need to mobilise the splenic flexure[17], for example [a] medial approach for the splenic flexure mobilisation which I'm not much confident with. [However] I know the planes and how to work through it, but I've not [yet had] much [experience] about that … Therefore I may need some more assistance with that … It needs much more competence and much more insight as to what you are doing. So I need much more support in that case."

Excerpt 45. T5 (right-side follow-up interview).

These comments, along with those of T3 (*excerpts 41-42*) and T7 (*excerpts 22, 43*), build a picture around situated learning and how they move through legitimate peripheral participation with respect to the people they are working with. If each CoP is built not just around the body of surgeons themselves, but more specifically around each particular type of operation, then trainees' sense of agency and identity is constructed through their movement from the periphery to the centre for each procedure, the mechanism of which may also include simulation for each one. Simultaneously, trainees negotiate their surgical language, learning and their place in the community when they are working alongside surgeons of greater, equal and lesser experience. A change in dialogue may occur with different assistants, but the goal of the community is maintained. The implication is that the trainees move toward the centre of the CoP by attaining fluency and competence around the use of structures that facilitate the community. It is a socially negotiated process not just referenced to the expectancy of the consultant (at the centre), but also on the outcome of the activity around which the community is focussed. This latter point is important because the surgical community works alongside other professional communities who have goals affiliated to those said communities, but there are common goals for which reaching them cannot happen without their combined intervention. This picture is also very much like knotworking activity described inside a system of activity in which such communities of practice are embedded. The trainee comments show then that learning is situated in a community which moves between simulation and operation.

6.3 Summary

Trainees recognise an implicit difference in ability with their partners, but they also stress the importance of having a shared goal and commonality of surgical language. The format of simulation and surgery follows that of having to anticipate a different working partner for each procedure.

[17] The splenic flexure is the section of colon and attached mesentery which occurs anatomically at the angle of the transverse and descending colon, above which and slightly ventral to it the spleen is situated.

The key findings here are that task simulation was not performed in isolation and the SBT environment engendered development of a common surgical language and structures specific to colorectal surgery. This agreed meaning was taken on as a learned tacit consequence of shared task activity. This commonality enabled trainees' negotiation of roles and activity.

Surgical activity in simulation is comprised of several separate threads of socially organised and technical activities through which participants co-construct their learning and further, by which their roles and task performance are negotiated. The semiotic cues identified and recorded may by no means be exhaustive. Their interaction can be described and illustrated as an interweaving of activity, where the focus or priority of that activity changes at the so-called knot, which breaks down and reforms at a different centre as the activity progresses, and so on.

Trainee reflections show evidence that within the community of colorectal surgery they are moving from the periphery through their acquisition of experience and agency, toward the influential centre. Participation in the WLCTS courses demonstrated that their learning and communication is underwritten by the tacit rules of their CoP. Participants acquired a sense of agency and mobility within their community that appeared to be task-specific and which was enabled by negotiating their task alongside someone with different (position within the CoP) experience.

7 Mental rehearsal is a prominent stage in preparation for operating, which is aided by SBT

As my literature review contends, much has been published supporting the strength of reflection and mental rehearsal as a way of reinforcing the cognitive scaffold and the decision-making process. Simulation could assist in this by connecting the learnt, stepwise process of activity with the visual and the semiotically embedded constructs. Looking at trainees' conversations reflectively reveals both explicit and implicit evidence of mental rehearsal. *Table 9* illustrates trainees' responses and the subthemes suggest they reflect on their simulation experience in relation to their training and decision-making processes.

Table 9. The theme of reflection and mental rehearsal along with its subthemes.

Reflection, mental rehearsal and developing decision-making subthemes	**Frequency in data**
Simulation provides a scaffold which enables mental rehearsal to plan and prepare for clinical activity	75
Rehearsal improves self-perception of competence which leads to confidence	63
Expertise develops through mental preparation and experience enabled by SBT	99

7.1 Simulation enables mental rehearsal to plan ahead of real operating

T7 revisited spatial and psychomotor memories from their SBT as a part of the planning exercise before the operation, drawing specifically on the learning of instruments and positioning during the course as a way of reducing the cognitive load by the time they went to the OT to perform the procedure for the first time (*excerpt 46*). In discussing simulation as a mental frame of reference, they alluded to how being able to practice it in SBT provided a spatial construct that they would not otherwise gain. T7 specifically saw simulation as helping to visualise the real thing; being visually oriented is an often-cited aspect of surgical ability. Other course participants also cited this visually oriented characteristic.

> *"Your planning is definitely better when it comes to the real thing because you know ideally where you want your ports to be and what instruments you need. It prepares*

you for the real thing more than anything else because it's one thing [having] your boss sitting there and drawing things on a whiteboard and saying 'right, you need to put your ports here and then we'll have a look at this.' It's not the same as actually visualising it."

Excerpt 46. T7 (left-side initial interview).

Receiving the ability to recall spatial positions and processes visually appears to have had a profound impact on the learning experience of T7 in mentally situating their skills from one place to another. T8, who also commented on the strength of the visual aspect of simulation in preparation for an operation, said in their initial interview that it helped not just to recall instrument positions and places, but to understand why the processes are done.

"[Simulation] changes your practice … because then you definitely know where to put the port and everything, and I could answer if somebody asked, 'why did you do that?' because this helps this and that, which … definitely helps to change our practice. Also, when you're doing it actually on your own you know this is the way it is done."

Excerpt 48. T8 (left-side initial interview).

There is an assurance that therefore comes from visually preparing for a procedure and imagining the process as it would transfer into the OT. To go deeper into the mechanics of this transaction process, T4 in the initial interview following the left-side course, discussed at length the elements of performance and craft skills which depend on haptics. (At this point in their training, T4 had completed the right-side and had eight months of right-side operatively preceptored experience). Reflecting on the development and consolidation of coordination in *excerpt 18*, (c*h.5*), T4 emphasised the need to develop user familiarity with operative equipment before use in the OT to avoid the added cognitive burden associated with undertaking and bringing skills together. The OT provides both the construct and the context in which trainees need to draw multiple, separate sets of knowledge together, including the steps of the operation. To reiterate the point, T4 (*excerpt 17, ch.5*) equated mental rehearsal as a construction of the operation in the mind, through intentional consolidation of all the steps, devices and sensations acquired during the course. Constructing a mental process for the procedure like this indicates the trainee anticipated how things may go, based on all the information available, including that which is embedded in the instruments. T4 went on to expand and extend the construct to situate this pre-reflection within the social environment of the OT.

"If you've got surgeons who are training and learning as well as anaesthetists and the scrub nurses to do it all together in a more realistic theatre environment, [the rehearsed mental construct is] less abstracted and each of you learn together. [For example], … where you're trying to do an operation and you've got a trainee scrub nurse, something falls apart or you ask for something and they're not quite sure what it is and actually as a way of making it more valuable for everybody … there's scope for [shared learning]. Though [usually] everyone [rehearses their part] individually and they're brought together."

Excerpt 48. T4 (left-side initial interview).

T4's comments imply that they have extended their mental process to assimilate skills initially learnt in simulation to make sense in the social. This means that trainees make a richer meaning of their surgical knowledge. This is not in isolation from but rather, by inclusion in the social professional environment.

To some extent, the reflective process may have been supported by near-peer and consultant discussions on their comparative approaches to an operation. The left-side course taught one particular type of colon dissection approach and T8 suggested this was useful when faced with having to adjust to the preference of the consultant in the OT because the anatomical landmarks were already understood.

"[In the operating theatre] [to] one of the consultants, who does more lateral than medial[18], you know, the different approach, I was saying 'yeah, they taught us [to go] from medial to lateral'. Some are more comfortable doing it the other way [doing] the lateral bit first and then coming to [the] medial bit. Everybody has a different perspective, but I think the course helped us because we already know the anatomy. We know the basic grasp of what's happening. We are, like, easily getting adjusted to whatever they're doing."

Excerpt 49. T8 (left-side follow-up interview).

This comment came in response to a query about similarities in surgical conversation in the SBT and OT and implies that T8 could speak from implicit confidence in being both visio-spatially aware and fully comprehending the conversational processes of the consultants. This point is valuable because it further confirms the importance of social engagement to draw out embedded knowledge.

[18] The anatomical line of dissection of left-side colon from its connecting tissues. Lateral to medial infers moving along a plane of dissection from the side of the abdomen to the middle, while medial to lateral infers dissection from the middle towards the side.

7.2 Mental preparation improves trainee confidence

Trainees reported that the right-side course gave them confidence by shaping mental preparation. Notionally, greater confidence in a trainee's ability to undertake a skill is related to acculturation towards fostering a surgical identity (Dornan et al. 2007), so it is an indirect indicator of how SBT is given richer meaning. T2 implied how the mental preparation that came through prior simulation experience helped progress their confidence to act on important surgical decisions:

> *"[The course approach] almost pre-empted every stage. You think, 'right, I'm going to do this [part of a procedure] first, so what could go wrong? Why would I convert this to an open at this stage?' For most of us, especially me, it is confidence. If you're mentally prepared for something it gives you more confidence. It makes your skills better because instead of going, 'do I do this next, or do I do that?' You're like, 'yes this is the next step. This is what I could do. Everything looks great. There're no problems with this,' and you carry on. It makes everything slicker."*
>
> *Excerpt 50. T2 (right-side initial interview).*

Extrapolating T2's comments, the mental preparedness set up as a result of the simulation process is a principal factor in applying the learnt skills in the right way and the right sequence. This notion was supported by others on the course; T3 (*excerpt 51*) summed up the consensus.

> *"I'm certainly someone [where] the more confident I feel, the better I operate actually. … If you feel more confident, you can feel more that your opinion has validity … whether it's surgical in theatre or anything else."*
>
> *Excerpt 51. T3 (right-side initial interview).*

Confidence enabled through mental preparation leads to a sense of legitimacy and validation; these are mechanisms of legitimate peripheral participation where learning is contextualised socially (Lave and Wenger 1991; Sfard 1998) and the trainee senses their progress. Furthermore, the course bred a sense of validation that supports the previously discussed dialogue of legitimate expectancy to perform parts or all of the operation, which perhaps may factor in the negotiation of access to surgery between the trainee and the consultant.

7.3 Expertise develops through further mental preparation and experience

The more experienced trainees of the cohort pointed out that mentally rehearsing the steps of an operation or instrument handling and positioning extends into thinking ahead and preparing for other possible surgical outcomes based on the way a process may go, perhaps akin to reflection-before-action (Schön 1983; Greenwood 1998) rather than reflection-in or on-action (Boud 1985). This

development indicates procedural fluency, which in turn implies fully embedded and automatic cognition within a given situation. T2, following the six-month interim during which preceptored operations took place, developed this notion of fluency acquisition in the accounts that follow (*excerpts 52-55*).

> *"[At my training level] I'm now thinking about the next step and thinking about the 'what if', rather than just turning up and the boss takes me through it. … When … cutting the tissues and vessels, I'm getting much more fluent in that, but I'm thinking more of what goes with that, rather than saying, 'right, the vessel is next' and sort of taking longer over it. I'm thinking a step ahead. I'm thinking, 'right, okay, so I'm playing around with the vessels now; have [the nurses] got the haemoloks[19] ready just in case they start to bleed?'"*

Excerpt 52. T2 (right-side follow-up interview).

When talking specifically about performing some of the key steps of the right-side hemicolectomy, T2 indicated that they were thinking beyond the basic steps and anticipating for themselves what might be needed; but moreover, thinking ahead into how they might negotiate their professional interactions with the other team members. The dialogue went further to build on this development in active reflection.

> *"I've been around the block a few times and you see where things go wrong. [You consolidate your knowledge], you know, things like, 'okay I'm near the duodenum now. I might, rather than using the harmonic[20], use something that's not 'hot' basically, rather than plough on,' because you've now got to the duodenum. … so I'm thinking probably more for myself, rather than just being taken through the skill of someone else."*

Excerpt 53. T2 (right-side follow-up interview).

For T2, experience in the OT consolidated technical expertise and led to independent thinking. This was further corroborated as the trainee continued to link independent thinking with independent decision-making which comes with the confidence of technical ability, demonstrated by anticipating and then integrating their position and their dialogue with other members of the OT staff.

> *"[I'm] maybe just being a bit more mature in my decision-making, taking more responsibility, and the actual skills itself they're flowing along now. I'm getting much more confident with my hands getting into position and things like that [which I don't*

[19] Haemolok is a laparoscopically discharged plastic degradable clip which is applied over blood vessels.
[20] Harmonic Scalpel.

need to think about]. [For example, asking for the patient to be tilted] is something I might say directly to the anaesthetist … rather than me cracking on with the boss going, 'do you want to tilt the patient?', 'Yeah that will be handy'. I'm much more independent in my thought processes."

Excerpt 54. T2 (right-side follow-up interview).

Therefore, there are tenets of thinking with expertise that develop and become supported by the fundamentals provided by simulation. T2 argued explicitly for the place of simulation in assisting their visual planning, corroborating T7 (*excerpt 46, this chapter*). When applied to the controlled operative environment of preceptored training, their procedural skills extend into thinking ahead; not just for the particulars of an individual case, but also for how they will interact with the team and the environment in the OT.

"I'm a visual person. I have to see it in my head to realise it. Whether it's partly this course or whether it's just, the leash getting longer and you have more responsibility, I don't know, but you get much more proactive in terms of [visual planning]. For instance, we had a colectomy in the anal pouch for a patient yesterday and I was trying to get it into my head 'this is what I'm going to do here and [there] and try to plan the path ... which parts of the bowel'. Almost trying to think a bit more like a consultant now and I'm thinking 'how will I plan this? How will I make my life easier?' Rather than just turning up and going 'oh I've got the boss there. He'll tell me what to do'."

Excerpt 55. T2 (right-side follow-up interview).

Therefore, experience consolidates mental preparation with visual cues taken from the course and hands-on elements, which gradually builds 'expert' thinking. T2's last comment here also suggests an implicit acquisition of expertise identity, which comes with the demands of independent thinking.

Following their six-month interim preceptorship period, T4 (*excerpt 56*) and T5 (*excerpt 57*) clarified how the simulation elements of the course provided a systematic approach to doing the right-side procedure which support the acquisition of expertise.

"You think, 'oh God am I doing the right thing here? Is this what I'm supposed to be doing?' You can refer back in your mind to the course and go, 'yes this is what I know I have to do in terms of a logical progression of the procedure'."

Excerpt 56. T4 (right-side follow-up interview).

"Before this course, I didn't have [much of a structured approach] to the right-sided operation…. Once I did this course they taught me how to do, how to approach the

problem and how to go step-by-step. Now, before cracking on with the operation I have a structure and strategy to how to deal with it."

Excerpt 57. T5 (right-side follow-up interview).

A systematic and logical approach to mental preparation and reflection put in place through simulation assisted a correct outworking of embedded knowledge and consequentially, situated the trainee in a more authoritative position within the team.

7.4 Summary

The findings of this chapter show that reflective practice and mental rehearsal was strengthened by the trainees' interactions with the tasks and with each other during the course. Trainees felt their mental construct was improved in spatial cognition for visualising the operation. SBT also instilled a haptic memory for the feel of the procedure. Further, simulation extended their rehearsal of the social construct, that is, the interplay of all actors in the OT procedure.

Trainees felt confident to make decisions within an operation as a result of their ability to reflect on their participation in the shared tasks achieved during the courses. The course activity imbued the trainees with a sense of structure and strategic approach. This enabled their agency and sense of expertise further.

8 Discussion

8.1 Introduction and overview

This chapter explores the findings of the videographic observations captured during SBT and thematic accounts through interviews from two points in time (soon after the training and six to eight months later, after a period of operative opportunity in laparoscopic colorectal surgery). I first discuss the initial discoveries through videographic observations; that of time taken to complete the procedure for each of the independent variables, while further indicating the potential pattern of social and knowledge distribution findings related to these variables. The purpose of this is to lay a contextual understanding of the observed social interactions as they integrate with trainees' accounts. Two semiotic themes are particularly supported through convergent parallel design. That is, combining a complimentary analysis of semiotic activity shown through (video content) regression data is an additional standpoint from which to build a wider, triangulated perspective. They are *knowledge embedded and shared through surgical instrument transfers* and that *knowledge and learning are mediated through social interactions*. Additionally, *learning through negotiated knotworking* as a theme exploring learning transfer concepts combines with task-process illustrations from video analysis through further convergence; the combination shows how social and instrument transaction cues interact and come together as individual threads and learning occur by consequence.

Following this contextual provision, I organise the discussion of my key findings in relation to my research questions set out at the end of the literature review. They are:

1. Through what social mechanisms are the complex clinical skills of surgery which, being learnt through the WLCTS, translated to the operating theatre context?
2. How do laparoscopic colorectal trainees perceive the value of, and make their training meaningful?
3. How could the learning theories discussed, inform a framework which can both acknowledge the social experience of simulation in facilitating the negotiation of learning and enable the professional development of the trainees?

8.2 Discoveries from video observations

8.2.1 Procedure complexity

Procedure completion time increased with increased procedure complexity. Further, while the exchange of unfamiliar instruments between trainees appeared to decrease with increasing complexity, partial regressions exploring a correlation of task complexity on verbal and non-verbal cues between trainees and between tutors and trainees, showed either very weak or negligible R^2 values (*Figure 24, ch.6*). This is not unexpected; the video observations afforded only a snapshot of trainees performing the procedures at one given moment, with no observation of performance in the OT and no follow-up observations in the simulation lab. To explore more accurately whether cognitive load indicated by complexity might directly influence the measured cues, repeat observations would be necessary (since the expectation is that cognitive load should reduce over distributed phases of consolidated learning). Prior studies have highlighted the effect of procedure complexity and cognitive load on the learning curve (Fitts and Posner 1967; VanLehn 1996; Kim et al. 2013; Tseng 2020). It is acknowledged in the surgical educational literature that there is an uptake time during which trainees refine their surgical proficiency through consolidation of units of declarative and procedural knowledge (Hopper et al. 2007; Spruit et al. 2014). It follows then that the increasing complexity of procedures by the addition of new anatomical planes and further motor sequences is likely to increase the procedural time.

