The role of deliberate practice informed simulation training in developing expert performance in Surgery and barriers to its implementation: A Mixed Methods Study

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Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other University.

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration, except where specifically indicated in the text.

Dakshitha Praneeth Wickramasinghe

1.1 Abstract

Background

The training of surgeons is undergoing a paradigm shift. Traditional apprenticeship models, rooted in time-based exposure and opportunistic learning, are increasingly viewed as insufficient for ensuring competence and expertise in a field where errors can have life-altering consequences. Deliberate Practice (DP), a pedagogical framework grounded in educational psychology, offers a compelling alternative by emphasising structured, feedback-driven, and goal-oriented practice. The application of DP principles in surgical education, however, particularly within simulation-based training, remains limited and poorly understood.

Aim

This study explores the role of DP in developing Expert Performance in surgery and investigates the barriers to its implementation in surgical training programs.

Methods

The first phase involved a systematic review of the literature assessing the extent to which Simulation-Based Surgical Training (SBST) interventions adhered to key DP principles—namely, learner motivation, structured task design, timely feedback, and repetition—and evaluating their outcomes. A scoring rubric was developed to assess DP adherence across studies.

The mixed-methods phase included self-administered questionnaires and semi-structured interviews with surgical trainees and trainers to explore their perceptions of DP and identify practical, cultural, and systemic barriers to its implementation. Data were analysed using thematic analysis and integrated with quantitative findings to understand the current landscape comprehensively.

Results

The systematic reviews identified multiple papers on open and laparoscopic surgery, most of which reported positive outcomes associated with simulation-based interventions. Only a minority of studies, however, fully incorporated all core elements of DP. Interventions with higher DP adherence scores demonstrated more consistent improvements in skill acquisition, retention, and transferability. Most studies assessed outcomes at Kirkpatrick levels 1 and 2, with limited evidence of behavioural or patient-level impact.

The qualitative phase involved self-administered questionnaires and 20 semi-structured interviews with surgical trainees and trainers. Thematic analysis revealed four major themes: (1) Value of Structured Practice, (2) Feedback and Faculty Engagement, (3) Institutional Constraints, and (4) Educational Culture. Trainees reported that while simulation was widely appreciated, access to structured, deliberate practice opportunities was inconsistent and often self-directed. Trainers expressed willingness to engage in DP-aligned instruction but cited lack of time, inadequate institutional recognition, and limited pedagogical training as key barriers.

Both groups identified a misalignment between educational aspirations and clinical service demands. The lack of protected time for practice, the absence of standardised curricula incorporating DP principles, and insufficient assessment tools to measure progression were cited as systemic barriers to meaningful implementation. Despite these challenges, there was strong consensus on the transformative potential of DP when applied effectively within simulation-based surgical training environments.

Qualitative findings also revealed widespread awareness of the benefits of structured, repetitive practice and expert feedback among both trainees and trainers. Barriers to DP implementation included a lack of protected time, limited faculty availability, underdeveloped curricula, and institutional emphasis on service delivery over education. Participants also highlighted the absence of clear performance benchmarks and insufficient training in feedback provision as additional obstacles.

Conclusion

DP offers a powerful model for optimising surgical education. While evidence supports its effectiveness in simulation-based contexts, current implementation is limited by structural and pedagogical barriers. This study highlights the need for a deliberate and theory-informed redesign of surgical training that prioritises competence, safety, and the pursuit of expert performance.

1.2 Table of Contents

1.3 List of abbreviations

CBME	Competency-Based Medical Education
DP	Deliberate Practice
EP	Expert Performance
EPAs	Entrustable Professional Activities
GOALS	Global Operative Assessment of Laparoscopic Skills
LC	Learning Curve
MGO	Mastery Goal Orientation
MIS	Minimally Invasive Surgery
NSQIP	National Surgical Quality Improvement Program
OSATS	Objective Structured Assessment of Technical Skills
PEARLS	Promoting Excellence and Reflective Learning in Simulation
SBST	Simulation-Based Surgical Training
VR	Virtual Reality

1.4 List of figures

1.5 List of tables

To my family, who have

Guided me through every uncertain step,

Lifted me when I doubted myself,

Stood silently strong in the background,

And reminded me, always, of where I began.

To my teachers and mentors, whose

Belief in me planted the seeds of perseverance,

Insight inspired ambition,

Wisdom shaped my journey,

Example I will always carry forward.

To those whose quiet presence shaped more than they know,

Driven me with love and quiet strength,

Offered endless patience and forgiveness,

Lifted me in moments of doubt, and

Led me back whenever I lost my way.

1.6 Acknowledgments

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Finally, I wish to thank my family and friends, for their patience, sacrifices, and unconditional support during this time. Their encouragement sustained me through the most difficult phases of the thesis

1.7 Publications derived from work on Doctoral Programme

1) Wickramasinghe, D., & Vincent, J. (2025). The use of deliberate practice in simulation-based surgical training for laparoscopic surgery–a systematic review. BMC Medical Education, 25(1), 1047. 10.1186/s12909-025-07613-w

2) The use of deliberate practice in Simulation-Based Surgical Training for Open surgery – A systematic review. Dakshitha Wickramasinghe, Jonathan Vincent - Submitted to Simulation in Healthcare

3) An evidence-based guide to designing effective simulation based surgical training – A Deliberate Practice based approach. Dakshitha Wickramasinghe, Jonathan Vincent – Currently being drafted.

4) A Deliberate Practice focussed view of simulation based surgical training: Findings from a mixed-methods study in a LMIC. Dakshitha Wickramasinghe, Jonathan Vincent – Submitted to Clinical Teacher

2 Introduction

"The performance of surgical operations is one of the most complex psychomotor activity human beings are called upon to perform", stated Dr Richard Bell (2009) (Page 1) in his presidential address. Surgery has followed the Halstedian apprenticeship style of training for decades, which includes progressively increasing autonomy in practice. Training aims to produce surgeons who can perform surgery well to create the best possible patient outcomes. A principal component of this training includes "technical skills", the ability to use surgical instruments effectively and efficiently to achieve surgical goals. The traditional, time-based training, also called a "tea-steeping" approach (Hodges, 2010), relies on immersion of the learner in a clinical environment, expecting the learner to absorb the content till they are saturated.

2.1 Surgical training

Many factors have adversely affected surgical education, including duty hour regulations (Klingensmith & Lewis, 2013; Scally et al., 2015), technology advances and Minimally Invasive Surgery (MIS) (Klingensmith & Lewis, 2013), exponentially increasing surgical knowledge (Fernández-Cruz, 2004), reduced opportunities due to ambulatory surgery (Klingensmith & Lewis, 2013; McKenna & Mattar, 2014), increased documentation requirement (McKenna & Mattar, 2014), and decreased operative autonomy for trainees (Sandhu et al., 2017; Sealy, 1999). Not surprisingly, NSQIP data suggest less time is being dedicated to teaching (Bohnen et al., 2015). The cumulative effect of these is twofold: limited opportunity for hands-on training and reduction in time spent operating. In more than half of the procedures considered essential by programme directors, the mode number of reported experience was zero (Bell, 2009). This indicates that most trainees fail to get sufficient exposure to even core procedures during their training. Dr Bell's estimates also indicate that a trainee spends approximately 1150 hours over five years operating, only 6% of the total hours worked. Chung et al. (2005) estimate that the operative experience is 2750 hours (14% of total time). Both highlight the inadequacy of surgical volume and the flaw of using time as an indicator of proficiency. An added confounder is the heterogeneity of the competence of surgeons (Stahl & Minter, 2020). These factors make a tea-steeping approach unsatisfactory, calling for more pedagogically sound techniques.