8.2.2 Trainee experience - combined

The initial partial regression, mapping trainee pairings' incremental combined experience correlated with a graduated decrease in procedure time. While no effect on completion time was seen through observing the divergence of experience between paired individuals, there was a trend of decreasing procedure time associated with greater *shared* experience, suggesting that a social mechanism of knowledge and skill exchange may be at work. In a recent study, Jenkins et al. (2021) proposed that complementary rather than identical roles, foster a strong sense of shared agency where identity and possibly language use are self-reinforcing. Obhi and Hall (2011) similarly suggest that shared agency arises from the reinforcement of individual identities within a shared social context. This role complementarity would be seen during SBT, where one trainee was operating while the other one held the camera and retractor, before intermittently switching over. Moreover, experience likely contributes a more coordinated response to a joint process (Bolt et al. 2016) and trainees could be said to have a stronger joint agency.

There are a few propositions arising from this. First, trainees working in pairs where (at least) one of the pair has the relatively greater experience may positively impact the development of the less

experienced trainee, particularly on their agency for the scenario in which they are partnered and help them to build an understanding of the social rules of an activity (Van Leeuwen 2005). Tørring et al. (2019) demonstrated a role for interdependence. This notion is strengthened by prior research advocating relational coordination (Gittell 2009) to achieve outcomes in surgery. Relational coordination is a construct describing how people in teams integrate their activity and communication with reliance on the each 'other' to perform their part in achieving a task objective. Second, it creates a perception that greater shared experience can underwrite the ability to make richer co-constructed meanings through social cues and objects which are used to exchange learning. There is theoretical support for this. If trainees have both a wider set of embedded knowledge and relatively greater pre-existing agency (or even perhaps greater fluency within the colorectal surgery culture (Alter and Oppenheimer 2009)) which comes from greater experience (Chambon et al. 2014), it follows that this experience should have a measurable impact on the social and knowledge distribution cues within the procedures, regardless of complexity faced. Video observations further provided empirical support for this notion, albeit weak to moderate; regressions correlating trainees' combined experience with their use of social and object exchange cues trended together. On their own these would be inconclusive, however, in combination with the supporting insights of thematic analysis, this concept deserves further exploration.

8.2.3 Trainee experience – difference between trainees

While increased combined experience correlated with a decrease in time to complete procedures, increased divergences in experience levels between individual trainees in a pair did not correlate with a pattern in procedure time. However, taken in conjunction with the pattern seen in accounting for combined experience, it further supports evidence for co-construction toward task completion rather than due to the strength of one individual in a pair. This is not to say that greater experience differences between individuals in a pair did not throw up correlations in observations of separate social cue exchanges, both verbally and non-verbal; this implies there may be a greater drive towards dynamic use of goal-oriented signals between individual trainees at different levels on the learning curve. The findings are, however, limited in that they do not reveal on their own which direction of experience dominates the exchange.

In summary, the video analysis revealed that increased cognitive load in two trainees working together impacts on performance time. Simultaneously, the role of shared experience and interaction in improving task completion times is evidence of co-constructed, interdependent learning.

8.3 RQ1: Through what social mechanisms are the complex clinical skills of surgery which, being learnt through the WLCTS, translated to the operating theatre context?

The interviews revealed that trainees had indeed acquired procedural skills and surgical knowledge of laparoscopic right and left hemicolectomy, communicated through a variety of cues. Meaning for each trainee was not made in isolation of the other (Garfinkel 1967; Mishler 2012). That is, making sense of their surgical work came via social exchanges rather than by the capacity of individual trainees to act and interact with their environment alone. Here, the learning experience of the trainees was dependent on its context and was only understood through the components that made up that context. To clarify, the simulation environment much like that in the OT, is a social construct. Laparoscopic surgery is performed by looking at the operation through a screen which requires learning new vocabulary, new instruments, new verbal and non-verbal cues, and new material processes of a surgical procedure in a simulation room. These must all be subsequently consolidated by the trainee to be reconstructed and understood in the OT. Therefore, it makes sense to underwrite such transitions through a distributed cognitive - semiotic lens; the important aspect of which is that whatsoever meaning becomes represented in a sign (such as the visual display or surgical device), must be socially agreed upon for the particular activity system it is contained within (Seel 2012). In this thematic analysis, the cognitive semiotic process revealed by the trainees was acquired through a combination of four elements; *scaffolding, the fidelity of simulation to operation, knowledge embedded in instruments and processes*, and *social negotiation through verbal and non-verbal exchanges*.

8.3.1 Scaffolding

An educational definition of a scaffold is a form of intentional support which can then be gradually removed as learner competence increases (Rosenshine and Meister 1992; Pea 2004; Miskovic et al. 2010). Trainees were explicit in their understanding that scaffolding was for them, a step-by-step layering of skill development, where each 'layer' relies on the foundational procedural skills learnt in the previous 'layer'. Each task layer built a framework for a stepwise understanding of the operation, identifying the main units of procedural knowledge and motor cognition, and delivering training through a 'chunking' mechanism of consolidating those unit skills and knowledge (Kim et al. 2013). Seeing and practising skills in context builds a process of understanding in the trainee. Therefore the SBT allowed the trainees to consolidate cognitively demanding skills and knowledge. The aim from the trainees' perspective is that scaffolding reaches a threshold where the skills learnt can be extrapolated into unknown (and as-yet uncontextualised operations). The transition from simulation to preceptored operations was also reported to involve an ongoing scaffolding process as the

trainees were allowed to undertake certain steps of a procedure within a consultant-controlled environment. Thus, scaffolding seems to comprise controlled skills exchange through preceptorship. Within the scaffold stages there is the graduated embedding of new information into unfamiliar instruments, devices and surroundings, including social cues that go with each layer (Paolucci 2021). Prior literature has suggested that scaffolding is supported by preceptorship (Swanwick 2013) since the intention of this position is to exercise control of stepwise learning toward certain thresholds (Ten Cate 2005; Frank et al. 2010; Sterkenburg et al. 2010). It engages a bespoke strategy of interaction between trainee and trainer (Miskovic et al. 2010) which could orient skills learning toward specific operative outcomes as a contextualised process. This notion is supported by the concept of the zone of proximal development (ZPD) which is considered further below. (Vygotsky et al. 1978).

8.3.2 Fidelity

Fidelity is the degree to which the context provided by SBT models that of a real surgical step (Hamstra et al. 2014; Agha and Fowler 2015). Fidelity is difficult to measure in quantitative terms; trainee accounts show that simulation must be recognisable to the trainees when they approximate it for real in the OT and vice versa when they 'pretend' based on what they have recognised in the OT. On this basis, fidelity is a mental construct; understood through a semiotic process and led by the intention of those designing the simulation. Research literature supports the strength of context in the recall of information and processes (Godden and Baddeley 1975; Finn et al. 2010). If a surgical simulation is authentic to the real setting, it follows that the information agreed through the semiotic process will be better understood and recognised by each trainee when in the OT. Trainees identified that the reason the simulation models work for them is not just because these models enable development of individual skills, in merely a mechanical way, but precisely because the practice opportunities are contextualised around anatomical structures represented in space which would be recognised clinically. This observation supports the argument in the literature that trainees make meaning for their skills by developing a mental picture of the task as it would embed into a process of operative steps (Palter and Grantcharov 2012). Moreover, Finn's research suggests that even the smallest details in simulation mirroring the clinical context may lead to deeper/richer learning (Bradley 2006; Finn et al. 2010), which implies that detailing the wider setting may be important for embedding knowledge. In terms of further development of the WLCTS, it can be seen from the screenshot of trainees during the left-side course (*Figure 9* in section 3.6.4) that participants are not wearing scrubs; the addition of these could add authenticity and aid retention as suggested in the literature review.

Thematic accounts open up speculation that how well a trainee can make it real in their mind might in some way be linked to their retention (and transfer to the OT) of the process, that is, the combination of the skills in sequence. Prior research on how three-dimensional objects are represented in the brain indicates that spatial ability is an important predictor of success in learning anatomy (Henssen et al. 2020); spatial understanding enhances visual observation, which in turn augments retention (Bülthoff et al. 1995). These points may further inform the usefulness of fidelity in supporting mental rehearsal (discussed further on). Therefore, it is important to represent the intended learning steps as accurately as possible. This representation includes not just the location and realism of the surgical model but the position of the trainee and their assisting partner, the language that they use and the instruments that they share. In *excerpt 5* (*ch.5*), T2 specifically noted the importance of pretending that the simulation is real, since engaging with simulation as if it were real is a key aim of its learning approach (Kharasch et al. 2011). Intuitively, this makes sense; simulations are abstractions of reality (Harré 2001; Kneebone et al. 2017).

As a caveat alluded to in section 5.3, for the live operational setting, full simulation fidelity would refer to its ability to accurately replicate the real-life conditions of an OT. To achieve this, it would be necessary to have a full multidisciplinary team involved in SBT. This includes surgeons, nurses, anaesthetists and other healthcare professionals, as well as any other relevant personnel, such as operating department practitioners or surgical assistants. This would allow SBT to mimic the communication and collaboration that occurs during a real-life surgery. This would support the trainees to learn and practise the skills they need to perform their roles effectively in an actual OT. Therefore, for a surgeon to get the most out of the simulation in its limited scope, they must not only be good at visual and haptic learning but they must be spatially and situationally aware, negotiating the available social exchanges that might also mirror the social negotiation across the table in the OT. Additionally, prior studies indicate that surgical trainees *are* predominantly visual and haptic (multimodal) in their learning approach (Preece and Cope 2016; Hernandez et al. 2020); in their right-side interview, T2 self-identified as a visual learner, by way of example (*excerpt 55, ch.7*). This gives further importance to having accurate visual representation in simulation.

Joined in particular by accounts from T4 and T7 (*excerpts 7-9, ch.5*), further notions arise from this. One is that complex learning negotiation requires that SBT is pitched at the right level for participants, since too much complexity can lead to cognitive fatigue and decreased process retention (Borragán et al. 2017). To allow trainees to abstract the intended meaning and process information, surgical exercises need to be presented in small, realistic sections. Moreover, such stepwise learning should support consolidation following the simulation during the preceptorship.

To summarise at this point, the skills that trainees acquire are being developed through a process of scaffolding layers of learning into simulated steps which aim to represent the OT as accurately as possible for the trainee, at least mentally. This learning is co-constructed through the joint agency of partnered trainees sharing complementary roles and perspectives. Situated within this construct of fidelity and scaffolding, are the skills specific to the steps of right and left-side hemicolectomies.

8.3.3 Knowledge embedded and embodied through laparoscopic instruments and devices

Regression correlations for pairs exchanging unfamiliar instruments showed that increased complexity led to a reduction in those exchanges. This effect may have been due to the cognitive burden experienced by trainees performing complex procedures, where handling unfamiliar devices hindered the learning of the procedures. It is possible that additional cognitive loads suppress the ability to process information socially, impeding the co-construction that is needed for tasks involving teamwork. Additionally, while increasing combined trainee experience led to a decrease in overall procedure time, the thematic analysis revealed that instrument familiarisation as a central component of learning assimilation in the right-side course, impacted trainees with relatively less experience through an intentional cognitive load. Conversely, the relatively more experienced trainees performing the more complex left-side tasks were impeded by the extra cognitive load placed on them through unfamiliar instrument handling during their learning process.

Trainee accounts (in *ch.5*) indicated that they connected the learning of their task steps through the gradual use of the laparoscopic devices provided and which were specific to laparoscopic colorectal surgery. Furthermore, the trainees raised the notion that the involvement of industry specialists (who are experts in specific surgical tools) is important in both establishing meaning and the process of embedding knowledge in instruments. From a cognitive semiotic lens, this learning must have involved acquiring a haptic sense of the instrument and its position as an extension of the body, contextualised and understood first within the simulated operation. This contextual understanding could then through DCog, mediate such extended knowledge into the OT. Surgical instruments and devices take on very real meaning in this framework because they become *artefacts* of the surgical culture, recognised by the way they extend a specific body of (surgical) information (Wartofsky 1979; Jones 2018). They also become *boundary objects,* containing information which can be recognised and used in different social environments (Wenger 1998; Akkerman and Bakker 2011) and thereby navigating different work boundaries (Lee 2005). In learning, the trainees extend their cognitive processes through these instruments, both making sense of, and embedding knowledge which is contextualised by the simulated environment (Daddesio 1995; Paolucci 2021). This embedding of knowledge is therefore represented externally (Pouw et al. 2014) and socially by the outworking and

co-constructed process of learning (Zhang and Patel 2006). To clarify this, trainees did not learn to use the new instruments in isolation; the course demanded they assist each other and instrument use may also at times be combined with verbal and non-verbal dialogue. Thus, instrument knowledge is shared as it is created.

8.3.4 Links with theories

In this section I briefly draw attention to how findings so far discussed, connect with the learning theories described in *ch.2*. The extension of cognition by which instruments take on meaning through their function and their industry name is externally represented through exchanges between pairs and mutual agreement over their use. It is also internally represented by practical and mental rehearsal. Distributed cognition (DCog) (Hutchins 1991), is the previously discussed term that describes how separate minds interact in a system to make mutual sense of multiple entities of objects and give them meaning through a semiotic process (Paolucci 2021).

The use of unfamiliar instruments brought mixed reactions depending on the experience of the trainee; the intention was to give inexperienced trainees the range of instruments which they might encounter in the OT. The more experienced of the cohort already had a certain level of bias toward the use of instruments they have access to in their hospital, favouring, for example, the instruments of a particular supplier. Cumulative insight from T7's comments (*excerpts 7-8, ch.5*) is that progressive experience can induce the trainee to select the most economical learning pathway for instrument handling, in the face of time, training and resource constraints. In other words, a trainee might use knowledge and skills already known and established earlier on in their training pathway rather than to divert time or cognitive burden in mastering a new device to perform a similar goal. The course intentionally exposed trainees to unfamiliar instruments because of the premise that the simulation room is the best place to begin to use something new rather than the OT when all the activity is focused on the patient. This design premise makes the cognitive burden of learning them necessary, but the scaffolded approach through which the devices connect the task steps may help to overcome this. Trainee comments implicitly support the rationale that complex motor activity is consolidated by co-construction of individual threads of process knowledge toward a more complete procedure, which fits with learning as a by-product of negotiated knotworking.

There is an interesting caveat between the more experienced trainees commenting on instruments; the right and left-side courses both exposed the trainees to novel instruments and devices. However, by the time the trainees come to the left-side course, they will have more experience due to the fact that the right-side course prepares them; the techniques are deliberately more straightforward in introducing and scaffolding skills. This means that cognitive load is present in the right-side course by

design, while the left-side course extends both the skills and knowledge already embedded into further operative tasks. For example, while T4 and T7 (*excerpts 7-9, ch.5*) argued that new devices detract from the purpose of the left-side course, being to extend the mental construct of existing knowledge into more demanding tasks, T1 and T6 (*excerpts 10-11, ch.5*) lauded the richer experience of using new instruments during the right-side.

8.3.5 Socially mediated knowledge and skills

The characteristics of verbal and non-verbal communication between trainee pairs and between pairs and tutors (the consultants doing the teaching) are discussed in the following sections. They depended on the prior experience levels of the trainees (as indicated by regression analysis), albeit weakly. Increasing procedural complexity did not appear to affect a change in communication characteristics. Despite some difficulty with the potential reliability of the regression, these communication characteristics supported the thematic analysis of the trainee accounts.

8.3.5.1 Verbal communication

That *casual* conversation decreased with increasing levels of difference in experience indicated that at least for trainees relatively less experienced than their partners, the surgical conversation was more intentional and task-oriented. Greater levels of combined experience produced a decrease in surgical-related conversation. Simultaneously, the time in which tutors engaged trainee pairs in conversation increased in alignment with a greater relative experience difference. Taken together, a possible explanation is found in the guided conversation commentaries coming from inexperienced and experienced participants alike. Inexperienced trainees found value in social interaction towards task objectives and possibly used explicitly goal-oriented procedure conversations to help negotiate their activity. More procedure-based conversations among trainees with less combined experience may supply evidence that knowledge is co-constructed through social and verbal exchanges (Zhang and Patel 2006; Kessler 2013; Cope et al. 2015). Conversely, trainees with more experience underplayed the value of verbally shared knowledge among their equals, which is a probable reason why greater casual conversation was observed among the cohort of more equal levels. From a theoretical CoP model, where common language was used among peers negotiating from a similar level of experience (Collins 2011; Markauskaite and Goodyear 2016), the pairing of experienced with inexperienced trainees can be explained semiotically. If there is a greater difference in experience or sense of agency between paired trainees, the less experienced of the pair may have an opportunity to acquire externally represented cognition through their interactions, while the more experienced of the pair may not see any value (in terms of their development) in their verbal exchanges. This might suggest that pairing a less experienced trainee with a more experienced one is not so helpful

educationally if the more experienced one does not recognise the value of the verbalisation as part of their own learning.