A review of adverse incidents involving surgical patients in the USA revealed that two-thirds involved an error in the intraoperative period (Gawande et al., 2003). Among operating theatre errors, 63.5% included errors in technique, and 29% contained errors in judgement (Fabri & Zayas-

Castro, 2008). These findings likely indicate a lack of experience (Bell, 2009). Several other studies have confirmed that residents often do not achieve the expected level of autonomy for independent practice at the time of graduation (Bohnen et al., 2020; George et al., 2017; Mattar et al., 2013). Of the eighty per cent of trainees who pursue fellowship upon completion of training (Klingensmith et al., 2015), 21% do so as they feel unprepared for independent practice (Napolitano et al., 2014).

Training programs, therefore, need to focus on two main changes: the "quality" of the product of the surgical training programme must be improved, and the heterogeneity must be reduced (Stahl & Minter, 2020). The solutions include changing learning strategies and implementing a competence-based approach in surgical training. Competency is defined as the observable ability to integrate knowledge, skills, values, and attitudes in completing the desired task (Touchie & ten Cate, 2016). A competency-based curriculum is outcome-based, focuses on students' abilities to perform job-related tasks, encourages learner-centeredness, and deemphasises time-based training (Frank et al., 2017).

2.2 Need for simulation

Many trainers believe that skills learnt from one surgery are transferable to another, and therefore, expertise in specific surgeries is not mandatory in credentialing (Bell, 2009). There is, however, no evidence to support skill transferability (Norman et al., 2018). Educational psychologists affirm that the "ability to perform one task derives from specific practice with that task and does not generalise to other, even apparently similar, surgical tasks'' (Schmidt et al., 1990). Trainees must therefore have the opportunity to practice each surgical procedure. With clinical and financial limitations, simulation is the best option.

The traditional Halstedian model (Sealy, 1999), premised on time-based apprenticeship and progressive autonomy, has proven increasingly inadequate in an era of rapid technological advancement, constrained clinical opportunities, and rising patient safety and competence expectations. Within this context, Simulation-Based Surgical Training (SBST) shows promise to enhance exposure.

To enhance the educational experience, it's essential to go beyond just incorporating a simulator. Creating a comprehensive learning environment that includes supervision and constructive feedback will significantly improve the effectiveness of the learning process (Stefanidis, 2010). Exploring effective ways to integrate simulation into medical education offers an exciting opportunity for educators and clinicians. Traditionally, the emphasis has been placed on acquiring advanced simulation equipment, like virtual reality simulators. There is, however, a tremendous opportunity to integrate these tools into training programs more effectively. By focusing on structured, ongoing training rather than relying on one-time sessions, the utility of these resources can be maximised and learning outcomes significantly improved. Adopting a strategic approach to simulation can cultivate an engaging and enriching educational experience for medical professionals, ultimately enhancing their skills and competencies (Bjerrum et al., 2018).

2.3 Need for Deliberate Practice

Deliberate Practice (DP) (Ericsson et al., 1993) has emerged as a promising pedagogical framework, offering a structured, feedback-driven, and goal-oriented approach to skill acquisition. DP is grounded in educational psychology and offers a compelling alternative to conventional surgical training, but its integration into SBST remains limited and underexplored. This study aimed to investigate the role of DP in developing Expert Performance (EP) in surgery and to identify the systemic, institutional, and cultural barriers that hinder its implementation.

There is a paucity of studies focusing on the application of DP in the acquisition of technical skills for surgeons (Ericsson, 2004; Ericsson, 2007). The rationale for examining DP lies in its strong theoretical underpinnings and empirical success in other domains such as music, chess, and athletics. DP posits that expert performance arises not from innate talent but from sustained, effortful, and structured practice aimed at improving specific aspects of performance. The core elements of DP include learner motivation, carefully designed tasks, immediate and informative feedback, and repeated practice under conditions of effort constraint. These principles are particularly well-suited to modern surgery's technical and cognitive demands, which require not only procedural knowledge but also psychomotor precision, judgment under pressure, and the ability to adapt to rapidly changing circumstances.

2.4 Gaps in knowledge

Several critical gaps in the existing literature and surgical training practices justify this research. First, while simulation has gained widespread acceptance as a training adjunct, its use is often technology-driven rather than pedagogy-driven. Many simulation programs emphasise access to high-fidelity tools without integrating educational principles optimising learning (Cristancho et al., 2011; Vangone et al., 2024). Studies frequently neglect core DP elements, leading to training that may be engaging but is not necessarily effective. The literature suggests that when DP principles are explicitly embedded in SBST, outcomes such as skill acquisition, retention, and transferability improve significantly. Yet, systematic analyses of DP adherence in surgical training interventions are scarce, and existing evidence remains fragmented and inconsistent.

Second, while the benefits of simulation are well-documented, evidence on how best to structure simulation to achieve expert performance is lacking. Most interventions focus on short-term outcomes, such as task completion times or error rates, without addressing long-term competence or patient-level outcomes. This limitation is particularly problematic in surgery, where the stakes are high, and the consequences of sub-optimal performance can be lethal. Furthermore, there is limited empirical evidence on how different elements of DP contribute independently or synergistically to learning outcomes. Understanding these dynamics is essential for developing evidence-based simulation curricula that consistently produce expert-level performers.

Third, current surgical training systems are hindered by structural constraints that conflict with the demands of DP. The reduction in operative exposure due to duty hour restrictions, increasing reliance on Minimally Invasive Surgery (MIS), and service delivery pressures have collectively diminished hands-on learning opportunities. Furthermore, the lack of protected time, insufficient faculty training in educational principles, and underdeveloped assessment tools create an environment where structured, purposeful practice is difficult to implement. Both trainees and trainers often operate within systems prioritising throughput and efficiency over education, leading to a misalignment between training objectives and clinical realities.

Fourth, there is an under-recognition of heterogeneity in learner performance and progression. Current training models often treat time and case volume as proxies for competence, despite evidence that trainees reach proficiency at variable rates. DP emphasises individualised learning trajectories and performance-based progression, which aligns closely with competency-based medical education (CBME) goals. Integrating DP into the CBME framework, however, remains conceptually and operationally challenging. Most CBME curricula provide outcome expectations but lack the granular instructional design that DP requires.