The central premise under a semiotic or DCog framework of thinking is that knowledge is gathered and exchanged through the acquisition and use of surgical language and through non-verbal gestures which become contextualised themselves since they are never used in isolation from the surgical learning activity (Hutchins and Palen 1997; Pimmer et al. 2013; Paolucci 2021). Preceptored training in the OT is a continuous situated learning intervention between the trainee and the consultant. Because consultants are tutors on the course, exploration of verbal engagement between them and the trainees also seems important. While verbal engagement remained overall constant with increasing complexity, it increased (albeit weakly) as the experience difference grew between pairs. This observation may need to become a focal point of further study. However, it is possible to suggest this may again be because less relative experience in a trainee pairing appears to be a greater drive for co-construction of embedded knowledge. The trainee comments showed an understanding of the tutors as experts, disseminating process information and creating a common surgical language among the cohort. Could tutors also tacitly recognise the difference in either or both their agency and fluency (Unkelbach 2006; Alter and Oppenheimer 2009) between pairs and step in to mediate the activity? Another way to consider this is that in SBT, the roles of the learner and tutor are more explicit and defined; consultants in the simulation room have a greater observer role, stepping into the activity whenever their part in the negotiation of learning is required. Those same consultants in the OT setting may be there to precept the trainee, but they are fully engaged in the wellbeing of the patient which takes priority. They are no longer situated outside the operating activity and trainee learning is not their central goal. In one sense, SBT can be seen as the new vertical hierarchy, where learning is organised and disseminated from the centre of the CoP to the periphery. The OT is conversely, more aligned to a flat hierarchy, where learning is given richer layers by being situated in the context of the patient and takes place through the negotiation of multiple activities (Bleakley et al. 2011) through a combined agency (Engeström 2008) in a manner very similar perhaps to the agency of trainees paired at the simulation table. Cognitively, situated learning at the operating table also supports the application of embedded knowledge by external representations (Wartofsky 1979) to specific clinical scenarios (Anderson et al. 1996; Kaufman et al. 2008).

8.3.5.2 Non-verbal communication

Non-verbal interactions are widely known to convey meaning in activities and conversations (Kurien 2010). That surgical trainees rely on visual learning has already been discussed and this learning approach implies that they will tacitly draw much meaning from contextualised gestures associated

with professional activity. To reiterate, regression analysis showed correlation between trainees' combined experience and use of non-verbal gestures while simultaneously showing an inverse relationship with directly operation-focussed verbal conversation. Gestures used in conjunction with specific activities delivered in teaching are semiotic (Kress 2010) and understood within the distinct colorectal surgical culture (Fry et al. 2011; Kneebone and Fry 2011). Non-verbal cues were not just noted because of their ability to convey information (Grisé 2012) or be an external representation of cognition (Hutchins and Palen 1997), but because social connection is informed by the use of non-verbal gesturing (Gittell 2009) in the sense that both gestures and verbal conversation reinforce belonging to a specific culture (Wenger 1998). Therefore, learning and belonging are interwoven (Goodwin 2007) and fit with a CoP model of moving towards the centre of the social group in terms of surgical identity formation. But learning and belonging also fit with the theoretical framework of DCog where knowledge is embodied and distributed socially, culturally and situationally between the participants and the environment in which the learning is taking place (Pimmer et al. 2013). Thus, trainee pairs of increasing experience may already understand surgical meaning implicitly through gestures and mental recognition of processes, while those of less experience may need to negotiate and talk through their processes in more explicit, i.e., verbal terms. This also suggests knowledge is already understood and embedded with increasing experience and externally distributed from positions of more organised cognitive representation, i.e., from tutors and trainees with more experience. Trainees' accounts revealed that non-verbal gestures were implied by their manipulation of surgical instruments in a particular way, further indicating that non-verbal gestures were a component of the way knowledge was imparted by the trainee through their instruments. Importantly, trainees reported that this gesturing was also repeated in the OT, which posits it as a mode of activating knowledge embedded through instruments (as transactional artefacts) and further, that their gestures helped to form part of the identity construct which is familiar to the professional collective culture of colorectal surgeons.

Of further note, consistent within trainees' comments is that within the OT their preceptors often gestured a few steps ahead with their instruments or with their gaze through the movement of the camera if they were holding it. While this activity on the part of the consultants may have been seen as unhelpful by some trainees, it does indicate that non-verbal activity coupled with the use of instruments is an intentional part of the learning exchange at the operating table and suggests that through this mechanism cognition is distributed from the preceptor to the trainee through operating together.

8.4 RQ2: How do laparoscopic colorectal trainees perceive the value of, and make their training meaningful?

Semiotically, meaning was underwritten by trainees' use of the discussed social and cognitive cues to co-constructively engage with simulation tasks. How these cues interact to carry that meaning outside of SBT and into the OT was suggested through abductive analysis of trainees' responses and a recognition of negotiated knotworking through a reframing of the video observations. Trainees indicated where and why they saw simulation as personally useful to them, captured in the two key themes of *negotiated activity* and *reflection and mental rehearsal*.

8.4.1 Simulation mediates socialisation of skills through negotiated activity and legitimacy in the surgical CoP

The discussion in section 8.3.2 shows that the contextual and material fidelity of simulating to operating provides a platform of meaningful activity. The value of SBT was found by trainees in forming accurate semiotic and cognitive representations which also aid in retention and rehearsal (discussed further below). Going further, trainees' shared negotiation of tasks to work out their operative approach used technical skills and instrument familiarisation coupled with verbal and non-verbal exchanges. Cumulatively, their training is given rich and accurate meaning if simulation can attempt to mirror the knotworked activity taking place at each step of a task. Tasks in SBT, like real operations, require the negotiation of work between multiple participants in order to achieve the desired outcome. SBT provided the opportunity for trainees to acquire cognitive and semiotic knowledge which was negotiated through multiple socially organised threads of activity. Significantly, the same threads must be made explicit in the OT to make sense of cognitively and semiotically distributed knowledge. Section 5.5.1 intimates that the social fidelity of negotiated activity may be important for learning patterns of procedure that work in real settings. Emphasising the faithfulness of social constructs within SBT could be fundamental to the way both psychomotor skills and the ability to develop the decision to use them are made meaningful in the OT.

Interpretation of trainee accounts supports the view that SBT provides a structured opportunity to develop language and activity specific to colorectal surgery. In this sense, their co-constructed and negotiated participation foments trainees' movement into the CoP. This is enabled during task-embedded activity, which legitimises trainee participation in the OT.

Through the negotiation of activity, first in SBT, then subsequently in their preceptored phase, the trainees acquired agency which marked out their increasing competence in undertaking either a right or left-side procedure. Rather than their CoP being developed through cohesion to a surgical body, trainee narratives showed that it was specific to each type of procedure; the fluency of their surgical

activity focused on the tasks. Since the WLCTS is not a mandatory requirement for colorectal training, the trainees recognise the social and cultural currency of simulation (Bourdieu 1986; Cleland et al. 2016). Furthermore, trainees expect to acquire a personal benefit from participation, specifically the acquisition of practical surgical knowledge, which could be described as a private capital (Sfard 1998). Simulation engenders surgical identity (Rowell 2015) since trainees recognise that simulation should accelerate not just their practice opportunities, but their movement toward the centre of the community. The preceptors supervising the trainees in the OT moderated this access. It is possible to describe a power relationship here, borne out of distinct social structures both in the OT and in the simulation lab. There is also a point of difference to be made concerning agency and power in these settings. An aim for a trainee investing in simulation is to increase their agency to act and make operative decisions independently (a notion supported by Barker (2002) and Ten Cate (2020)), which is situated within and subsequently negotiated by their submission to the greater agency of their 'boss'. This insight supports a view that agency is subjectively and temporarily embedded within each activity system (Emirbayer and Mische 1998; Edwards 2009).

8.4.2 Mental rehearsal and reflection of surgical simulation activity

8.4.2.1 Simulation informs decision-making and situates surgical identity

Mental rehearsal is 'the cognitive rehearsal of a task in the absence of overt physical movement' (Driskell et al. 1994). It is a reflective exercise and reflection is linked to a specific activity. Conversations with the trainees regarding reflection on surgical training and surgical practice, demonstrated three phases of reflective thinking, namely *pre-reflection, reflection-during and reflection-after-action*. These phases of reflection happen simultaneously which was seen in trainees' thoughts on how SBT prepared them for practice in the OT. Reflecting during the simulation activity grounded their decision-making on specific learning goals. In reflecting-after-action, the trainees drew on their simulation experience and assimilated it into their understanding. Pre-reflection, which might also be called anticipation, was shown in *excerpt*s where trainees engaged their prior learning and course reflections to cognitively rehearse the procedure ahead of operating. (Hays and Gay 2011). More implicitly, trainees revealed another tenet of reflection regarding the activity and development of 'self' mirrored through the activity and position of their fellow surgeons and trainees, which some refer to as realising identity through difference (Bleakley 2011; Bleakley et al. 2011). Trainees' accounts of reflective activity evidenced that they linked the colorectal task steps in simulation to their decision-making at specific stages of the colorectal procedures. Moreover, visually anticipating the operative pathway *and* their physical position at the operating table (surrounded by surgical devices and their colleagues) enabled their planning. This is a significant observation because

mental rehearsal and mindfulness have been mechanistically linked to reduced clinical error (Morey et al. 2002; Green et al. 2017; Brennan et al. 2020). Consequently, whether it comes after, during or before a task, reflection might support the move from experience to expertise, because it allows the trainees to visualise and consolidate their learned process steps by additionally reducing anxiety and promoting mindfulness, both of which create greater situational awareness (Yeganeh and Kolb 2009; Molloy et al. 2019).

One contemporary research study (Skervin and Scott 2021) has postulated that mental rehearsal may be instinctive for surgeons, which is perhaps related to their strength in visual-oriented learning. Here, rehearsal is predominantly individualistic (Ibrahim et al. 2015; Skervin and Scott 2021) and trainee *excerpt*s substantiate individualistic accounts of rehearsal and reflection. However, video data and accounts supporting socially organised learning (already discussed) through peer-to-peer communication, trainee-tutor communication and non-verbal cues all give a contribution to building a mental rehearsal strategy which acknowledges the partnership aspect of learning. Therefore, simulation may be a place to make collective mental rehearsal strategies more explicit. This is worth noting because *shared* rehearsal may lead to *shared* mindfulness and greater co-construction through participation (Krieger 2005) which uses mutual language and communication in rehearsed situations (Weick and Sutcliffe 2001). For example, scenarios involving thinking-aloud-pair-problem-solving have been shown to improve outcomes in aviation problems in reduced timeframes (Johnson and Chung 1999). T4 (*excerpt 48*) explicitly acknowledged that co-constructed rehearsal of roles was taking place. T2 (*excerpts 50-55*) commented on the development of expertise through experience acquisition and increasing confidence linked to their mental rehearsal of social interactions which occur during each operative step. There are grounds within the observation of communication in SBT to therefore enable anticipation of social encounters in the OT. Such rehearsal is an example of social cognition, referred to in existing literature as 'imagined interaction' (Zagacki et al. 1992). This describes the process by which a subject will organise their thoughts on communication strategy in an activity. Additionally, it has been argued that imagined social interaction is cognitively represented and embodied (Gardner 1985), implying that social rehearsal may be a means of creating an understanding and meaning on objects in a shared activity (and therefore an example of DCog).

8.4.2.2 Simulation provides a cognitive scaffold for reflection and mental preparation

Analysis of trainee accounts demonstrated that learning through simulation helped provide a scaffold of visual and material cues which would prepare them and support their planning, imagining the steps and situating themselves in the OT environment. The experience of reconstructing the operation appropriately is tied to the haptic fidelity and execution of devices within the SBT domain.

The simultaneous development of internal mental constructs for instrument handling may therefore be as important for recognising the external, socially agreed meanings assigned to the surgical devices. A further reasonable conjecture from *excerpt 17* is that knowledge embedding into such objects that cross these activity systems may also facilitate moving from competency to proficiency when they become extensions of a trainee's proprioceptive reflex. Learning is a physical process which reinforces neuro-cortical pathways in the brain. Cognitive processing is known to be mapped to neuronal activity in the motor cortex (Lakoff and Johnson 1999), to which procedural training is linked and posited to be understood through the psychosocial environment in which psychomotor skills have been learnt (Huotilainen et al. 2018). Likewise, through studies of arts and crafts learning to stimulate the same neuro-cortical pathways in the brain (Schwartz et al. 2017), mental rehearsal in the absence of a physical environment and material cues has been found to promote psychomotor development through the activation of multiple interconnecting cognitive functions, including perceptual ability (Tyler and Likova 2012). This is useful since surgery is a craft activity (Kirk 1996). A further study on the observation of motor skills has shown that the observing brain also incorporates and understands external actions through simulation (Calvo-Merino et al. 2005), particularly if the 'observers' already have a level of procedural ability associated with an activity.

Clearly, mental rehearsal involves cognitively gathering multiple series of procedural skills and social imagination. Materially, it is therefore likely to be governed by distributed cognition (DCog) as a way of reinforcing internally and externally represented knowledge embodied in social interactions and embedded in material surgical objects, for several reasons. First, research supports a link between the effectiveness of mental practice and strong disposition toward visual learning (Anton et al. 2017; Ruffino et al. 2017). Second, mental rehearsal is a central tenet of social-cognitive theory, which also contributes to development of individual and perceived collective agency (Bandura 2000). Third, cognitive acquisition may occur through mental rehearsal, which is reinforced by distributed learning because it can occur in the spaces between hands-on training (Woodworth et al. 1971; Morin and Latham 2000). This is modelled through gradual improvement in trainees' procedural fluency. Imagined interaction, which is to say, rehearsal of communication, might also be facilitated by DCog as discussed above. Therefore, trainees anticipating an opportunity to operate and apply their learnt skills may rely on a variety of both materially and socially-constructed boundary artefacts that carry representational knowledge from one activity system to another.

8.5 RQ3: How could the discussed learning theories inform a framework which can both acknowledge the social experience of simulation in facilitating the negotiation of learning and enable the professional development of the trainees?

This thesis provides evidence that learning in simulation occurred through co-construction of process knowledge and by the consolidation of individual skills, which is described through semiotic DCog and negotiated knotworking. The trainee comments substantiate that the strategies they use to navigate their operating in different teams and partnerships are negotiated through situated learning within a cultural and historical framework. They are mediated materially and socially, therefore involving the intertwining of multiple threads of activity (Roth and Lee 2007). This is therefore an explicit link to my literature review which contends activity theory, conceptualised by Vygotsky (1978) and developed by Engeström (1987), emphasises action by and between the individual and the community in which the individual is situated, and the objects and outcomes which form the activity (Fry 2011). Its central tenet of learning assumes that tacit knowledge is embedded within the participating community engaged in a common goal, such as material and social processes or behavioural norms which are understood but must be learnt by novices to the system. Learning occurs consequentially rather than being the intention of the activity.

In the simulation setting, psychomotor ability, spatial knowledge and anatomical recognition came together through internally and externally represented cognition. This knowledge was tangibly embedded and embodied in the surrounding instruments and devices, in the operating layout, through the language and cues of the trainees' partners *and* tutors, and the semiotic process. Situated learning occurred through a process of socialisation of surgical knowledge into the occupational community (Amin and Roberts 2006) by taking on language, gestures and mental constructs specific to the culture of colorectal surgeons. Despite the difference in goals for the activity of both systems, both SBT and the OT are systems of socially organised learning (Young 1999; Wenger 2011), enabling trainees' commonality of responses and mutually defining language through shared negotiation of learning, of which the CoP model is comprised.

Physical signs of co-construction were revealed through both video observation and interview accounts signposting the interaction of trainees and tutors regardless of rank experience or the level of complexity facing them. These findings could be explained through CoP and DCog theories to varying degrees. That is, co-construction of learning could be imagined through individual threads of activity which intertwine and through which *that* learning is negotiated and transacted (Bleakley 2011) (as illustrated in *Figures 25-27*). In this interaction, skills consolidation occurs through a process of gradual external and internal representation of cognition in surgical tools, space and colleagues.

Therefore, through cultural-historical activity theory (CHAT), SBT and the OT can be described as two individual yet co-operating activity systems where learning may not necessarily be the goal but occurs as a consequence of the interaction of the co-constructed activity. The model provides a way to integrate and orient the interaction between the subject (which is the trainee), objects, motivations, social and cultural context, and consequences towards a goal (Davydov 1999; Lazarev 2004; Yamagata-Lynch 2010).

CHAT brings together the complexity of learning by gradual acquisition and the CoP, where gradual acquisition is both understood and represented through mutual recognition of those facets which belong to the surgical occupational community. Again, DCog is an interface between individual skills and their socially understood meaning during this negotiation of learning by participation (Bartlett 2005; Smith and Greenwood 2012). So far then, in SBT and the OT, the end goal provides the direction of the various threads of interweaving activity. These threads are social constructs and they seemingly intertwine and come together as knots that un-tie and then reform where emphasis within the activity changes. This is the essence of negotiated knotworking (Engeström 2008; Bleakley 2011). The findings have shown that this negotiation is an explicit component of tasks within the right and left-side courses. CHAT is an interactionist-learning model (Engeström et al. 1999b), such that an individual's mental process relates to their interaction with 'cultural, historical and institutional settings' (Wertsch 1991, p. 119). This is a ZPD perspective (Vygotsky 1987), which is important because ZPD integrates and extends the importance of scaffolding in socially mediated learning (Schaffer 2006; Obukhova and Korepanova 2009).