The present study is also driven by the paucity of qualitative insights into the lived experiences of trainees and trainers regarding DP. Much of the existing research focuses on quantitative metrics and intervention outcomes, with limited exploration of perceptions, attitudes, and cultural norms that shape training experiences. Understanding these contextual factors is critical for translating DP from theory to practice. For instance, *how do trainers perceive their role in providing* *structured feedback*? *What motivates trainees to engage in effortful, repetitive practice despite limited extrinsic rewards*? *How do institutional cultures support or hinder DP-oriented training*? These are questions that require qualitative inquiry and thematic exploration.

Moreover, the literature is notably silent on how to sustain EP over time. Skill decay due to non-use is a recognised phenomenon in surgery, particularly for rarely performed procedures. DP offers a pathway to mitigate this decay through structured refresher training and performance monitoring. Evidence on maintenance strategies and the role of DP in lifelong learning for surgeons, however, is minimal. This research seeks to address this gap and contribute to designing more sustainable training paradigms by examining barriers to implementation and perceptions of DP among trainees and trainers.

2.5 Aims

2.5.1 Primary objective

To assess the role of deliberate practice (DP) and barriers to its use in optimising surgical training through simulation

2.5.2 Secondary objectives

- To identify the existing evidence for each step of DP in surgical simulation in the published literature
- To compare the relative benefits of structured practice, purposeful practice, and DP in surgical simulation
- To explore the current use of simulation in surgical training and its adherence to principles of DP by surgeons and trainees
- To identify the differences in adherence to DP between expert surgeons and trainees
- To examine the barriers to the use of DP-based SBST

2.6 Research questions

RQ – What is the role of DP in optimising surgical training through simulation?

RQ1 – What current evidence supports the use of DP in SBST?

RQ1.1 – What is the evidence for each step of DP in surgical simulation?

RQ1.2 – What are the differences between, and the difference in benefits of, structured practice, purposeful practice, and DP in surgical simulation?

RQ2 – How is DP currently used in SBST?

RQ2.1 – How is Deliberate Practice currently integrated into simulation-based surgical training, and how does the current training adhere to principles of DP?

RQ2.2 – What are the similarities and differences between expert surgeons and trainees in using DP?

RQ3 – What limits the integration of DP into SBST?

RQ3.1 – What are the perceived barriers to using DP-based simulation in surgical training?

RQ3.2 – What are the potential solutions to overcome these barriers?

Given the increasing complexity of surgical practice and the imperative for safe, effective, and equitable training models, these questions are timely and relevant. As surgical procedures become more technologically complex and patients become more comorbid, the margin for error narrows. Training models must therefore evolve to ensure that every surgeon achieves not only competence, but EP. DP offers a promising framework for this evolution, but its implementation requires deliberate effort, institutional commitment, and a shift in educational culture.

This thesis includes two systematic reviews of DP in SBST, with a mixed-methods approach involving surgical trainees and trainers. The goal was to comprehensively understand current practices, identify actionable barriers, and propose contextually relevant strategies for improving surgical education. In doing so, it aims to bridge the gap between educational theory and clinical practice, offering academically rigorous and practically meaningful insights.

This thesis aims to contribute to the field of surgical education by applying the theoretical construct of DP to the context of SBST—a domain in which its systematic use has not been fully explored or operationalised. By integrating both qualitative and quantitative methodologies, the study offers novel insights into how surgical expertise is developed and sustained through SBST, and identifies key organisational, cultural, and individual barriers that limit its implementation, and contributes to the broader discourse on surgical education reform. The findings inform the design of educational interventions that go beyond simulation-based learning to promote real-world skill acquisition through feedback-rich, targeted experiences in clinical environments. It advocates for a shift from time-based, opportunistic training to an intentional, structured, and learner-centred model. This work extends the applicability of Ericsson's expertise theory to the surgical domain and proposes a framework for embedding DP within the surgical curriculum. In doing so, it aligns surgical training with the ultimate goal of producing safe, competent, and expert surgeons prepared to meet modern healthcare's evolving demands.

3 Literature review

3.1 Introduction

"The conditions necessary for a surgeon are 4: first, he [sic] should be learned. Second, he should be an expert. Third, he must be ingenious. Fourth, he should be able to adapt himself"

- Guy de Chauliac. *The Art of Surgery* 1363

Deliberate Practice (DP), feedback, and the opportunity to obtain sequential experience remain vital cogs to effective learning (Ericsson, 2004). Embracing DP, seeking constructive feedback, and gaining sequential experience are essential components that can significantly contribute to growth and improvement.

The literature review attempts to position this study within the current literature on DP and SBST by highlighting the gaps in knowledge, the importance of this research, and clarifying the potential contributions. It discusses seminal papers and focuses on the current nature of laparoscopic surgical training and its limitations, the need for EP, the unrealised potential of SBST, the role of DP in improving the benefits of SBST, and the present barriers to this implementation.

The following sections will provide a synopsis, with DP being discussed in detail under the theoretical framework. The Venn diagram (Figure 3-1 Venn diagram of scholarly areas used in this study) illustrates the interaction between the three scholarly areas.

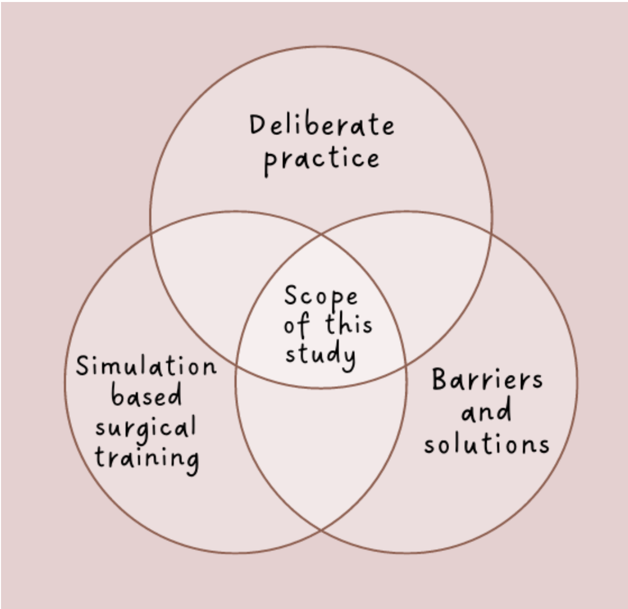


Figure 3-1 Venn diagram of scholarly areas used in this study

3.2 Motor learning theories

Motor learning is defined as the array of cerebral processes involved in the acquisition of a skill, associated with practice and experience that will produce relatively permanent changes in how motor activity is elicited (Salehi et al., 2021). Various theories have been developed to structure, characterise, and explain the acquisition of motor skills. Some theories are broad and applicable to many learning situations, while others are tailored to specific skills or tasks, such as laparoscopic skill training. A deep understanding of these stages is crucial for providing effective instruction to learners. For instance, some individuals may need to enhance their cognitive understanding of the skill, while others might thrive with encouragement to explore different movement options (Coker, 2017; Edwards, 2010). Academic achievement has been found unrelated or negatively correlated to surgical skill (Schueneman et al., 1985).