Both video and interview accounts show that trainees' interactions were constrained by their experience or procedure complexity. The increasing complexity of the tasks incorporated the minimum number of psychomotor steps to perform them. Each task had several different laparoscopic instruments to use. For less complex tasks, that is, those likely to be less cognitively demanding such as seen on the right-side and further, where less experienced trainees were present, the exchange of instruments may have been a central point of learning task dexterity. It is plausible through the notion of cognitive load, which represents a threshold of the mind's capacity to process multiple threads of activity knowledge, that increasing complexity can then put a greater demand on how declarative knowledge becomes procedural knowledge and therefore proficiency. The exchange of unfamiliar instruments seen in simulation tasks could be an indicator of how easily new skills consolidate with the experience of trainees. However, the lack of correlation observed suggests that all levels of prior experience were equal in terms of capability to acquire new skills and devices. Yet, experience could predict a greater mutual understanding of social and professional transactions, driving the distribution of knowledge through surgical tools and other cues, and reinforcing

professional development and meaning within the surgical community. Increased experience may lead to increasingly efficient negotiated knotworking through surgical activity because trainees acquired a greater fluency and ability to navigate the social exchanges resulting from SBT.

The trainee relationship with social artefacts and surgical tools is dynamic and changes over time; through the environment (or activity system) individuals make sense of it by their activity, engaging with operating objects and tools and people specific to it (Scribner et al. 1997). Subsequently, the semiotic process of meaning-making is reinforced by reflection and rehearsal, which also facilitates mediation of learning from simulation to the OT. This orients the trainee to engage with the system through objects and tools (Leont'ev 1974).

Observation of the OT as an activity system could be useful for future follow-up of this study; trainees' conversations indicated by their reflections and experience with their preceptors in the clinical setting showed that trainees negotiated threads of activity there too. It is reasonable to extrapolate into the OT activity system, similar conversations, cues and learning consolidations to those of SBT. Of more material significance to this study is how these two systems relate to each other. *Figure 6*'s (*ch.2*) binary representation of the two interacting systems, (SBT of the right and left-side course and the colorectal OT), suggests how trainees might use their learning transactions to reinforce their surgical development toward expertise. The literature review initially contended that learning was likely to be transferred through the development and use of common surgical language and operative tools shared by both systems. Material and social objects are semiotically understood through CHAT as boundary-crossing artefacts containing embedded cognitive representations of process knowledge (Toomela 2000). The concept of rehearsal of internally represented cognition has also been seen as an 'orienting activity' (Gal'perin 1989) which enables trainees to explore and predictively anticipate possible outcomes of their actions (Prawat 1999). Although mental rehearsal is an abbreviated experience of real activity (Yamagata-Lynch 2010), the CHAT literature suggests that trainees make it an important component of the progressive decision-making process.

Through the model of CHAT, it is possible to suggest that transaction of SBT to the OT is mediated largely through cognitively embodied and embedded knowledge represented in the social structures of surgical language and gestures specific to colorectal surgeons, surgical tools and devices, spatial arrangements of the surgical-set-up and laparoscopic anatomy. Gradual acquisition of experience leads to expertise via developing interactional agency through consolidation of multiple cognitive processes, including rehearsal of skills and interactions.

This concept supports a theoretical model in which DCog is central in learning co-construction. It would be particularly identified at the loci or 'knots' of multiple process threads in negotiated

knotworking activity, as illustrated in *Figures 25 (ch.6)* and *26 (below)*. The cognitive process of consolidating individual steps of learning through a social template helps to describe the way psychomotor skills become understood and have their meaning in social settings. Rehearsal and repetition create opportunities to refine the cognitive pathway. Rehearsal and repetition with a surgeon of greater experience contributes to improved task completion because learning is socially organised. That trainees advance within their CoP through increasing fluency and agency, is a consequence of their ability to improve their negotiation of surgical activity. Preceptors gradually allow more space and opportunity for trainees to make decisions. This may indicate trainees' increasing ability to make sense of their operative thought processes within a complex social environment.

In an ideal world, the activity system of SBT described through CHAT should map onto that of the OT. However, the reality is dictated by the level of fidelity and the difference in the weight of knowledge distributed across all the elements of the activity system, of which all will be represented to some extent. This occurs because the emphasis on SBT is mainly on trainees' acquisition of the psychomotor process. Teaching a surgical procedure is by definition, a limited system aiming to deliver one aspect of an extraordinarily complex reality.

Adapted illustration (from *Figure 25*) that multiple treads of activity intertwine. The top diagonal lines point to knot or node points at which such social cues and the exchange of devices as activities may join to construct semiotic meaning in external objects of surgery. Surgical knowledge and process understanding becomes distributed across them and more richly internalised.

The lower diagonal lines indicate where dense moments or knots of activity may construct learning in a fragmented way. These fragments of process learning can become 'chunked' together and consolidated. In this model they are consolidated and linked by social interactions.

Figure 26. Illustration of how learning and meaning can be constructed through cognitive distribution as multiple threads of activity combine at loci or knots.

While instrument handling and procedural skills aim to be the same across both systems, the community is limited to the surgeons across the operating table. In SBT this may be the point of entry into the CoP associated with a particular operation, while preceptorship may subsequently allow the trainee to expand into a more divergent system over time. The right and left-side courses of the WLCTS were originally conceived to deliver training in key elements of laparoscopic colorectal operations, which might then be extrapolated into the OT. One perspective that makes it easier to realise how the simulation maps onto the clinical work is to reconsider the 'way of seeing' through the closest circles of focus (see *Figure 2, ch.2*) (Kneebone, 2010). This perspective brings the fidelity at the centre back into significance and perhaps helps to reframe it through CHAT here as the degree to which the simulation activity might emulate the clinical one.

Consequently, in keeping the defines of the simulation system intentionally narrow, that is, to map onto a small circle of clinical activity in the OT, at least at the preceptorship stage, then the parameters of the activity system might be visibly more aligned and therefore more easily recognised and transferred. *Figure 27* illustrates how the activities of SBT and OT interact within the constraints of the WLCTS. This diverges from *Figure 6*, (*ch.2*) which provided the initial theoretical framework for my contentions. However, similar to my original assertions, the CoP is embedded within the activity system and develops through the negotiation of its components.

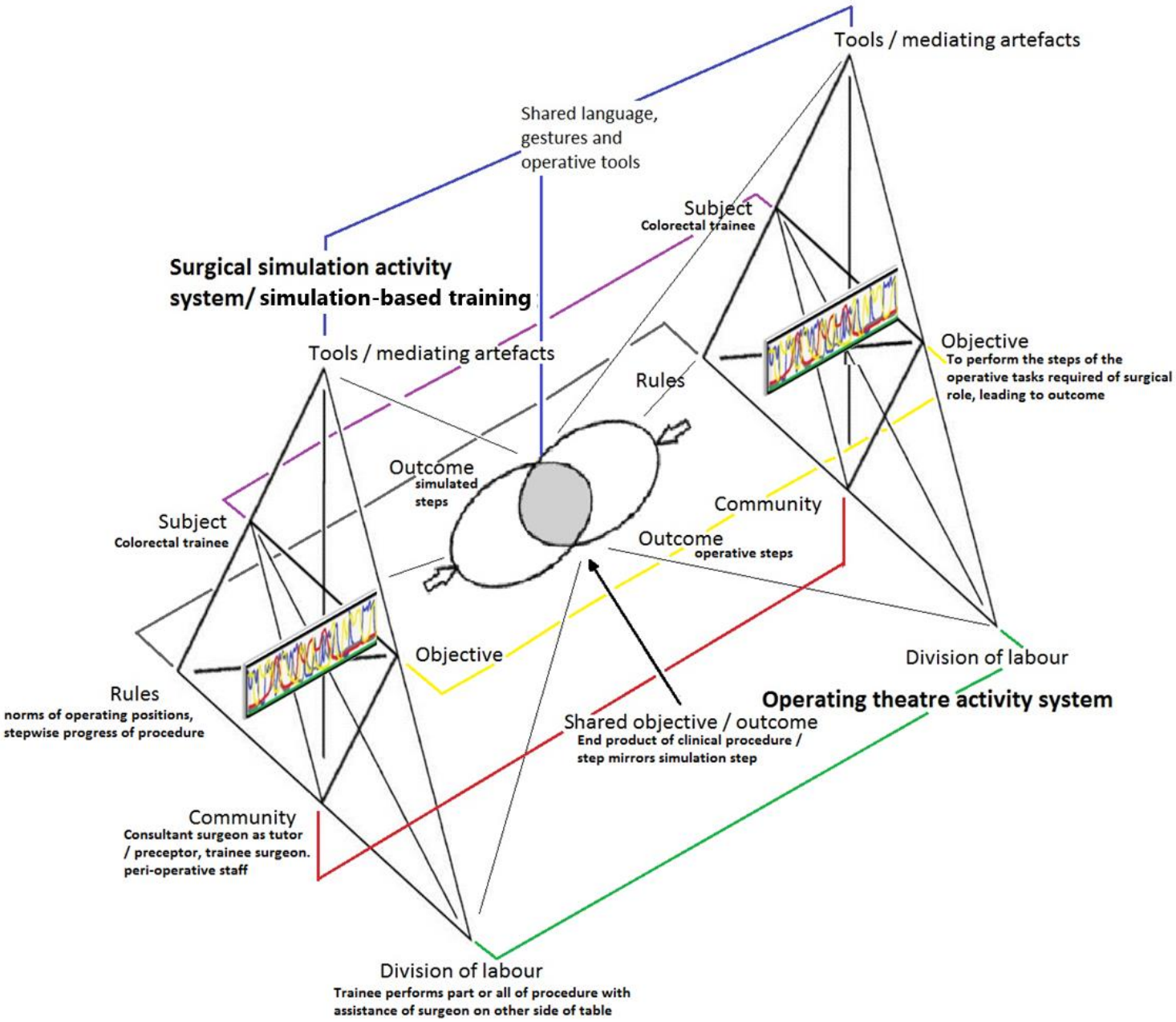


Figure 27. Illustrating through expansive interaction how the right and left-side simulations can overlay the activity of operating at entry to preceptorship.

8.6 Summary

This discussion puts forward *and* links evidence from my findings to the challenges set out in the considerations raised in the literature review and then subsequently explored through my research questions. Both the complexity of the tasks and the shared experience of the trainees performing those tasks appeared to influence the negotiation of the observed social cues involved in the co-construction of learning and meaning to varying degrees. The structure of the simulated activity, through its fidelity, scaffolding, preceptorship and socially mediated activity in tandem with the

handling of devices, indicates an answer to the social mechanisms of skill transfer. It is semiotic and it combines the theoretical notion of cognitive architectural development through procedural work, with learning through co-constructed experiences. It is through this combination of co-construction that trainees' learning appears to be made meaningful; they make sense of their practice in the OT by their reflection on the socially organised training of the simulation room. Additionally, the operative decision-making process of trainees is influenced by their ability to perceive their skills through a sociological imagination facilitated by their negotiated learning in SBT.

9 Conclusions

9.1 Overview

Set against the contextual backdrop of apprenticeship-style training changing to targeted simulation, surgical training continues to produce experts despite the difference in time traditionally prescribed to accomplish expertise (Chikwe et al. 2004; Schaverien 2010). Previously, learning occurred consequentially by exposure to patients over many work hours, while in the present model, learning is centred on targeted exposure to surgical tasks using limited representations of reality over a narrow time frame. Being professionally acquainted with the culture of simulation, I suspected the common factor between these two worlds could be the learning and meaning made by social interactions occurring between professionals.

There is good evidence to indicate that simulation leads to uptake of skills, as shown by a reduction in task completion time or improved movement economy. However, it has been mooted that practice in simulated tasks leads to improvement in simulation only (Bleakley et al. 2011). Moreover, the benefit of psychomotor skills acquisition tends to be largely at the foundational level (Card et al. 1983; Hamdorf and Hall 2000; Lee and Anderson 2001; Kim et al. 2013). Therefore, skills acquired in simulation alone cannot indicate increased competence in the OT. Consequently, for simulation at a more complex level to lead to improvement in the colorectal OT, it must engage a whole subset of component mediating factors, which are catalysed by trainees' negotiation of learning in the colorectal SBT courses and are subsequently honed through preceptorship in the OT. Interactive factors which could be observed in SBT, such as trainee experience and task complexity, were anticipated to influence learning negotiation.

9.2 What was investigated?

The research questions opened up three avenues of exploration. Briefly these were to ask first, what social cues (between trainees learning a task together and between trainees and the tutors) observed in the simulation could become conduits through which the surgical task learning is socially understood and likely replicated in the OT? Second, what meaning and value do the colorectal trainees attach to their participation in SBT? That is, how they perceive its benefit in advancing their professional position, since participation in the WLCTS is a voluntary exercise. Third, given that there are several theoretical models of learning which could apply to the SBT–OT linked activity systems, how could they be integrated to show how technical skills acquired individually are organised,

transferred and understood socially, which is to say the place of their contribution to the development of expertise?

This thesis has presented an exploration of the impact of a specific SBT course on the development of trainees' surgical proficiency. From this exploration, three key outcomes have been elucidated and they are reviewed here.

9.2.1 Taking task activity from simulation to operation is a shared, cognitive semiotic process.

The acquisition of hard procedural skills is entangled simultaneously with semiotic processes of meaning and language and acculturation to the colorectal surgical community. Task completion is accounted for more effectively by considering the shared agency and experience of trainees than by individual proficiency. SBT provides a series of scaffolded stages during which layers of social and technical cognition are added. Surgical skills are developed through the systematic consolidation of smaller steps into increasingly greater portions of procedure, indicated by trainees' perceptions of cognitive load. The significance of describing the cognitive process in this way is that learning through cognitive reductive steps enables the mind to make sense of the activity before it is developed further. Moreover, meaning derived from the interaction of these negotiated threads is interpreted accurately in the OT *if* there has been high fidelity between the two activity systems in two areas; the approximation of the task, which includes spatial, temporal and material factors to the operation and the social construct of SBT to that of the OT. Surgical devices and instruments common to SBT and operating activity are given meaning through a semiotic process involving distributed cognition (DCog), that is, co-construction of knowledge through social cues and psychomotor skills which embed into those objects making up the working environment. For any meaning made in simulation to be faithfully reproduced in the OT, social fidelity must be a given an explicit focus in surgical course design, not just for accurate reproduction of the objects used, but reproduction of the way they are handled and discussed at the table.

Surgical tasks become understood and contextualised in the trainees' minds as connected parts of a complete procedure but importantly, this consolidation comes through a socially and spatially interactive learning process. During learning, new instruments and devices are handled and become extensions of the operator's hands, through which they take on psychomotor procedural knowledge, which in turn becomes exchanged through mutual process-negotiated use. Gestures and verbal cues also form part of the negotiation of simulation tasks and through them an understanding of the task process becomes cognitively represented, both internally and externally to other participants and objects in the space of the activity. The shift of verbal to non-verbal cues exchanged between

trainees as their shared experience increases, indicates a gain in implicit shared meaning and understanding in moving through a task toward a common goal.

9.2.2 Skills-learning in SBT is a by-product of sharing multiple social and material interactions.

The negotiated interaction of multiple threads of activity, although limited to those observed and recorded in this study, are common to both SBT and the OT. The transient working relationships in SBT which mimic those of the OT are around an agreed focus. SBT also helps to develop and establish clear communication and a common colorectal language. Such multiple threads of activity are shown to co-construct and focus at knots, indicating points of learning and cognitive distribution. Such learning is situated within and interpreted through the colorectal community where a common reference point is provided; in SBT it is the completion of a task. Trainees also view SBT as a means of advancing within the CoP as they acquire further surgical language and skills and become enabled to apply their new knowledge and improve their own agency. In this sense, the activity system of SBT in colorectal training, to be effective, relies on the surgical community. In addition, some trainees' reflections of their operating experience in relation to their participation in simulation, supports the enquiry that social cues of gesture, verbal and non-verbal communication and instrument exchange are extended from SBT into the OT and convey learning which has first been negotiated through simulation. In moving towards the OT, trainees make sense of their learning through a continual, graduated process.

9.2.3 Simulation facilitates mental rehearsal, which is important in preparing trainees to operate.

Simulation gave the trainees a framework from which to build a mental picture of the surgical process, so as to anticipate and rehearse a procedure. SBT helps to situate the trainees' own level of capability as they acquire a spatial and temporal account of how an operation is supposed to go in their thinking. Importantly, this cognitive development as a result of simulation, includes a social context, rehearsing the interactions required for the surgical activity, which in turn leads to fluency and thinking ahead. Mental rehearsal instils confidence and decisiveness in trainees, in their planning and execution. Furthermore, it is linked to mindfulness, which could be important given its reported association to the reduction of clinical error.

9.3 Significance of this research (key insights)

Several key insights of this thesis address possible areas of SBT and how it translates into the development of surgical expertise. I summarise them here and detail them further below. First,

acknowledging the combined trainee experience that comes through pairing experienced and inexperienced trainees together improves the co-constructed knowledge and negotiated activity of both. Second, SBT may better support operative experience through acknowledging and addressing fidelity of the social construct and knotworked threads of activity. Third, trainees' reflective activity could be made explicit within the WLCTS. Fourth, SBT is the optimum place to acquire familiarity with the range of laparoscopic surgical devices on offer, although instrument handling might not be useful as a tandem component of advanced laparoscopic procedural training. Fifth, the OT is a wider, more diverse milieu than the constrained space of surgical training. Therefore, simulation, which accounts for multiple professional exchanges within specific aspects of laparoscopic colorectal surgery, may improve specific procedural outcomes.