The following sections will delve into these theories in more detail. It is important to note that the stages discussed are not strictly discrete or categorical, and their progression is not necessarily linear or unidirectional. This view allows for a more fluid and adaptable learning process, catering to the diverse needs of learners. These models are relevant because they mirror how trainees move from learning basic surgical steps to performing procedures with expert-level fluency.

3.2.1 Fitts and Posner's three-stage model of skill learning

Paul Fitts and Michael Posner introduced their theory of motor learning, which was founded on their observations that different points in the learning process involve different cognitive, perceptual, and motor processes (Fitts & Posner, 1967). Focussing on the cognitive state of the learner, it describes three phases every learner passes through (Table 3-1).

In the cognitive stage, a basic movement pattern is developed. The primary focus is on cognitively oriented problems of the tasks, including what the elements are and how to perform them, and then formulating a conscious mental plan (Magill & Anderson, 2010 (c.f. Mental representation in Deliberate Practice)). The movements are crude, inaccurate, and uncoordinated. The prefrontal cortex is highly activated.

The associative stage is when the individual develops the knowledge of what to do and refines their movement patterns. The learner associates environmental cues with the required movements. This is a phase of refinement, with errors becoming fewer and smaller, and performance being more consistent between attempts (Magill & Anderson, 2010).

The learner is in the autonomous stage when the performance requires minimal cognitive activity or conscious attention. The performance is at the highest level of proficiency and is automated. The learner, therefore, can perform multiple simultaneous tasks. Learners make fewer errors and can detect and correct their errors (Cano-De-La-Cuerda et al., 2015). Fitts and Posner highlighted the possibility that not every learner may reach this skill level.

3.2.2 Gentile's two-stage model of learning

Following an information processing model, this model focuses on the learners' goals for each stage (Gentile, 1972) (Table 3-1).

In the getting the idea stage, the learner develops a good pattern to achieve the required goals of movement. This stage is characterised by creating a basic motor pattern and acquiring little knowledge of how to perform it (Salehi et al., 2021). The learner also recognises both the environmental conditions that dictate the movement characteristics required for the task and other factors not inherently related to the motor response (Magill & Anderson, 2010), and develops selective attention to differentiate them (Salehi et al., 2021).

In the fixation/diversification stage, the learner develops the ability to adapt to changing circumstances and increases the consistency of performance. There is also an improvement in the economy of effort. In closed skills, the emphasis is on refinement of the movement plan, while in open skills it is on adaptation of the movement to conform to changing environmental demands (Salehi et al., 2021).

3.2.3 Gallahue's model for the combination of levels and stages of motor skill learning

Introduced initially in 1972 (Gallahue et al., 1972), and with subsequent modifications (Gallahue, 1982; Gallahue & Donnelly, 2007), this model distinguishes both the cognitive state and the learner's goals in each learning stage. It also suggests appropriate actions for skill development in each stage (Table 3-1).

In the beginner/novice level, the learner tries to develop a conscious mental plan for the skill. The performance is variable, inconsistent, and error-prone (Salehi et al., 2021). This level is accompanied by three sequential stages: awareness, exploration, and discovery. Gallahue states that the trainer must demonstrate the skill to promote cognitive awareness, provide opportunity for practice and self-discovery of the elements, and provide immediate and precise feedback (Gallahue & Donnelly, 2007). These recommendations align closely with the DP framework (vide infra). The cerebellum, motor cortex, basal ganglia, and occipital cortex are highly activated during this learning phase.

At the intermediate/practice level, the learner possesses an understanding of the task and can perform the motor task nearly to the final goal level. The mental plan has improved, and there is less conscious attention. The kinematics sensitivity is more attuned (Salehi et al., 2021). The learner attempts to combine more skills progressively, with decreasing conscious attention, and refines the skill further. The trainer must promote skill refinement through providing opportunities to practice and maximising feedback. The caudal striatum, hippocampus, and motor and parietal cortex are more involved in this stage (Savion-Lemieux & Penhune, 2010).

The advanced/fine-tuning level is characterised by a complete understanding of a skill and a highly developed mental plan. The learner can filter irrelevant information. The performance is nearly automatic, and the learner reaches a stage of precision. The cerebellum, basal ganglia, and parietal cortex show most activity during this phase of motor learning (McMorris, 2014).

<table>
<tr><th>Fitts and Posner</th><th>Gentile</th><th colspan="2">Gallahue</th><th>McClusky</th></tr>
<tr><td rowspan="3">Cognitive stage</td><td rowspan="5">Getting the idea stage</td><td rowspan="3">Beginner/Novice level</td><td>Awareness stage</td><td>Module 1 – Knowledge acquisition</td></tr>
<tr><td>Exploratory stage</td><td rowspan="2">Module 2 – Psychomotor assessment and initial acquisition</td></tr>
<tr><td>Discovery stage</td></tr>
<tr><td rowspan="2">Associative stage</td><td rowspan="2">Intermediate/Practice level</td><td>Combination stage</td><td rowspan="2">Module 3 – Integration of knowledge and psychomotor skills</td></tr>
<tr><td>Application stage</td></tr>
<tr><td rowspan="2">Autonomous stage</td><td rowspan="2">Fixation / Diversification stage</td><td rowspan="2">Advanced/Fine-tuning level</td><td>Performance stage</td><td>Module 4 – Supervised real-world application</td></tr>
<tr><td>Individualised stage</td><td>Module 5 - Mastery</td></tr>
</table>

Table 3-1 Comparison of motor learning theories

3.2.4 McClusky surgical skills simulation curriculum

McClusky (2008) proposes a sequential, progressive, modular curriculum which begins by imparting the necessary knowledge (Module 1). The next phase focuses on technical skills (Modules 2 and 3), while the final phase develops judgement (Modules 4 and 5) (Table 3-1). These phases and modules are conceptually similar to the abovementioned models (Table 3-1).

This model proposes proficiency-based or criterion-based milestones as endpoints to demonstrate progression from one stage to another. These could include measures of attention, analysis of motion during the task, and errors (Carswell et al., 2005; Satava, 2005). These criteria could range from a single procedure-based task (e.g. tying a knot) to an entire fellowship curriculum (Fried et al., 2004).

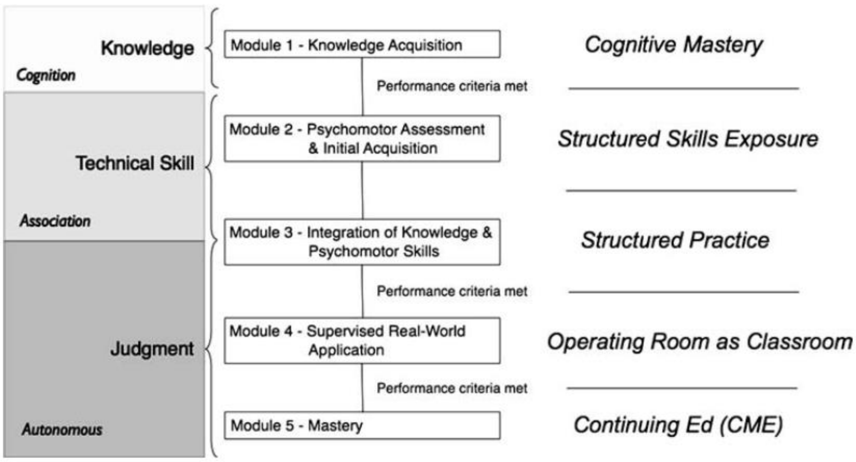


Figure 3-2 From (McClusky and Smith 2008)

3.2.5 Aggrawal's Framework for Systematic Training and Assessment of Technical Skills

Rajesh Aggarwal and team (2007) proposed a framework for training and assessment of skills for surgeons. This is conceptually similar to the proficiency-based milestones advocated by McClusky (3.2.4), but more prescriptive for developing an SBST.

The first step in training a skill is task deconstruction. Each procedure is ideally fragmented into 6-10 tasks, each with unambiguous start and end points. One or two of these tasks are often the most challenging to master. Acquisition of technical skills to an expert level in them would enable expert-level performance (Rajesh Aggarwal et al., 2007). The authors also emphasise the importance of construct validity of the assessment tools, to ensure the measured trait is the one intended and required to measure. As a surgical skill training programme, they highlight the utility of skill transfer and accurate measurement of this.

3.2.6 Critique

The motor learning theories described above offers valuable guidance for designing effective SBST curricula in laparoscopic surgical training. Fitts and Posner's model highlight the importance of structured progression from cognitive understanding to autonomous skill execution, mirroring the DP's hypothesis of continually improving performance through guided feedback. Gentile's emphasis on goal-oriented adaptation reinforces the need for simulation environments that evolve with task complexity, allowing trainees to refine and generalise their skills. This also aligns with the mental representation described in DP. Gallahue's stages advocate for targeted trainer involvement—demonstration, guided exploration, and precise feedback—all central to DP. McClusky's modular surgical curriculum operationalises these stages into concrete educational modules with criterion-based milestones, facilitating objective assessment and progression tracking. Similarly, Aggarwal's task deconstruction framework enables focused repetition on high-yield subcomponents of surgical procedures, fostering the sustained, effortful practice required for expert performance. Collectively, these models inform a pedagogically sound approach to simulation design—one that scaffolds learning, encourages reflective refinement, and aligns with the structured, goal-driven ethos of deliberate practice.

A hallmark of all models of skill development is the development of the mental plan for the activity to be learnt. Furthermore, all models place this early in the chronology of development. This is akin to the "mental representation" described by Anders Ericsson in DP (3.6.3.5).

Most training programs permit the learner to reach an automated phase. This, however, only leads to the development of competence, but rarely to expertise (Rajesh Aggarwal et al., 2007). It is comparable to "arrested development" in DP. Anders Ericsson emphasises the development of EP in all learners when using DP.

3.3 Surgical training

3.3.1 Styles of adult learning

A basic understanding of adult learning styles is essential to provide an education targeted at the individual learner (Drew et al., 1999; Newble & Entwistle, 1986).

- Behaviourist – relies on the stimulus-response principle, focusing on the observable behaviour change rather than the underlying cognitive processes.
- Cognitive – emphasises the cognitive processes, and places the locus of control of learning with the student

- Humanist – founded on the self-determination of humans, and their innate urge to develop their potential
- Constructivism – believes that learning is the active process of creating knowledge by transforming experience. Kolb described a four-stage cycle of translating experience, through reflection, into concepts (Kolb, 2014)

3.3.2 Developing and teaching new surgical techniques

When a new surgical technique is being developed, there are three distinct phases of surgical learning: initiation, standardisation, and proficiency (Gumbs et al., 2021). The number of procedures required to migrate from one stage to the next depends on the level of experience in other surgeries, and the stage of evolution of the speciality (Gumbs et al., 2021). "Pioneers" develop the technique (initiation) and teach other practising surgeons. "Early adopters" are surgeons who learn from the pioneers and deliver patient care (Standardisation). Once a procedure is standardised, fellowships are created for trainees to follow (Proficiency).

3.3.3 Current state of surgical training

William Halstead introduced his apprenticeship-based residency training, which emphasised gradual patient responsibility, at Johns Hopkins University in 1889 (Choy & Okrainec, 2010). There is a growing body of literature highlighting the shortcomings of the present training system and demanding changes in the pedagogy of training (Grantcharov & Reznick, 2009; Reznick & MacRae, 2006). This is despite an increase in total operative volume and MIS volume (Malangoni et al., 2013). A surgical trainee spends only 20% of their training time operating (Jackson & Tarpley, 2009). Training on patients is inefficient and expensive (Meier, 2010). Training in the operating costs an additional 50,000 USD per trainee (Bridges & Diamond, 1999). Although no recent estimates are available, a 2016 paper indicated that surgeries take longer when trainees are present and estimated an annual cost to nearly USD 500,000 per hospital (Allen et al., 2016). Preventable medical errors cause 44,000-98,000 deaths in the USA every year (Donaldson et al., 2000) and 3% of the deaths worldwide (Rodwin et al., 2020). SBST must therefore supplement training.

There has been a steady increase in MIS training volume, with basic, complex, and total procedure volume increasing by 49%, 37%, and 82%, respectively. This is due primarily to an increase in the procedures that are already commonly performed (e.g. cholecystectomy). Procedures less commonly performed did not see an increase over time (e.g. splenectomy) (Malangoni et al., 2013). Despite this, many graduating from residency are not ready for independent practice in many MIS (George et al., 2017) and rely on fellowships for additional training (Shockcor et al., 2021). As this training pattern reflects disease burden and disease distribution between teaching and non-teaching hospitals, increasing operative exposure through real patients is impossible. One potential solution is in SBST and DP.

3.3.3.1 Types of training

MIS training can be broadly classified as basic and advanced training.

Basic training provides training of fundamental skills and is not specifically designed to simulate a particular surgery (A. M. M. D. Derossis et al., 1998). This fundamental learning is a requirement for the American Board of Surgery board certification requirement (Brian et al., 2022).

Conversely, surgery-specific advanced tasks are taught in courses like Advanced Training in Laparoscopic Abdominal Surgery (ATLAS). These structured training modules are capable of producing outcomes in trainees superior to those of current surgeons (Varas et al., 2012) and has a high correlation with real surgical performance (Boza et al., 2013).

3.3.3.2 Differences in training between open and laparoscopic surgery

The orchestration of a surgical procedure requires close interaction between multiple stakeholders, including the primary surgeon, assistant surgeons, and nurses. Among these social interactions, there are two principal domains: coupling and interactive complexity (Choy & Okrainec, 2010; Zetka, 2003). Coupling is the degree of reliance between the different actors in a system. Interactive complexity is the level of interaction between the actors.

Open surgery is tightly coupled but relatively low in interactive complexity. In contrast, Laparoscopic surgery is both tightly coupled and highly complex; the surgeon relies heavily on the camera assistant. The former is ideal for training, instruction, and control, which is almost entirely unidirectional; therefore, trainees do not require significant knowledge or skill to participate. In laparoscopy, however, the trainees must possess a baseline skill level before arriving in the OR.