9.3.1 The importance of sharing experience at the simulation table

While trainees come to the WLCTS course from a similar level in their career, individuals come with varying levels of prior experience. The regression analysis in combination with the analysis of trainees' comments, provided empirical evidence that trainee experience measurably impacted on the distribution of social and knowledge cues within the procedures, regardless of task complexity. Although task complexity did impact learning time, trainee experience level on the other hand, dictated the ability of trainees to make better use of social interactions to transact learning. Greater experience also equates with quicker task completion. As trainees gain experience, their ability to use the skills appears to be improved through their acquisition of greater social agency. This finding is supported by the combination of two ideas; that trainees gain more embedded knowledge and relatively more pre-existing agency, legitimacy and fluency within the colorectal surgery culture which then creates an opportunity for further surgical experience. It is important to note that there is a tacit power relationship between pairings of different prior experience. Each trainee may exploit the training activity for their own gain, without recognising the mutual benefit of their shared activity. Discussion of socially (especially verbally) mediated knowledge in section 8.3.5 calls for more explicit verbal exchanges between trainees, which could facilitate the experience of both.

9.3.2 Fidelity of the social construct between SBT and OT

Psychomotor skills, howsoever they were conventionally acquired, may become understood by the trainees through several interacting, socially organised threads; verbal and non-verbal language, and shared surgical tools and activity through which meaning is externally conveyed and internally understood. Each task was shown to involve negotiation of such channels towards a common goal. Despite the difference in outcome objective between SBT and the OT, trainees understood that their

negotiation of activity in simulation supported their subsequent negotiation of clinical activity, through graduated and preceptor-controlled opportunities in the OT.

9.3.3 Trainees reflect by using the simulation template

It is important to recognise the significance of reflective activity, where trainees exercise operative mindfulness. This may form a significant additional plane between simulating and operating. Whether this ought to be considered as a possible third interacting activity system or whether it is a consequence of the binary SBT-OT system is worth further exploration.

Instrument familiarisation processes may not be useful alongside advanced procedural training, given the extra cognitive load that has been reported to distract trainees' focus from their learning goals. Therefore, this thesis supports the suggestion that within the WLCTS foundation courses, adding training to the plethora of instruments specific to laparoscopic colorectal surgery may be initially useful. Simulation remains the best location to learn instrument handling but it may not be conducive to learn how to use them simultaneously with advancing procedures such as those found in laparoscopic colorectal surgery. This finding supports the inferences of previous studies (Seymour et al. 2002; Stefanidis et al. 2006; Stefanidis et al. 2007).

9.3.4 The OT milieu is diverse relative to WLCTS simulation

One advance in simulation as a consequence of this thesis is to suggest designing surgical hands-on courses with a greater degree of social fidelity to the wider OT. Whole team SBT, that is, the whole diverse group of professionals working in an OT has been mooted in the recent past as a possible direction to improve the outcome of specific surgical procedures, both in practical competencies (Paige et al. 2009) and in social-oriented, non-technical skill development such as communication (Robertson et al. 2017). This would involve training and negotiation of the whole multitude of theatre skills through social exchanges, expanding the avenues through which surgical skills processes and cognition can become crystallised together. However, it has proved difficult to get all peri-operative specialties into a training room at any one moment. It would also require greater material resources, including full simulated operating space (Foell et al. 2013). Currently, the turnover success of programmes such as the WLCTS is derived from their ability to deliver training with relatively basic resources, support and low physical footprint (Agha and Fowler 2015). At its original conception, the WLCTS demanded the training of existing consultants and colorectal theatre teams *in situ*, which was considered novel and remained unexplored once those who would become the initial cohort of tutors were trained, which was originally conceptualised as immersion training. The advantage of learning *in situ* however, is negotiating activity within the presence of the authentic material resources and negotiating artifacts. As a result of the social impact on deep learning inferred

by the findings of this thesis, the immersion concept as a learning approach deserves future exploration.

9.4 Design challenges and suggestions for improvement

A major strength of my research design choice is that the simulation environment is the observed social system of activity. It is a standard format for every cohort of trainees coming to undertake the WLCTS and is therefore consistent as an observable milieu. In this sense, my videographic recording of the social system is holistic only in the sense of what is captured in the frame of activity taking place between trainees, tutors and surgical instruments as actors and actants. Through this context, (along with a descriptive analysis of the history and environment of the trainees involved in SBT (which I have discussed previously)), the place and impact of simulation on the contemporary surgical trainees' development is understood. Although mainly quantitative, performing the video content analysis is supported by recent precedent in surgical simulation (Ruis et al. 2019), showing that numerical accounts of social transactions are loaded with meaning (Shaffer 2017).

An unforeseen limit in my design was the presence of background noise interference. Retrospectively, I could have set up an initial pilot observation to test the feedback quality and identify data capture issues. Video recording devices in the lab set for general audio pickup were particularly good at capturing the range of sounds at a training station (such as conversation, whispers, movement of equipment, etc.); however, I did not consider that it would also capture the background noise created by superfluous conversations and 'pickup' of conversations at other training stations and that this would create so much interference. This prevented me from making a clear, unbroken analysis of the conversation and language at the simulation tables; my original intention was to transcribe all verbal interactions at the simulation tables in synchronicity with the procedures and explore whether trainee experience or task complexity might show insights into the specific language used. To address how simulation contributes to the development of specific surgical language as a tool or indicator of learning negotiation, a future study could use unidirectional microphones to mitigate noise interference.

Furthermore, my dual responsibility as a tutor and technical support at times needed to take precedence over fulfilling my role as an observer. For example, my ability to make notes synchronous with trainee activity was limited, while simultaneously my responsibilities formed part of some activity recorded in the background. To meet the need to observe and make organised notes without restraint, it would be ideal to defer the role of technical support to a colleague where possible, although this has resource implications.

Additional issues affecting useful data collection, arising mainly as a consequence of the WLCTS layout and programme were i), a small cohort size available for gathering trainee quantitative data for content analysis; ii), only one trainee was observed who, during the observation interval attended both right and left-side courses (and could not be interviewed for 8-month follow-up after the left-side due to Covid-19). Therefore, some findings regarding shared experiences were limited; iii), I was, as a tutor and technical support, the only shared faculty between the right and left-side courses, while all other surgical tutors were different in each.

My comments on the social mechanism of transfer to the OT are limited to inferences from the participants' interview accounts. Observation of OT activity presented a research ethics challenge, extending beyond the simulation scope of this thesis. Obtaining preceptor feedback may have added further insights to address skills transfer and perspectives, however I omitted to undertake this due to time constraints.

This thesis has examined the real simulation setting with all its caveats. If the course were to be designed from the focus of my study objectives, or from a longitudinal perspective, it could be possible to acquire data in two ways. First, I would set three specific laparoscopic colorectal tasks designated as basic, intermediate and advanced using a larger cohort of pairs. Second, I would observe social interactions between a larger cohort of trainees paired for obvious differences between experience undertaking one complex colorectal simulation, with two baseline cohorts comprising experienced pairings (of both senior trainees and consultants as clinical experts) and inexperienced pairings (CT3 level registrars). While my quantitative data could be organised in the same way as in this thesis for statistical treatment, I would extend the video study with a qualitative content analysis.

9.5 Queries/directions for further study

The development of specific surgical language (through SBT) as a means of constructing a shared meaning between trainees and tutors is an interesting idea, which could contribute to further refinement of the way learning is consolidated and mediated through negotiation of activity and extend the importance of the CoP in facilitating this within simulation and clinical work. This would contribute a semantic and syntactic perspective to the existing material semiotics. Moreover, analysis of language and script during operative work, either in SBT or in the OT, could yield an entirely distinct set of data from that revealed in the present trainee interview accounts which were reflective. For example, although interview analysis revealed similar ratios of thematic content and word usage between genders, would a difference be seen in specific (key)-word frequency and volume for homogeneous and /or mixed trainee pairs? To my knowledge, such an analysis has not

yet been undertaken, but would add value to studies of gender communication strategies in the OT where gender bias is discussed (Lim et al. 2021). Additionally, it could address studies of ineffective teamwork (which is linked to surgical complications) and could be underpinned by differences in gender communication (Etherington and Boet 2018; Etherington et al. 2021).

One further environment in which sociocognitive interactions between trainees could be observed for comparison would be in the OT, for comparable sections of surgical procedure as they link to the simulation stages. A follow-up study could include aspects of this present one and extend some observations to the OT to verify the presence of similar themes and negotiation of social cues and provide a more developed picture of the way simulation and operation activities interact. Preceptor perspectives would add a richer dimension of thematic analysis, also adding extra layers of data for comparison.

The observation of the operative context would also include the addition of indicators of surgical outcomes, such as conversion[21] rates. It is difficult to directly observe any impact of SBT on surgical outcomes; however, conversions could be monitored anonymously among trainees performing right and left-side colorectal procedures. The significance of this is that conversions are usually unplanned and are known to be linked with increased postoperative morbidity and mortality (Marusch et al. 2001; Papandria et al. 2013). To support pursuit of this inquiry, there are datasets which, if made accessible, could help to analyse the link between simulation experience and conversion rates (Rees et al. 2014; American College of Surgeons 2016). Conceptually, changes in conversion rates among developing trainees could indicate that SBT may be linked.

Finally, the literature review contended that mental reflection and spatial training are linked to reduced error and improved decision-making because it supplements a very material process of cognitive development in the cortical pathways of the brain. The findings of this thesis support the notion that trainees' participation in simulation, through a distributed, gradual, scaffolded process, is important in the development of their neuro-cortical pathways. Furthermore, these pathways are activated and reinforced through mental rehearsal. The accounts of the latter somewhat confirm the former since rehearsal has been shown to stimulate pathways of the prefrontal cortex involved in decision-making (Hall 2002; Luft and Buitrago 2005). Practically, encouraging training in explicit reflective activity as part of hands-on simulation regarding the practise of specific procedures may prove helpful, since so much research in reflection points to its ability to reinforce neuronal pathways concerning motor control and decision processes. The literature review also contends that emotions are central to the development of learning processes and may be essential to their meaning-making.

[21] Conversion in surgery is associated with changing the procedure at some point in the operation, from laparoscopic to standard open format.

Therefore, further investigation to discover any emotional difference between learning through simulation and learning through direct clinical intervention, may yield distinctions to bring simulation into closer alignment with practice and the results of such a study may have wider implications in other fields where simulation has a role in real life.

9.6 Summary

A surgical trainee's journey to being an expert comes through shared education and experience. Traditionally, expertise has been viewed as resulting from the accumulation of many hours of practice. SBT, where intentional, focussed aspects of surgical tasks have attempted to mitigate the reduced time with which trainees have to get to their proficiency goals in the OT, has offered an alternative. Simulation achieves this because it provides measurable targets on which further targets are built. Simulation comes to the trainees at intervals of intervention, which then provide a mental platform from which to exercise their skills in a controlled, guided, clinical environment. Before SBT, surgeons trained and accumulated their experience through a different socially driven environment. Importantly, simulation provides targeted training, but it is still socially driven. Trainees' learning becomes understood through their gestures and their verbal exchanges and is extended through their tools in the OT. Their identities as colorectal surgeons become shaped through mutual understanding of their work environment, their interactions with their tools and their language, all of which must begin to form at the simulation table. This thesis has shown that learning is negotiated during simulation through verbal and non-verbal cues and the use of instruments. The efficiency with which this negotiation happens appears to be enhanced when trainees of less experience are paired with trainees of more experience. As their distinctiveness as colorectal surgeons becomes more defined by their actions and their words and further, as their ability to negotiate the complexity of interacting components of surgical activity through the social system becomes more fluent, their agency to act and make surgical decisions independently comes from a platform of confidence in their competence.[22]

[22] 54,708 words

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Course Programme

Welsh Laparoscopic Colorectal Training Scheme

Right Side Course

Course Convenor

Mr P____
Consultant Colorectal Surgeon
University Hospital Llandough, Penarth

Mr A____
Consultant Colorectal Surgeon
Princess of Wales Hospital, Bridgend

Faculty

Mrs C____
Consultant Surgeon
University Hospital of Wales, Cardiff

Mr D____
Consultant Surgeon
University Hospital of Wales, Cardiff

Mr H____
Consultant Surgeon
University Hospital of Wales, Cardiff

Mrs S____
Consultant Surgeon
West Wales Hospital, Carmarthen

Day 1		
8.30 – 9.00	**Coffee and registration**	
9.00 -9.30	Course introduction Introduction to the Training Scheme, passports and hospital visits	Mr A____
9.30 -10.30	Laparoscopic Appendicectomy: Why, When, Who and How? Video Session via ARCHOS / Welsh footage on appendicectomy	Mr P____
10.30 – 10.45	**Coffee**	
10.45 – 11.15	Practical Session using 30° Scopes	All Faculty
11.15 – 11.30	Roeder Knot	All Faculty
11.30 – 12.15	Practical Session: appendicectomy models, endoloops, extracorporeal knot tying	All faculty
12.15 - 13.00	**Lunch**	
13.00 - 13.30	Radiological views	
13.30 - 14.30	Laparoscopic Right Hemicolectomy Why, When, Who?	Mr P____
14.30 – 14.45	Suturing and Knot Tying	All faculty
14.45 – 15.45	Practical session: intracorporeal suturing / knot tying	All Faculty
15.45-16.00	**Tea**	
16.00 – 16.30	SBT	All Faculty
16.30 – 17.00	Video and feedback	Mr P____
19.00	Course Dinner - tbc	

During this afternoon we will be live linked with OR1 in UHW where 2 right hemicolectomies will be performed. Timings will work around this.

Day 2		
8.30 – 9.00	**Coffee and registration**	
9.00 – 10.00	Complications (not that there are any)	Mr P____
10.00 – 10.45	Energy Talks	Covidien/Ethicon/Lotus
10.45 – 11.00	**Coffee**	
11.00– 12.30	Practical Session: vascular pedicle and mobilisation	All faculty and Company Reps
12.30 – 13.00	**Lunch**	
13.00- 15.30	Intracorporeal anastomosis (to include tea break)	All faculty
15.30 – 15.45	Diary analysis – scheduling hospital visits	
15.45 – 16.00	Feedback	All faculty

Course Programme

Welsh Laparoscopic Colorectal Training Scheme

Left Side Course

Course Convenors

Prof H_____
Consultant Surgeon
Prince Charles Hospital, Merthyr Tydfil

Mr W_____
Consultant Colorectal Surgeon
Royal Gwent Hospital, Newport

8.15 – 8.30	**Coffee and registration**	
8.30 – 8.40	Introduction to the Course	
8.40 - 8.55	Relevant Anatomy	Mr W____
8.55 – 9.20	The Stepwise Approach to left colonic and rectal excision - Video and Discussion – complete procedure - Recap – Step 1-small bowel stacking	Prof H____ Mr S____
9.20 – 9.50	Lab Session on Step 1 - 3 per station + faculty	Faculty
9.50 – 10.00	Video and Discussion Steps 3 – 7 Right ureter, medial dissection at promontory, left ureter, gonadals, IMA pedicle	Mr W____
10.00 – 10.20	**Coffee**	
10.20 – 11.50	Lab Session on Steps 3 – 7 Ethicon/Covidien/Lotus/Olympus equipment demonstration	Faculty
11.50 – 12.00	Video and Discussion Splenic Flexure Mobilization	Mr W____
12.00 – 12.50	Lab Session on Splenic Flexure Mobilization	Faculty
12.50 – 13.30	**Lunch**	
13.30 – 13.40	Video and Discussion Rectal isolation, cross stapling, delivery and anastomosis	
13.40 – 15.10	Lab Session on isolation, cross stapling of rectum, specimen delivery and proximal division (extracorporeal) Intra-corporeal anastomosis Ethicon/Covidien equipment demonstration	Faculty Mr W____
15.10 – 15.30	**Tea**	
15.30 – 16.40	Video and Discussion Tips, Tricks and Potential Hazards	Prof H____
16.40	Feedback and Close	Participants and Faculty

Appendix 2 – Learning and teaching plan of right and left-side courses – hands-on procedures only

Right-Side Hemicolectomy hand-on sessions – Summary plans and learning objectives

Setting - Training lab at WIMAT with basic operating surface, human torso model with neoprene skin in which to situate training models. Trainees work on either side of table. Lab gloves, aprons, sharps disposal bins and waste bins.

Key accessories required for all exercises - 30^{O} laparoscope, laparoscopic HD camera, light lead, laparoscopic stack and surgical monitor. For keyhole entry - 12mm blunt port x1, 12mm sharp entry ports x2, 5mm ports x2. Basic laparoscopic curved graspers x2, basic laparoscopic scissors x1, basic kit of surgical instruments *(needle holder x1, forceps x2, curved haemostats x2, allis x2, retractors x1, self-retaining retractor x1, #3 BP and #4 BP scalpels x1 with attached blades), swabs*.

Exercise	Name	Key equipment and accessories required	Learning objective: Learner should be able to (LSBAT:)	~ Time for task
1	Right-side Practical Session using 30^{O} scopes	• Basic task models for practise of manipulation and hand-eye coordination using 30^{O} scope rather than a 0^{o} scope; plastic models and objects such as sugar cubes and dried peas strategically placed in working view.	• LSBAT: demonstrate spatial competence by: grasping, rotation, exchange of objects between instruments, arranging objects. This shows ability to process 3D activity through a 2D view seen on the surgical monitor. • LSBAT: direct the position of the camera to their camera-assistant through clear communication with intention of their needs.	30 min
2	Roeder knot and laparoscopic	• Surgities (industry sponsored pre-made roeder knot loop ligation)	• LSBAT: follow and repeat the techniques of roeder knot tying	45 min

	appendicectomy	• Animal model prepared to mimic anatomical arrangement and 'feel' of appendix attached to caecum, with meso-appendix • Energy devices for electrosurgical or 'harmonic' dissection of meso-appendix • Patient return electrode for electrosurgical circuit – laparoscopic diathermy L hook and pencil, harmonic graspers • Harmonic and diathermy generators	and application from in-person demonstration and video footage. • LSBAT: apply pre-instructed steps of appendicectomy to the appendix model • LSBAT: demonstrate understanding of each step of procedure and transfer steps • LSBAT: show working knowledge of electrosurgical devices; power settings and manipulation	
3	Basic laparoscopic intracorporeal suturing and knotting	• Chamois pad with angular incision for basic practise of suture technique • Laparoscopic needle holders x2 • 70cm braided sutures crimped with 22-26mm 2/3 arc reverse-cut needles	• LSBAT: suture a line of interrupted stitches laparoscopically and in correct orientation • LSBAT: manipulate needle holders so that they will be able to transfer skills across a range of procedures and tissue planes	60 min
4	SBT – small bowel and mesentery examination	• Johan's laparoscopic fenestrated atraumatic graspers x2	• LSBAT: 'walk' thoroughly through the small bowel, grasping the tissue at the mesenteric border to identify possible lesions or perforations • LSBAT: demonstrate that they can manipulate the Johan's graspers without damaging the tissues	20 min
5	Vascular Pedicle and Mobilisation	• Animal model prepared to mimic anatomical arrangement and 'feel' of right-side ascending colon, superior mesenteric artery and vasculature of pedicle toward terminal ileum	• LSBAT: follow pre-procedure video and instructor demonstrations of stepwise sequence to mobilise the tissues	60 min

		and caecum, with perineum, duodenal arch • Johan's laparoscopic fenestrated atraumatic graspers x2 • Laparoscopic diathermy hook and pencil • Harmonic graspers • Ligasure electrosurgical coagulation device • Ligatures • Laparoscopic stapling device with vascular clips (endo GIA or endo TA) • Patient return electrode pad	and dissect appropriately using the devices and provided • LSBAT: Demonstrate knowledge and understanding of the procedure steps as they relate to the anatomical planes of the tissues	
6	Small bowel laparoscopic intracorporeal anastomosis	• Specimen of porcine small bowel, cut for side-to-side stapled anastomosis and full-thickness suturing • End GIA for cross-stapling and staple reloads • 70cm braided sutures crimped with 22-26mm 2/3 arc reverse-cut needles • Laparoscopic needle holders x2	• LSBAT: combine multiple skills and instruments learned in prior tasks to manipulate the tissue, suture and staple across the correct planes in order to reconnect bowel without obstructing flow or allowing leaks	120 min

Left-Side Hemicolectomy hand-on sessions – Summary plans and learning objectives

Setting - Training lab at WIMAT with basic operating surface, human torso model with neoprene skin in which to situate training models. Trainees work on either side of table. Lab gloves, aprons, sharps disposal bins and waste bins.

Key accessories required for all exercises - 30^{O} laparoscope, laparoscopic HD camera, light lead, laparoscopic stack and surgical monitor. For keyhole entry - 12mm blunt port x1, 12mm sharp entry ports x2, 5mm ports x2. Basic laparoscopic curved graspers x2, basic laparoscopic scissors x1, basic kit of surgical instruments *(needle holder x1, forceps x2, curved haemostats x2, allis x2, retractors x1, self-retaining retractor x1, #3 BP and #4 BP scalpels x1 with attached blades), swabs*.

Exercise	Name	Key equipment and accessories required	Learning objective: Learner should be able to (LSBAT:)	~ Time for task
7	SBT – small bowel and mesentery examination with table tilt	• Johan's laparoscopic fenestrated atraumatic graspers x2	• LSBAT: 'walk' thoroughly through the small bowel, grasping the tissue at the mesenteric border to identify possible lesions or perforations, while overcoming the effect of down-tilt on bowel direction • LSBAT: demonstrate that they can manipulate the Johan's graspers without damaging the tissues	30 min
8	Steps 3-7 right ureter medial dissection at promontory left ureter gonadals IMA pedicle	• Animal model prepared to mimic anatomical arrangement and 'feel' of left-side descending colon, sigmoid colon and rectum over right and left ureter running to bladder, over aortic bifurcation distally into right and left femoral arteries, with inferior mesenteric artery	• LSBAT: follow pre-procedure video and instructor demonstrations of stepwise sequence to mobilise the tissues and dissect appropriately using the devices and provided	50 min

		pedicle fixing from bifurcation to descending colon-sigmoid colon junction. • Johan's laparoscopic fenestrated atraumatic graspers x2 • Laparoscopic diathermy hook and pencil • Harmonic graspers • Ligasure electrosurgical coagulation device • Ligatures • Laparoscopic stapling device with vascular clips (endo GIA or endo TA) • Patient return electrode pad	• LSBAT: Demonstrate knowledge and understanding of the procedure steps as they relate to the anatomical planes of the tissues • LSBAT: use the devices to manipulate and work with the model in the correct anatomical approach to achieve intended outcome	
9	Splenic flexure mobilise	• Animal model prepared to mimic anatomical arrangement and 'feel' of left-side transverse colon running to descending colon at spleen with mesenteric artery vasculature embedded in mesentery. Situated underneath stomach and covered in connective tissues. • Johan's laparoscopic fenestrated atraumatic graspers x2 • Laparoscopic diathermy hook and pencil • Harmonic graspers • Ligasure electrosurgical coagulation device • Ligatures • Laparoscopic stapling device with vascular clips (endo GIA or endo TA) • Patient return electrode pad	• LSBAT: follow pre-procedure video and instructor demonstrations of stepwise sequence to mobilise the tissues and dissect appropriately using the devices and provided • LSBAT: Demonstrate knowledge and understanding of the procedure steps as they relate to the anatomical planes of the tissues • LSBAT: use the devices to manipulate and work with the model in the correct anatomical approach to achieve intended outcome	40 min
10	Isolation and cross-stapling of sigmoid colon / rectum	• Same anatomical model and accessories as in exercise 8 • Circular / intra-lumenal stapler • Anvil grasper • Purse string device	• LSBAT: follow pre-procedure video and instructor demonstrations of stepwise sequence to mobilise the tissues and dissect appropriately using	50 min

		• Suture for purse string • Hand-port • Atraumatic intestinal clamps	the devices and provided • LSBAT: Demonstrate knowledge and understanding of the procedure steps as they relate to the anatomical planes of the tissues • LSBAT: use the devices to manipulate and work with the model in the correct anatomical approach to achieve intended outcome	

Appendix 3 – Ethical approval letter

School of Social Sciences
Ysgol Gwyddorau Cymdeithasol
Head of School, Pennaeth yr Ysgol
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21 June 2018

Our ref: SREC/2791

Stuart Goddard
PhD Programme
SOCSI

Dear Stuart,

Your project entitled *'Educational Journeys to colorectal surgical expertise: The place and Impact of simulation training.'* has now been approved by the School of Social Sciences Research Ethics Committee of Cardiff University and you can now commence the project should all necessary forms of approval been received.

If you make any substantial changes with ethical implications to the project as it progresses you need to inform the SREC about the nature of these changes. Such changes could be: 1) changes in the type of participants recruited (e.g. inclusion of a group of potentially vulnerable participants), 2) changes to questionnaires, interview guides etc. (e.g. including new questions on sensitive issues), 3) changes to the way data are handled (e.g. sharing of non-anonymised data with other researchers).

In addition, if anything occurs in your project from which you think the SREC might usefully learn, then please do share this information with us.

All ongoing projects will be monitored and you will be obliged periodically to complete and return a SREC monitoring form.

Please inform the SREC when the project has ended.

Please use the SREC's project reference number above in any future correspondence.

Yours sincerely

Professor Alison Bullock
Chair of School of Social Sciences Research Ethics Committee
Cc: Alyson Rees, Rebecca Dimond

Appendix 4 – Participant consent and research info sheet

Educational Journeys to colorectal surgical expertise: The place and impact of simulation training

PARTICIPANT INFORMATION SHEET

You are being invited to take part in a research study that I am undertaking as part of my doctoral studies. The focus of my research is on how simulation impacts on colorectal trainees' sense of development and value in their learning. To help inform your decision to participate, it is important for you to understand what is required of you and why your involvement is needed. Please take time to read the following information.

Background

Colorectal trainees face ever decreasing training time, and surgical simulation is advocated as the de facto mode of learning to support the development of clinical competence. This shift potentially impacts on colorectal trainees' sense of development and value in their learning. It also requires re-evaluation of current theories of learning.

The study aims to find out how the laparoscopic colorectal trainees in Wales make sense of their learning and how this supports their sense of professional identity.

What is involved?

Observation

- Video cameras will be set up to record the practical sessions taking place in the WIMAT training lab during the right-side colorectal course. The focus is on the interaction / dialogue taking place between delegates and tutors during the simulation exercises.
- Field notes will be taken during each skills exercise to accompany the video footage.

Interviews

- A short post-course one-to-one interview with participants will be conducted at the end of the course or very soon after to ask questions around the specific exercises and general feelings / attitudes about the simulation elements of the course. With your permission, this will be audio recorded. Written transcripts will be created.
- Further follow-up short interviews will take place by arrangement at intervals following the right-side course, which will be linked to observation (video) data. These will be audio recorded, with your permission. Written transcripts will be created.

Online Questionnaires

- You will also be invited to respond to a brief online survey about perceptions of training on service impact, perceived patient benefit, and what value you have gained from the simulation programme.

- Feedback data from the RCS evaluation tool for the right-sided course will also be analysed and contribute information to the study.

What will happen with your data?
All data gathered will be kept securely in accordance with the data protection act. It will be anonymised and will not be used for anything other than the purposes of this research. The information will form part of the doctoral thesis and could be published in academic literature. You will also be offered a link to the thesis and/ or publications.

All participants' identities will remain confidential at all times. Pseudonyms will be used where reference to individual responses are written in the dissertation.

Video footage will not be used to assess or scrutinise psychomotor ability for any reason outside the study.

Will participation impact on your course learning objectives?

No. The aim of the research is to understand the learning process and development of competence in a more social-oriented way. However, your participation will create an opportunity to improve our understanding about learning in simulation and skills transfer, and may advance future simulation training.

What if you don't wish to participate?

If you do not wish to participate in all or some stages of the project, you will not be disadvantaged, and this will not affect your training in any way.

However, the rooms will be set up for video recording. All attempt will be made to make sure you are not included on the video footage; face occlusion editing will be used where necessary. None of your interactions will form part of the analysis.

You might want to be excluded for a part of the information gathering process. Please state in the consent form whether you wish to be excluded from any part of the process.

What if you change your mind about participating at any stage?

Participation is voluntary. You can withdraw at any time without providing a reason. However, any information already obtained prior to abstaining would still be included for data analysis and used toward the research.

Who is doing the research?

Stuart Goddard is undertaking the research toward a doctorate in health studies and has the approval of Cardiff University School of Social Sciences Ethics Committee. If you would like further information about the research, please contact him on 029 2068 2135 or email goddardsg@cardiff.ac.uk. If you would like to complain about the conduct of the study, please contact the Chair of the Research Ethics Committee, School of Social Sciences at socsi-ethics@cardiff.ac.uk.

Cardiff University
Cardiff School of Social Sciences
Glamorgan Building
King Edward VII Avenue

Cardiff CF10 3WT

CONSENT FORM

Educational Journeys to colorectal surgical expertise: The place and impact of simulation training

Name of researcher Stuart Goddard

1. I Confirm that I have read and understood the information sheet and had any questions about the research answered to my satisfaction.	**YES / NO**
2. I agree that observations of my course activity will be video-recorded. No identifying images will be used in the thesis or in any presentation.	**YES / NO**
3. I agree that interviews with the researcher will be audio-recorded and anonymised.	**YES / NO**
4. I give my consent to take part in the research and understand that I can withdraw from it at any time without giving a reason, and without it affecting my participation in the right sided course or Welsh laparoscopic colorectal training scheme	**YES / NO**

_____	_____	_____
Name of participant	Date	Signature
_____	_____	_____
Name of person taking consent	Date	Signature

2 copies: 1 for participant and 1 for research file.

Appendix 5 – Interview question guides for right and left-side participants

Post-course interview guide

1. Do you think this course – and the simulation exercises in particular, are a good starting point for the right / left side learning curve?

- What are your experiences of simulation training in general?
- What are your feelings about simulation training in general?

2. How do you see the course linking to your job?

- What is your expectancy now following this course?
- Do you expect any significant areas of development in any specific areas of your work?

3. How do you perceive your skills and the place of this training course in that development?

- What are the most important 'take-home' aspects of this course for you?
- How do you see this course in helping you to prepare for surgery?
- Does this course change what you would normally do to prepare for a clinical procedure?

(concepts prior knowledge, technical ability and mental rehearsal)

4. Are there any parts of the simulation exercises which you struggled with or even felt like you failed at?

- How do you think other trainees might feel about struggling in simulation exercises?
- If this happened, can you say specifically what took place?
- How and when did you know you had failed and / or were struggling?
- How did you feel about it?
- How did you correct it or deal with it?

5. One aspect about this simulation training course is deliberate use of partnering and attempting a high tutor / participant ratio.

- Has being paired up with changing partners in the skills exercises helped or hindered your experience?
- Do you normally reflect on how you interact in simulation and in the clinical environment?

Follow-up interview guide

6. Do you still think this course – and the simulation exercises in particular, were a good starting point for the right side / left-side learning curve?

- Have your impressions of simulation training changed?
- In what ways have you been able to link the simulation exercises to your operation experience?

7. How do you see the course linking to your job?

- Has your expectancy of the course matched your experience?
- Did it help you develop any significant areas in specific areas of your work?

8. How do you perceive your skills and the place of this training course in that development?

- Have the take-home aspects changed?
- How do you see this course in helping you to prepare for surgery?
- Does this course change what you would normally do to prepare for a clinical procedure?

(concepts prior knowledge, technical ability and mental rehearsal)

9. In operative situations where you might have struggled or faced difficulty, particularly in decision-making or skill limitation, how has the preceptorship and /or prior simulation training intervened?

- How do you think the other trainees might feel about struggling in the operation?
- How did you feel about it?
- How did you correct it or deal with it?

10. One aspect about this simulation training course is deliberate use of partnering and attempting a high tutor / participant ratio.

- Did being paired up with changing partners in the skills exercises helped or hindered your experience?
- Do you normally reflect on how you interact in simulation and in the clinical environment?

11. At what stage of proficiency with your hands-on surgical skills do you see your own ability?

- Talking in terms of fluency – conscious incompetence / conscious competence / unconscious competence
- Abstract question – what cues in the operating theatre environment / team / language, do you think you use to 'measure' your perceived ability and projected outcome during a procedure?
- Are you conscious that learning is taking place when you are doing it?

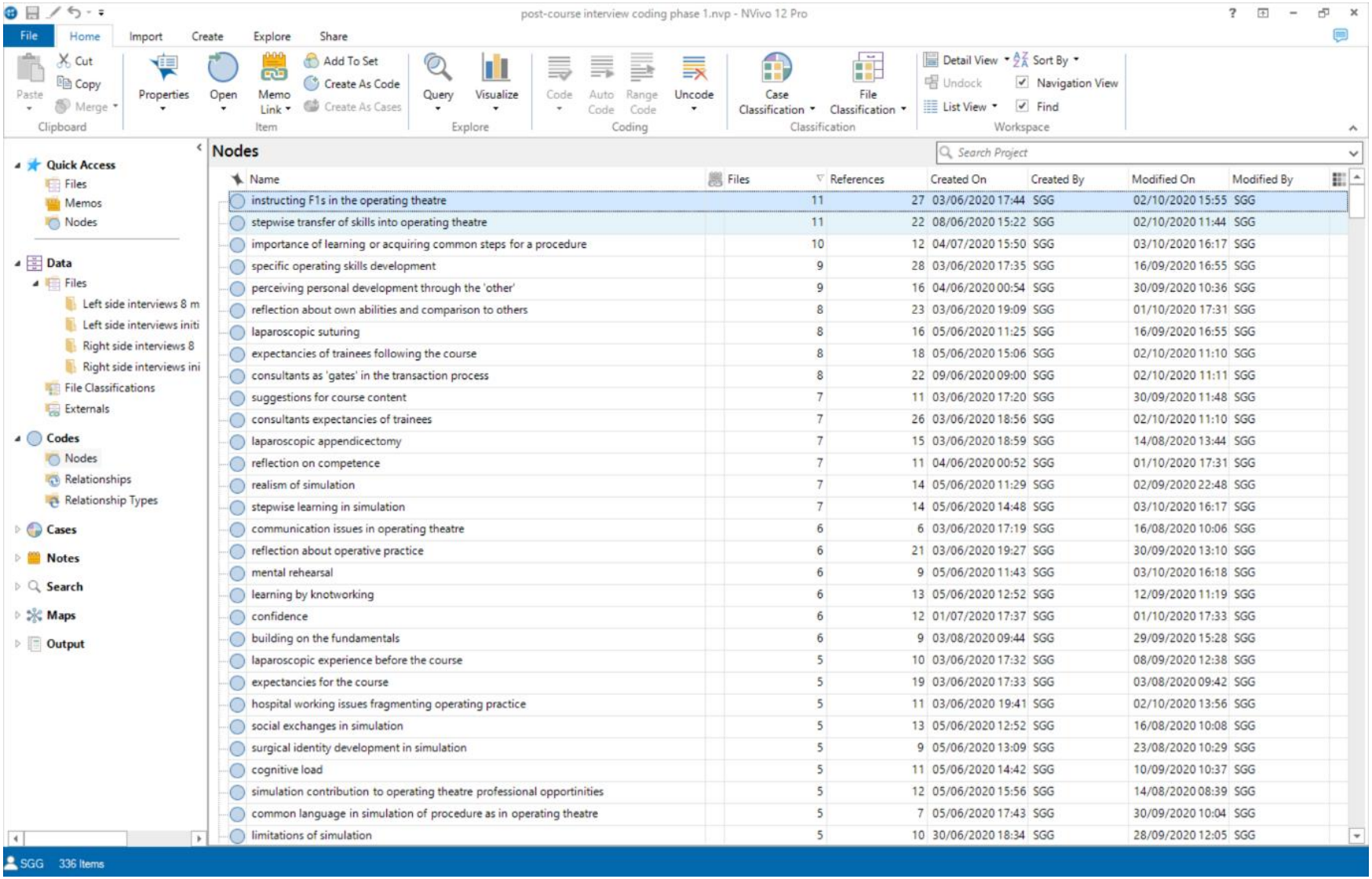
Appendix 6 – Discussion on discounting inductive and deductive approaches for my thematic analysis

Inductive reasoning premises that evidence from data may support an argument toward a conclusion in varying degrees of strength (Copi et al. 2016); in inductive thematic analysis, this implies emerging themes which are strongly linked to the data (Patton 2015) though not necessarily exclusively to it (Fereday and Muir-Cochrane 2006), thus revealing to what extent the data might support a theoretical framework. Inductive logic allows inferences to be drawn by the empiricism of the data (Thornberg and Charmaz 2014). Within a qualitative method, the significance of induction is that the emerging themes, theories and conclusions are *always* hypothetical (Kennedy and Thornberg 2018) and they can only be held locally, rather than universally 'valid'. Meanwhile, a deductive rationale in qualitative research implies that any evidence emerging from the data is valid if it supports a pre-existing model or theory about how that data should actually look (Boyatzis 1998; Copi et al. 2016). That is, the qualitative-deductive approach begins with a theoretical framework and assesses the extent to which collected data substantiates it. The theoretical framework is adopted as the lens through which to gather and analyse the data (Kennedy and Thornberg 2018).