This complexity also increases the cognitive demands during the surgery (Gallagher et al., 2005). Skills of psychomotor performance, depth perception, and spatial judgment for MIS can be learnt outside the OR. If these are pre-trained, trainees may automate these skills and reduce the cognitive overload during the OR time. This permits better focus on OR-dependent skills like operative judgment, comprehending instructions, and gaining additional knowledge during surgery (Gallagher et al., 2005).

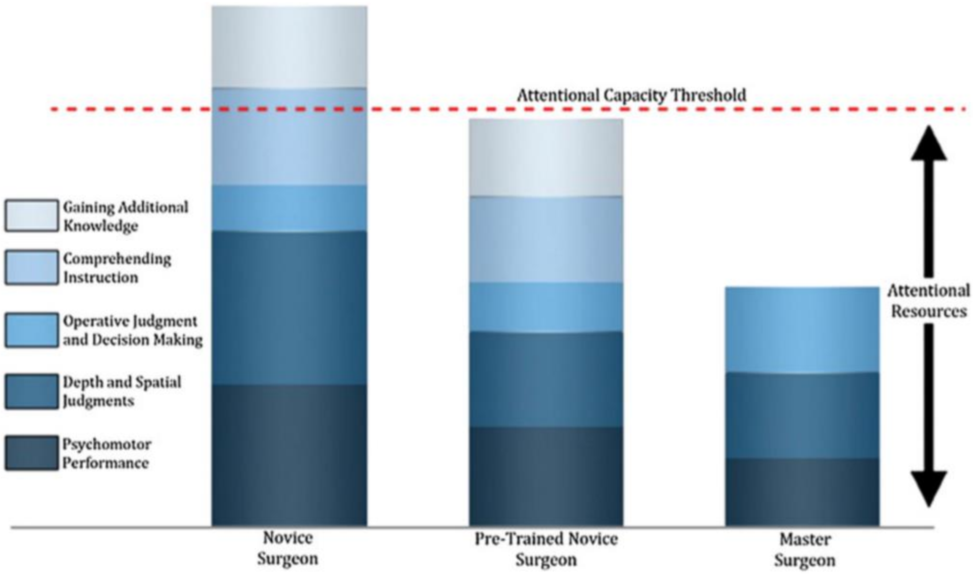


Fig. 1. Hypothetical attentional resource benefits of simulation training. *Modified from* Gallagher AG, Ritter EM, Champion H, et al. Virtual reality simulation for the operating room: proficiency-based training as a paradigm shift in surgical skills training. Ann Surg 2005;241(2):367; with permission.

Figure 3-3 The effect of pre-training on cognitive overload (from (Gallagher et al., 2005))

3.3.3.3 Simulation

Although 85% of residency programs considered skills training centres to be effective, only 55% had a skills laboratory. Also, only 55% of programs had mandatory training requirements (Korndorffer Jr et al., 2006).

The American College of Surgeons developed a Surgical Skills Curriculum in 2005 (Scott & Dunnington, 2008). This has multiple modules structured around video tutorials. They are followed by guided practice until the trainee achieves a pre-determined performance goal. Finally, a global rating scale-based assessment is made.

3.3.4 Present training

3.3.4.1 Mentorship and feedback

The provision of feedback is an essential component of training. There are two main aspects to providing feedback on operative skills. Scales like Objective Structured Assessment of Technical

Skills (OSATS) provide objective feedback on different aspects of the performance. The 4-level Zwisch scale indicates the trainee's autonomy and faculty guidance in performing the surgery (Table 3-2). Trainees in the top 2 stages are considered independent (George et al., 2014). Ten Carte et al (2016) suggests assessing autonomy may be better than evaluating performance.

TABLE 1. The Zwisch Scale and Its Relationship to Meaningful Autonomy and Near-independence

Zwisch Level	Attending Behaviors	Meaningfully Autonomous?	Nearly Independent?
Show and Tell	Performs >50% of critical portion	–	–
Active Help	Leads the resident (active assist) for >50% of the critical portion	–	–
Passive Help	Follows the lead of the resident (passive assist) for >50% of the critical portion	Yes	–
Supervision Only	Provides no unsolicited advice for >50% of the critical portion	Yes	Yes

Table 3-2 The Zwisch scale

Another important aspect of feedback in the theatre is the trainee's level of preparedness for the procedure being performed. The SIMPL performance scale can be used for this and is indicative of competence (Table 3-3).

TABLE 2. The SIMPL Performance Scale and Its Relationship to Competence

Performance Level	Trainee Behaviors	Competent?
Unprepared/Critical Deficiency	Poorly prepared to perform this procedure and/or included critical performance errors that endangered the safety of the patient or the outcome of the procedure.	–
Unfamiliar with Procedure	Frequent problems regarding technique, execution, smoothness, efficiency, and forward planning.	–
Intermediate Performance	Performance of procedural elements is variable but acceptable for the amount of experience with this procedure. Not yet at the level expected for graduating residents.	–
Practice-Ready	Resident is ready to perform this operation safely, effectively and independently assuming resident consistently performs procedure in this manner.	Yes
Exceptional Performance	One of the best performances I have ever seen. Above the level expected of graduating residents.	Yes

Table 3-3 The SIMPL performance scale

3.3.4.2 Assessment

Traditional assessments relied heavily on In-Training Evaluation Reports. These, however, are crude indicators of performance as they judge competence based on the number of procedures performed (Choy & Okrainec, 2010; Ibrahim & Katechia, 2018). Furthermore, they are confounded by central tendency errors, the halo effect, and recall bias (Vassiliou et al., 2005).

The call for more objective and valid measures led to the development of the Objective Structured Assessment of Technical Skills (OSATS) by the University of Toronto (Martin et al., 1997). It has good construct validity for live and bench models, and a moderate-to-high interrater reliability (Martin et al., 1997).

OSATS, however, was not developed or validated for the assessment of laparoscopic skill (Choy & Okrainec, 2010). For laparoscopic skill assessment, the Global Operative Assessment of Laparoscopic Skills was developed by Vassiliou and colleagues at McGill University in 2005 (Vassiliou et al., 2005). Based on OSATS, it was developed initially for laparoscopic cholecystectomy. It has been subsequently validated for other surgeries (Gumbs et al., 2007).

3.3.5 Learning curve of laparoscopic surgery

A Learning Curve (LC) is defined as "the amount of procedural training required for a surgeon to achieve competence in a new procedure" (Leijte et al., 2020). LC in surgical training was first explored by Tyras et al (1980) in their study of arterial surgery. They demonstrated that outcomes for the patients operated on in the first year were worse than those of the subsequent patients. Several measures, ranging from hand motion to operative time and mortality, have been used in measuring the LC (Brian et al., 2022). LC also presents an ethical concern with patient safety and outcomes (Eyers, 2017).