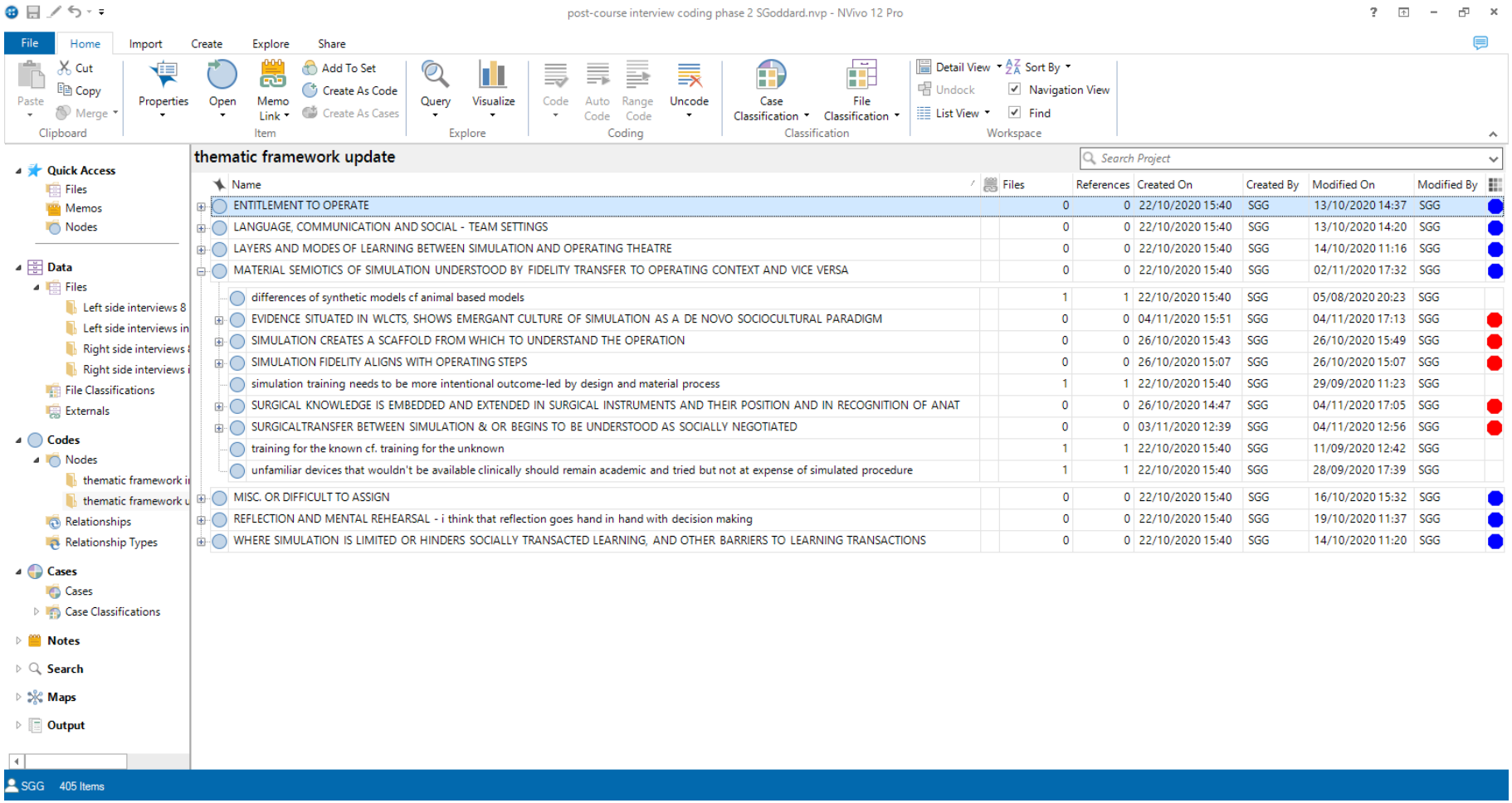
There are shortcomings to both these approaches. In considering induction, Braun and Clarke note that researchers "cannot free themselves of their theoretical and epistemological commitments, and data are not coded in an epistemological vacuum" (Braun and Clarke 2006, p. 84). I acknowledge this admonition within my own methodological planning; although my questions do not presume to adhere to one theoretical position, I am biased toward a synthesis of theory supporting socioculturally mediated learning transactions from one system of activity to another. I must also not be blind to the emergence of themes which may point to another kind of social mediation. The assumption that inductive exploration is a value-free activity is a challenging one, given that researchers and the research are situated in a historical, ideological and sociocultural context (Chalmers 1999; Kennedy and Thornberg 2018); prior knowledge through both experience (Alvesson and Kärreman 2011) and theory (Maxwell 2018) shapes a researcher's lens and conceptual ideas (Kelle 1995), and therefore their interpretive observation (Kelle 1995; Alvesson and Kärreman 2011). The importance of this is that induction, therefore, leads to an interpretive representation of the raw data (Charmaz 2014). A deductive approach meanwhile, has led researchers to only focus on the portions of data which fit the *a priori* theory while overlooking other portions of the data which lie outside of it (Kennedy and Thornberg 2018). Glaser (1998) also points out that data might be over-

interpreted; where it might be 'force-fit' or distorted to bring it into relevance with a theoretical framework and pre-existing concepts. The danger of this is that research might only ever repeat or add minorly to a pet theory (Tavory and Timmermans 2014), where a researcher's focal effort is to assert their *a priori* arguments and demonstrate the theory (Kennedy and Thornberg 2018).

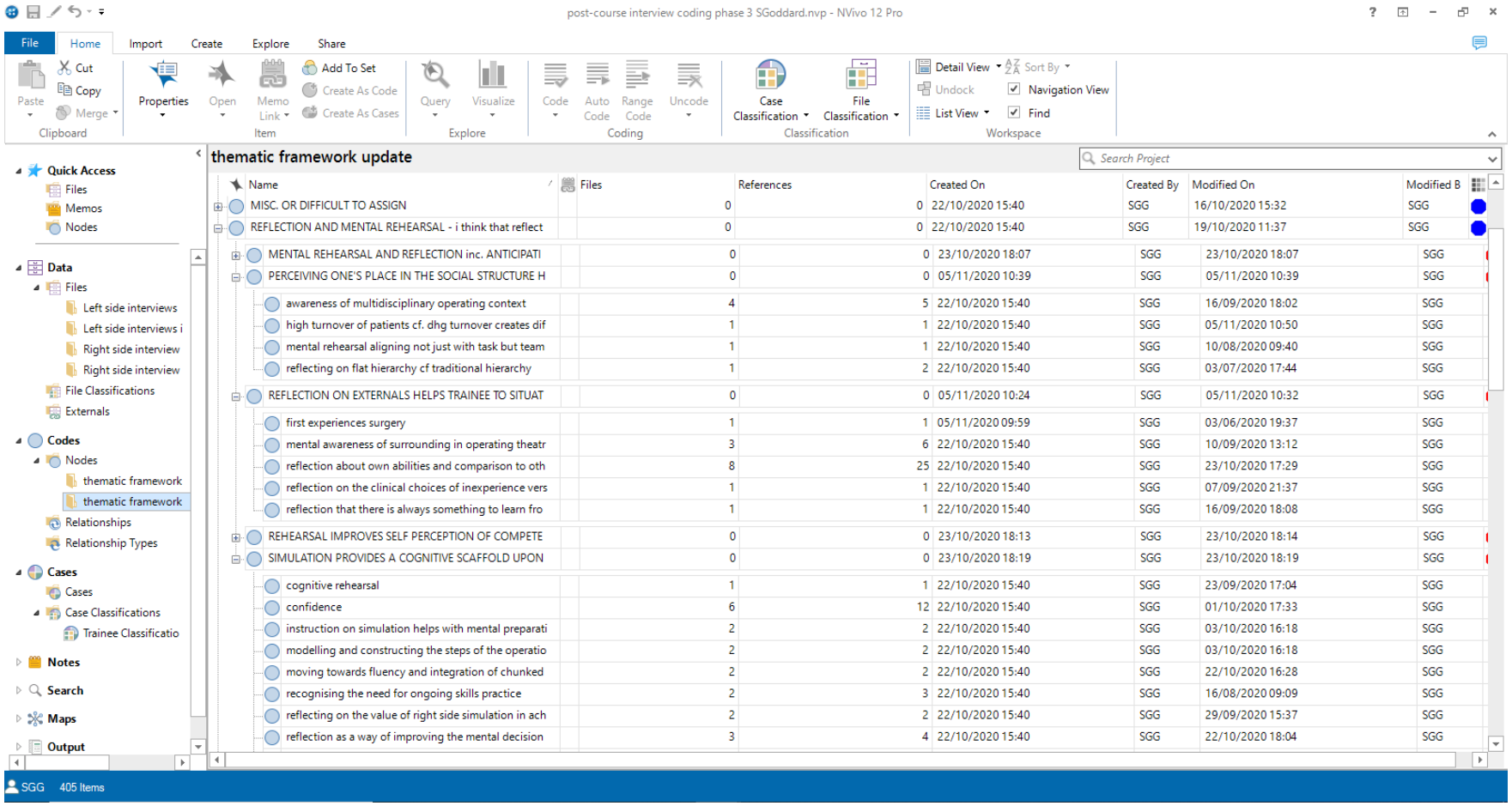
Appendix 7 – Development of themes using NVivo



Phase 1 – tags for specific commentaries are initially raised across all interview transcripts.

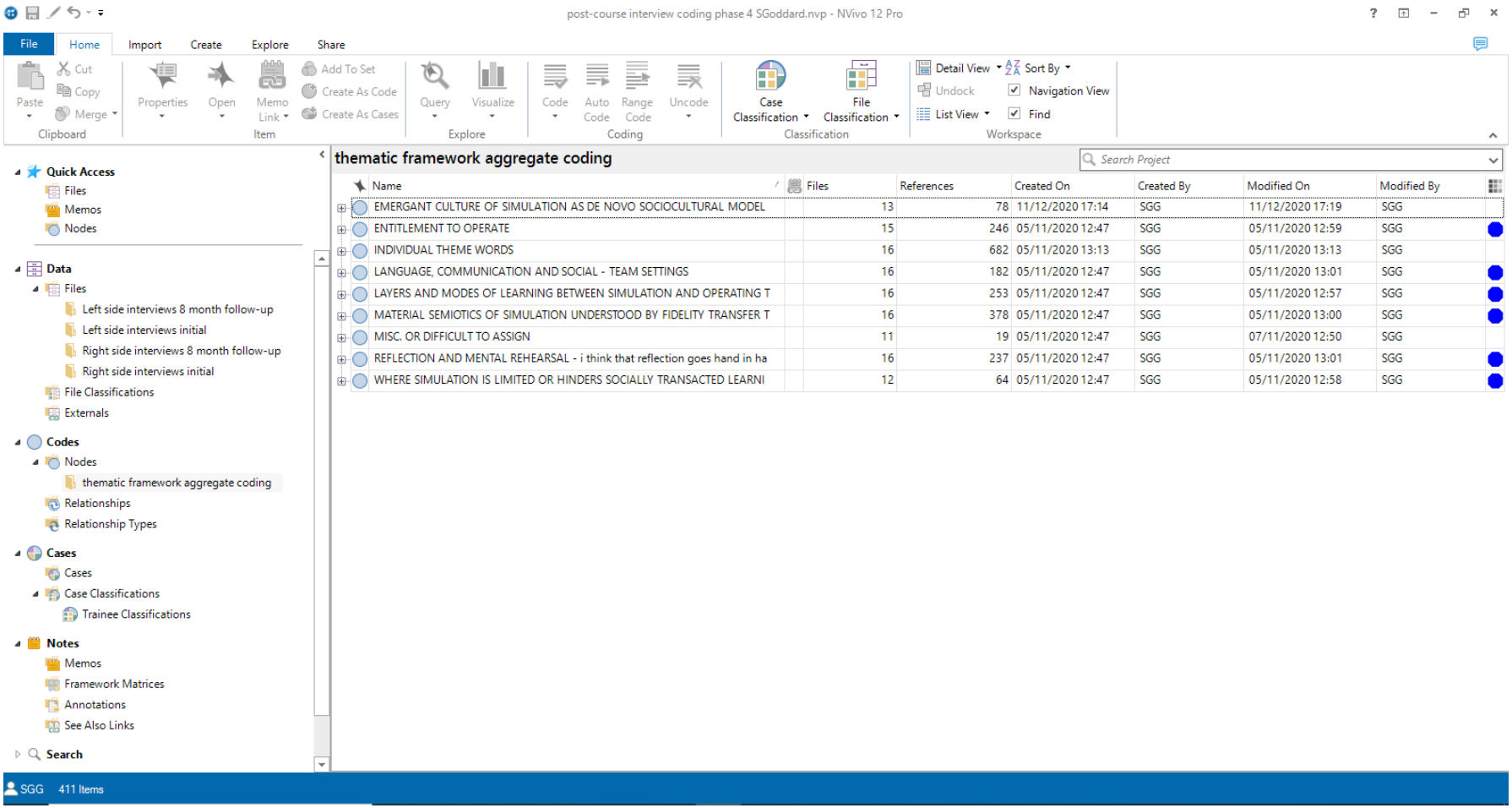


Phase 2 – an iterative process of tag consolidation according to wider topics beginning to emerge.



Name	Files	References	Created On	Created By	Modified On	Modified B
MISC. OR DIFFICULT TO ASSIGN	0	0	22/10/2020 15:40	SGG	16/10/2020 15:32	SGG
REFLECTION AND MENTAL REHEARSAL - i think that reflect	0	0	22/10/2020 15:40	SGG	19/10/2020 11:37	SGG
MENTAL REHEARSAL AND REFLECTION inc. ANTICIPATI	0	0	23/10/2020 18:07	SGG	23/10/2020 18:07	SGG
PERCEIVING ONE'S PLACE IN THE SOCIAL STRUCTURE H	0	0	05/11/2020 10:39	SGG	05/11/2020 10:39	SGG
awareness of multidisciplinary operating context	4	5	22/10/2020 15:40	SGG	16/09/2020 18:02	SGG
high turnover of patients cf. dhg turnover creates dif	1	1	22/10/2020 15:40	SGG	05/11/2020 10:50	SGG
mental rehearsal aligning not just with task but team	1	1	22/10/2020 15:40	SGG	10/08/2020 09:40	SGG
reflecting on flat hierarchy cf traditional hierarchy	1	2	22/10/2020 15:40	SGG	03/07/2020 17:44	SGG
REFLECTION ON EXTERNALS HELPS TRAINEE TO SITUAT	0	0	05/11/2020 10:24	SGG	05/11/2020 10:32	SGG
first experiences surgery	1	1	05/11/2020 09:59	SGG	03/06/2020 19:37	SGG
mental awareness of surrounding in operating theatr	3	6	22/10/2020 15:40	SGG	10/09/2020 13:12	SGG
reflection about own abilities and comparison to oth	8	25	22/10/2020 15:40	SGG	23/10/2020 17:29	SGG
reflection on the clinical choices of inexperience vers	1	1	22/10/2020 15:40	SGG	07/09/2020 21:37	SGG
reflection that there is always something to learn fro	1	1	22/10/2020 15:40	SGG	16/09/2020 18:08	SGG
REHEARSAL IMPROVES SELF PERCEPTION OF COMPETE	0	0	23/10/2020 18:13	SGG	23/10/2020 18:14	SGG
SIMULATION PROVIDES A COGNITIVE SCAFFOLD UPON	0	0	23/10/2020 18:19	SGG	23/10/2020 18:19	SGG
cognitive rehearsal	1	1	22/10/2020 15:40	SGG	23/09/2020 17:04	SGG
confidence	6	12	22/10/2020 15:40	SGG	01/10/2020 17:33	SGG
instruction on simulation helps with mental preparati	2	2	22/10/2020 15:40	SGG	03/10/2020 16:18	SGG
modelling and constructing the steps of the operatio	2	2	22/10/2020 15:40	SGG	03/10/2020 16:18	SGG
moving towards fluency and integration of chunked	2	2	22/10/2020 15:40	SGG	22/10/2020 16:28	SGG
recognising the need for ongoing skills practice	2	3	22/10/2020 15:40	SGG	16/08/2020 09:09	SGG
reflecting on the value of right side simulation in ach	2	2	22/10/2020 15:40	SGG	29/09/2020 15:37	SGG
reflection as a way of improving the mental decision	3	4	22/10/2020 15:40	SGG	22/10/2020 18:04	SGG