An added complexity of MIS is the inability for the trainee to observe the trainers' hands and the operative field simultaneously (Charokar & Modi, 2021). The LC for a particular MIS depends on prior experience in related open surgeries, unrelated MIS, and simulation (Leijte et al., 2020). Good mentorship, coaching, and collaborations are known to improve learning (Kluger et al., 2013; Rekman & Alseidi, 2019). Although attempts have been made to define and shorten LC, several complexities have prevented universal implementation. This includes the variation in case complexity for a given MIS, prompting educationists to define learning curves for both simple and complex cases of a procedure (Guilbaud et al., 2019). Despite the difficulties of MIS, autonomy rates for MIS surgery were higher than for non-MIS, and the trainees progressed more rapidly in MIS surgery (Bohnen et al., 2020). This may indicate that trainees and trainers are concentrating more on MIS training.

A critical consideration in the use of LC plateauing as a measure of proficiency is that curve stabilisation can occur at different levels for novices and experts, and therefore may not reflect proficiency (Peláez Mata et al., 2021).

3.3.6 Competence-based education (CBE)

CBE is defined as "an outcome-based approach to education that incorporates modes of instructional delivery and assessment efforts designed to evaluate mastery of learning by students through their demonstration of the knowledge, attitudes, values, skills, and behaviours required for the degree sought" (Gervais, 2016) (Page 1). For a doctor, there are six domains of competence (Harden, 1999; Swing, 2007). In modern surgical training, however, competence is defined chiefly by duration or completing a fixed number of procedures (Ibrahim & Katechia, 2018).

The widespread use of CBE in surgery requires defining a national curriculum, eliminating clinical duties without educational value, and verifying competence at each level of training (Debas et al., 2005). Given the evidence of poor transferability of skills between procedures, surgical training also needs to ensure the same minimum competence in every procedure before clinical practice (Thinggaard et al., 2016). These principles align closely with the DP framework (see below).

3.3.7 Self-assessment

Self-assessment is defined as "a personal evaluation of one's professional attributes and abilities against perceived norms" (Colthart et al., 2008). It has been recognised as an essential professional skill by many regulatory bodies (Colthart et al., 2008). Most studies, however, examined cognitive skills rather than technical or surgical skills (MacDonald et al., 2003). Evidence on the use of self-assessment in surgical skills training is limited (Gordon, 1991).

Similar to evidence from the original study by Dunning and Kruger (1999), evidence among doctors also indicates there is overconfidence, especially among the learners who know less (Gordon, 1991). The study by MacDonald et al (2003) identified that learners can accurately self-assess their errors during laparoscopic training, and the estimates improve with experience. Similar findings were reported by Moorthy et al (2006) on open surgery simulation. The study also identified a poor correlation between self and expert assessment regarding nontechnical skills.

3.3.8 Limitations of the current approach to training

Concrete experiences are a key component of learning, and few experiences provide more instructive feedback than witnessing your own complication following surgery (Jackson & Tarpley, 2009). This cannot be permitted as a learning exercise for patient safety reasons, and SBST is essential.

Trainee work hours are becoming progressively more stringent, therefore reducing operative exposure. This has also led to operative exposure being shunted away from junior trainees to benefit senior trainees and reduce exposure to complex procedures. The rate of surgical complications has also increased following work-hour restrictions, indicating inadequate training volume (Jackson & Tarpley, 2009).

The modern surgical trainee needs to learn 158 procedures before completion (Teitelbaum et al., 2014). Other clinical responsibilities further confound this by limiting operating time (Hashimoto et al., 2015). Therefore, apprenticeship teaching during live operating is insufficient to teach technical skills. Patient safety mandates low tolerance for learning inefficiency and often eliminates deliberate practice. It also cannot provide exposure to rare but important adverse events (Feins et al., 2017). Skills training during live surgery requires a significant time commitment from faculty (Hashimoto et al., 2015).

The reduced training opportunities due to working time directives (Franzese & Stringer, 2007) were further worsened by the impact of COVID-19 and reduced surgery (Iqbal et al., 2021). Limited training opportunity is also aggravated by the lack of experts (Loveland et al., 2012). Multiple factors prevent the adoption of an ideal learning environment (Sharma et al., 2020), including the apprenticeship-based format (Franzese & Stringer, 2007), poor awareness of education principles and existing evidence (Issenberg et al., 2005), and the arbitrarily defined competence and expert performance (Price et al., 2015).

Simulation improves surgical skill, care, precision, and speed (Crochet et al., 2011). During training, the initial phase is hypothesised to require around 50 hrs. After reaching this milestone, if no further efforts are made to progress, performance often plateaus, leading to ''arrested development'' (Hashimoto et al., 2015). While the premature plateau may be above the level of everyday skill, it falls short of expert performance (EP). DP attempts to improve the performance of all participants beyond this plateau, to the level of expert performance (Hussein et al., 2020). SBST and DP can also overcome skills deterioration (Baumann & Barsness, 2018).

Simulation in surgical training, however, should be treated as a prelude to live surgery, and never as an end in itself. It offers a means of detaching skills from their clinical context, and thereby permitting learning without the pressures of clinical responsibility (Kneebone, 1999).

3.4 Mastery learning

As Deliberate Practice (DP) attempts to produce expert performance in all participants, it aligns closely with Mastery Learning (ML).

3.4.1 Overview

Based on his work in the 1960s, Bloom determined that the most effective learning occurred with one-on-one tutoring (Guskey, 2007). Resource scarcity, however, impedes widespread adoption of this method. Instructors and curricular designers must therefore find practical ways to target individual learning needs in a group-based classroom (Winget & Persky, 2022). Mastery Learning (ML) is an instructional strategy which aims to produce identical outcomes of high performance standards in all learners (Issenberg et al., 2005). It was introduced by Benjamin Bloom in (1968). ML requires learners to achieve a level of mastery (e.g. 90% of the content) before proceeding to the next section of learning. Mastery is achieved through formative assessment that identifies and corrects any learning difficulties. These assessments align in complexity and format with the learning objectives (Guskey, 1986).

Unlike most educational approaches, where the time spent is uniform, the ML approach emphasises that learning outcomes are uniform while the time needed to reach them varies (Bloom, 1974, 1976; Carroll, 1963; Issenberg et al., 2005). ML, therefore, remains a key component of competency-based education (Issenberg et al., 2005; McGaghie et al., 1978).

3.4.2 Steps

The main steps of ML include initial learning, formative assessment, corrective activities, and/or enrichment activities (Bloom, 1968; Guskey, 1986) (Figure 3-4).