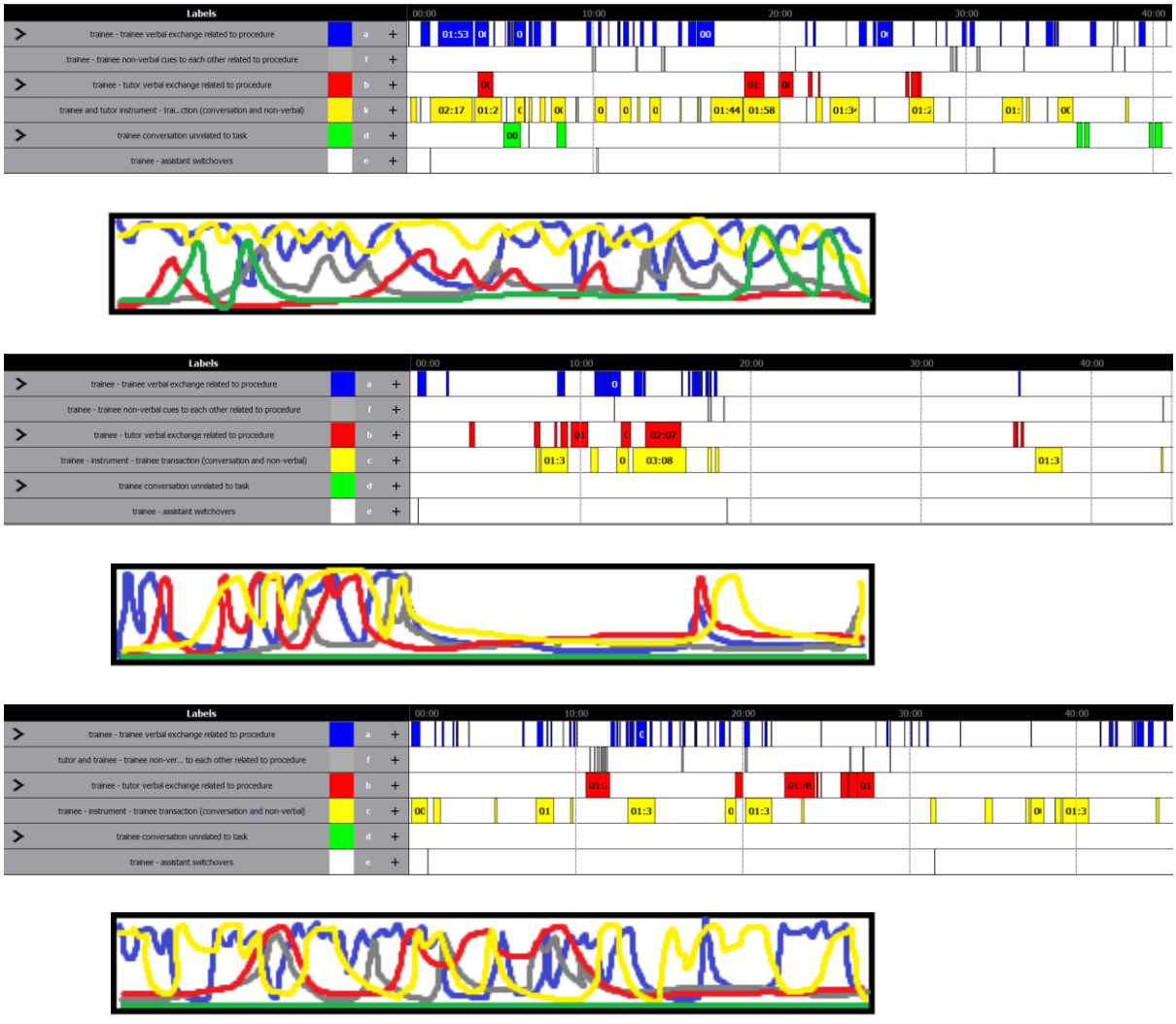
Phase 3 – further consolidation and reorganising of tags according to fit and cross-checking context in transcripts.



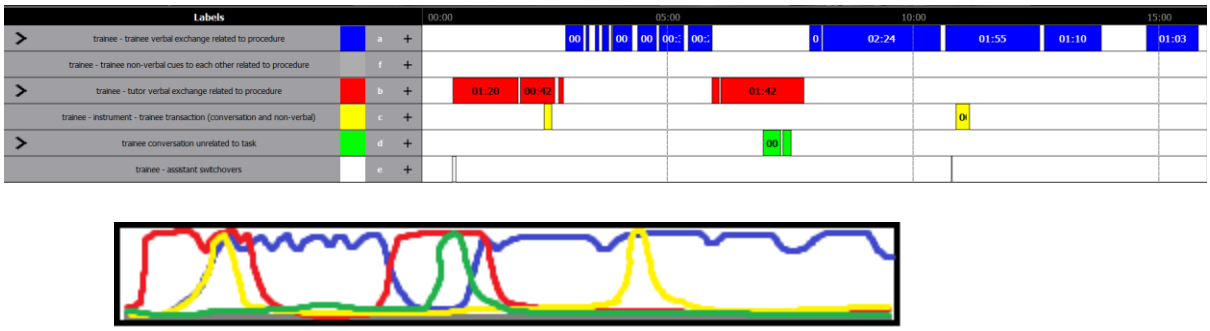
Phase 4 – the process of aggregation of codes to identify major themes and subthemes. Trainee classifications based on data such as gender and professional-grade are also present for analysis based on demographic criteria.

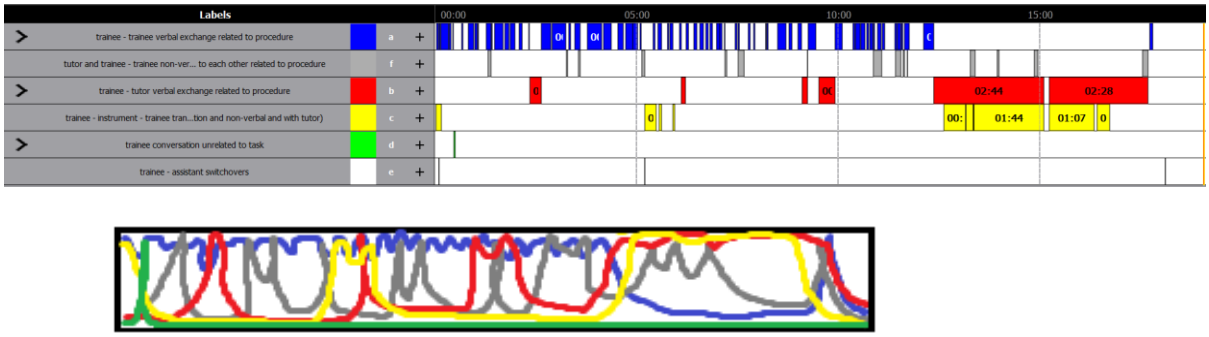
Theme Name Sub Theme	How many times mentioned across all interviews	How many Interviews mentioned it
SEMIOTICS OF SIMULATION	**378**	**16**
- SCAFFOLD CREATION TO BUILD UNDERSTANDING OF OPERATION	161	16
- SIMULATION FIDELITY ALIGNS WITH THE OPERATING STEPS	88	16
- SURGICAL KNOWLEDGE IS EMBEDDED AND EXTENDED IN SURGICAL INSTRUMENTS	70	13
- SURGICAL TRANSFER BETWEEN SIMULATION AND O.R. IS SOCIALLY NEGOTIATED	55	14
LAYERS AND MODES OF LEARNING BETWEEN SIMULATION AND OPERATING THEATRE	254	16
- EVIDENCE OF ACT-R AND CHUNKING CONSOLIDATION OF LEARNING	101	16
- PRECEPTORSHIP IS A BRIDGE BETWEEN SIMULATION AND FULL AGENCY OF OPERATING THEATRE FOR LAP RIGHT & LAP LEFT COLECTOMIES	49	13
- EVIDENCE OF NEGOTIATED KNOTWORKING AND ACTIVITY THEORY	36	15
- EVIDENCE OF SITUATED LEARNING AND CoP	29	10
ENTITLEMENT TO OPERATE	245	15
- INVESTMENT OF TIME AND MONEY INCREASES OPERATING EXPECTANCY	81	14
- CONSULTANTS EXERCISE GRADUATION IN TRAINEES' OPERATING AGENCY	67	13
- ACQUISITION OF AGENCY AND STICKY KNOWLEDGE AS A RESULT OF WLCTS ATTENDANCE	65	12
REFLECTION AND MENTAL REHEARSAL (TIES INTO DECISION-MAKING)	237	16
- SIMULATION PROVIDES A COGNITIVE SCAFFOLD UPON WHICH REFLECTION AND MENTAL REHEARSAL CAN RETURN TO IN PREPARATION FOR THE CLINICAL ACTIVITY	75	15
- REHEARSAL IMPROVES SELF PERCEPTION OF COMPETENCE LEADS TO CONFIDENCE	63	14
- MENTAL REHEARSAL AND REFLECTION IMPROVES ANTICIPATION INFORMS AND IMPACTS DECISION-MAKING	56	14
- REFLECTION ON EXTERNALS HELPS TRAINEE SITUATE THEIR OWN PROFESSIONAL DEVELOPMENT	34	10
- PERCEIVING ONE'S PLACE IN THE SOCIAL STRUCTURE HELPS TRAINEE NEGOTIATE THE MULTIDISCIPLINARY WORK CONTEXT	9	6
LANGUAGE, COMMUNICATION AND SOCIAL SETTINGS	182	16
- MEANING MADE BY TRAINEE RECOGNITION OF OWN ABILITIES THROUGH THEIR OPERATING INTERACTIONS	86	16
- TRANSFER OF SOCIAL EXCHANGES FROM SIMULATION TO OPERATING THEATRE	75	14
- REFLECTION INDICATING WHERE SIMULATION MAY ACT AS A BUFFER FOR OPERATING THEATRE BARRIERS	21	11
WHERE SIMULATION IS LIMITED OR HINDERS SOCIALLY TRANSACTED LEARNING, AND OTHER BARRIERS TO LEARNING TRANSACTIONS	64	12
- SIMULATION DOESN'T OFTEN AFFECT REALITY	34	11
- SIMULATION ONLY TRAINS TO ANTICIPATE WITHIN FRAMEWORK OF SIMULATION	18	6

Appendix 8 – Diagrams of negotiated knotworking activity mapped for trainees in pairs according to tasks

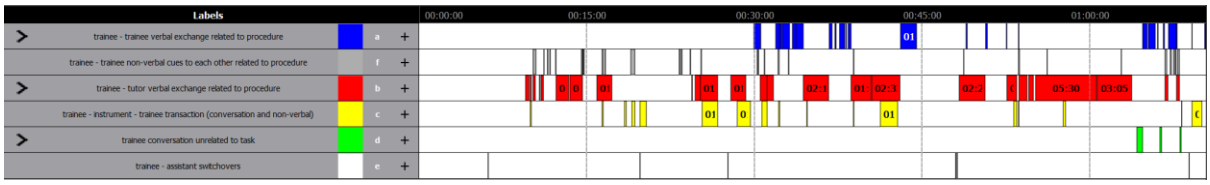


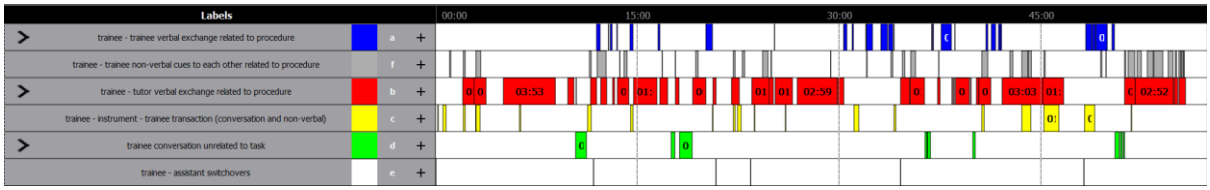
Exercise 2 "threads" or social cues which could exchange learning

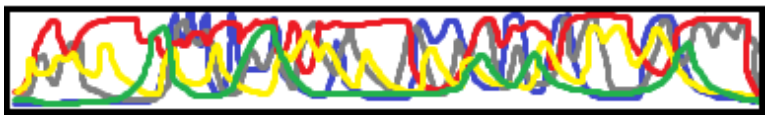


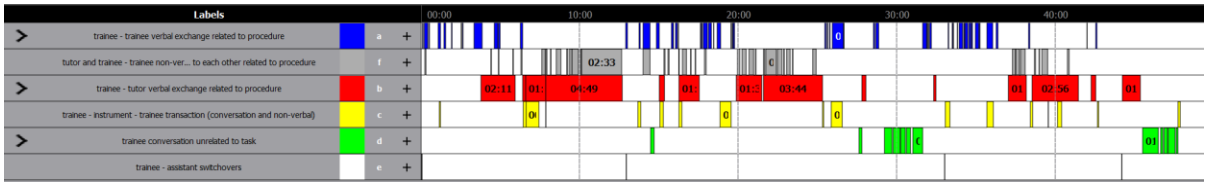


Exercise 4 "threads" or social cues which could exchange learning

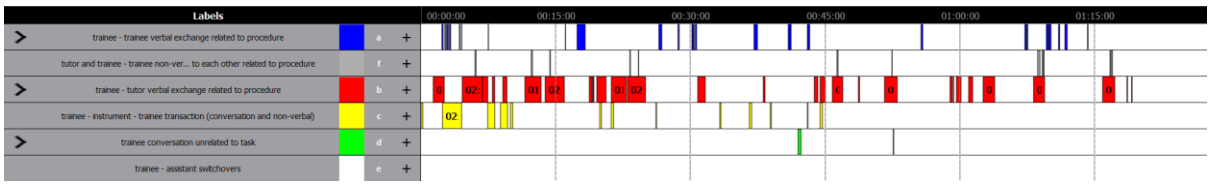


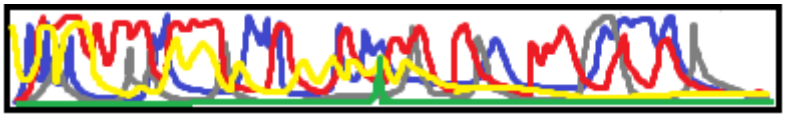




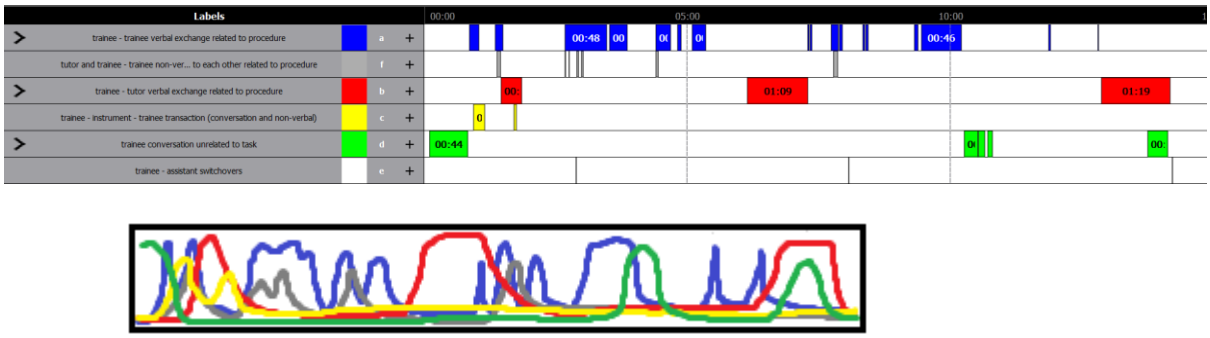


Exercise 5 "threads" or social cues which could exchange learning

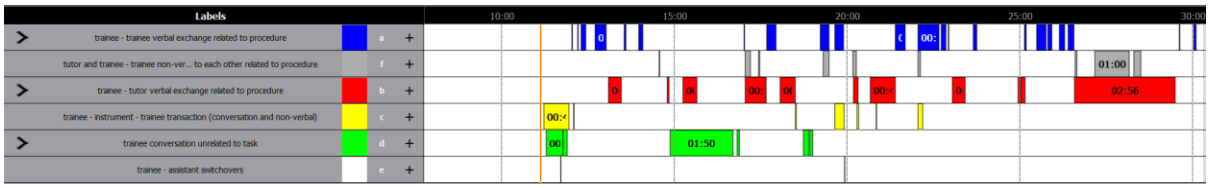


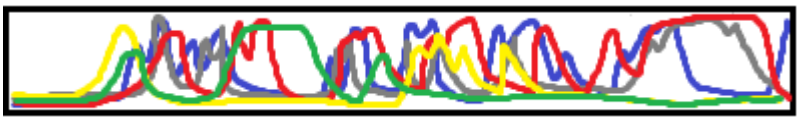


Exercise 6 “thread” or social cues which could exchange learning



Exercise 7 “threads” or social cues which could exchange learning





Exercise 9 “threads” or social cues which could exchange learning

Figure 27. Exercise 2 through to 9, showing recorded social cues between pairs for observed exercises, and their concomitant interacting 'threads' of activity.