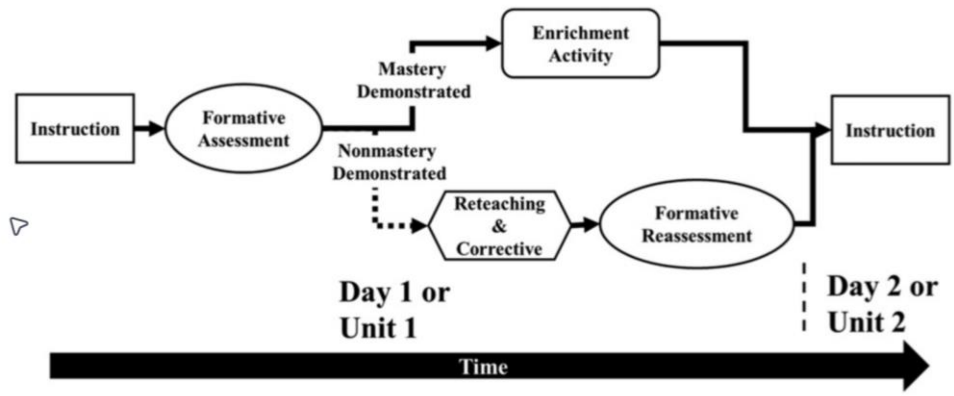


Figure 3-4 Mastery learning activities (Winget & Persky, 2022)

The nature of ML encourages avoiding spending time and effort on learning to a high initial criterion, and instead utilising these resources for subsequent relearning (Winget & Persky, 2022).

The goal of the formative assessment is to manage learning (Block & Airasian, 1971), and they therefore must be no or low stakes (Winget & Persky, 2022). These also require pre-defined performance thresholds. The standard for passing these assessments must be no lower than 80% ("B") and no higher than 90% (Guskey, 1986). A common form of threshold definition is the use of Mager models, which include the minimum acceptable performance and the context for that performance (Mager & Peatt, 1962). Mager models are often preferred in competency-based education due to their ability to define the level of mastery (Winget & Persky, 2022). The mastery standard can be based on the achieved quantity of learning outcomes (e.g., competent on 80% of learning outcomes), or it can be the competence on each learning outcome (e.g. 80% correct on each learning outcome) (Winget & Persky, 2022). One limitation of these assessments is the lack of direction on how students can improve their weak areas (Sekulich, 2020; van de Ridder et al., 2015; Van De Ridder et al., 2008).

Students who accomplish the predefined level of mastery are offered enrichment activities, which are different to the original learning activities. Guided by the results of the formative assessments, students who do not accomplish the predefined mastery level complete corrective activities to improve the concepts missed. These corrective activities must involve different types of activities (Ellaway et al., 2018; Kalet et al., 2016). The predominance of formative assessment also aligns with the Mastery Goal Orientation of learning and increases motivation (see page 166). For knowledge acquisition, part of the strategy may be self-directed learning or guided self-paced instruction, as these may be most cost-effective because of their efficiency (Murad et al., 2010)

In addition to the formative assessments, ML includes summative assessments. These should be aligned with the learning objectives, formative assessments, and all instructional activities. (Winget & Persky, 2022). To ensure pedagogical vigour, assessments must be criterion-based, aligned with the learning objectives, and ensure blueprinting to cover the content and objectives adequately (Winget & Persky, 2022). To encourage "mastery", the assessment uses a three-tiered ("honours-pass-fail") system because it acknowledges reaching a superior competence standard, and it does not reward poor work (Guskey, 1986).

3.4.3 Effectiveness

ML has demonstrated effectiveness as an instructional strategy. A meta-analysis of 36 ML studies demonstrated an average effect size of 0.59 with a medium-to-large effect (Kulik et al., 1990). Another study identified an improvement in GPA by nearly 1.5 grades (Guskey, 2007).

There are several explanations for the effectiveness of the ML approach. ML creates a motivational environment, offers regular opportunities for retrieval and practice, and provides regular, focused feedback (Winget & Persky, 2022). Furthermore, the ML approach attempts to improve the performance of students of both performance levels; those who have not grasped the content, and those who have. This contrasts with a regular classroom where higher-achieving students may not be challenged to exceed baseline expectations. ML offers enrichment activities for these students (Winget & Persky, 2022). ML provides a pathway for competence for the struggling student despite an initial poor performance (Winget & Persky, 2022).

The formative assessments improve learning and metacognition by permitting application of knowledge and serving as a retrieval opportunity (Barenberg & Dutke, 2019). The feedback is essential for learning and leads to large effect sizes (Marsh & Eliseev, 2019). Furthermore, ML improves long-term retention through successive relearning (Rawson et al., 2013)

3.4.4 Use of ML in surgical training

Due to changing circumstances, surgical training is moving away from the Halstedian training model. The original model was a pyramid, with some trainees not progressing (Teitelbaum et al., 2020). Presently, however, all residents who begin training are expected to graduate in the same number of years and function as independent general surgeons (Teitelbaum et al., 2020). ML acknowledges that learners will not all progress at the same pace but also attempts to ensure a fixed endpoint of operative safety and autonomy for all learners. One way to achieve this is through simulation.

A key element of using ML in SBST is identifying critical steps in each surgery, both technical manoeuvres and decision-making points. Simulation is best utilised at the beginning of a training programme to ensure the development of generic skills in all participants. In endoscopy, for example, five simulation-based training sessions produced outcomes equivalent to 150-300 endoscopies (Ritter et al., 2018). As a trainee progresses, the use of ML in simulation-based training becomes more complex, due to the complexities of the surgery, and the multiple domains of expertise needed (Teitelbaum et al., 2020).

The main factor preventing widespread use of ML is the faculty workload it requires, especially in the initial development of the course. Once established, however, this content is reusable annually and does not overwhelm the teachers.

3.5 Simulation

3.5.1 What is simulation

Simulation is defined as "a person, device, or set of conditions which attempts to present education and evaluation problems authentically"(Bismuth et al., 2010) (Page 1073). For effective learning from simulation, the learner must respond to the problems as they would under natural circumstances (Issenberg et al., 2005).

In surgical training, the overall aim of simulation is to improve surgeon competency and thereby increase patient safety (Derevianko et al., 2010).

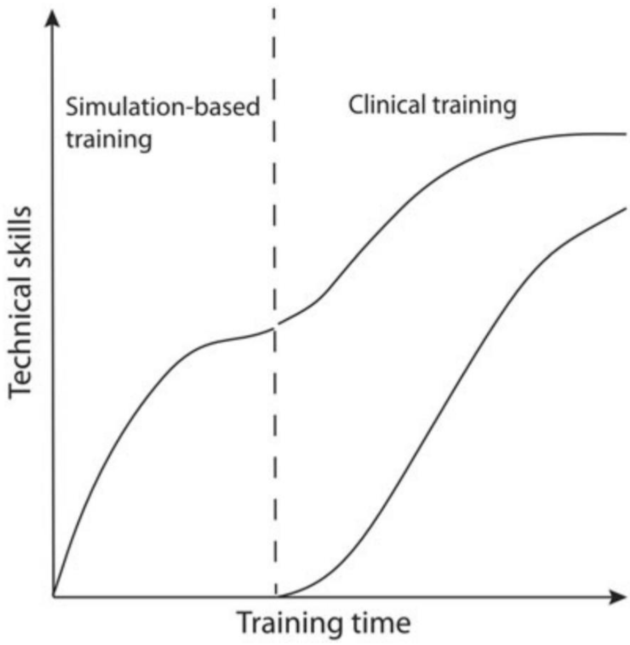


Figure 3-5 Skill gain from clinical training and simulation, From (Bjerrum et al., 2018)

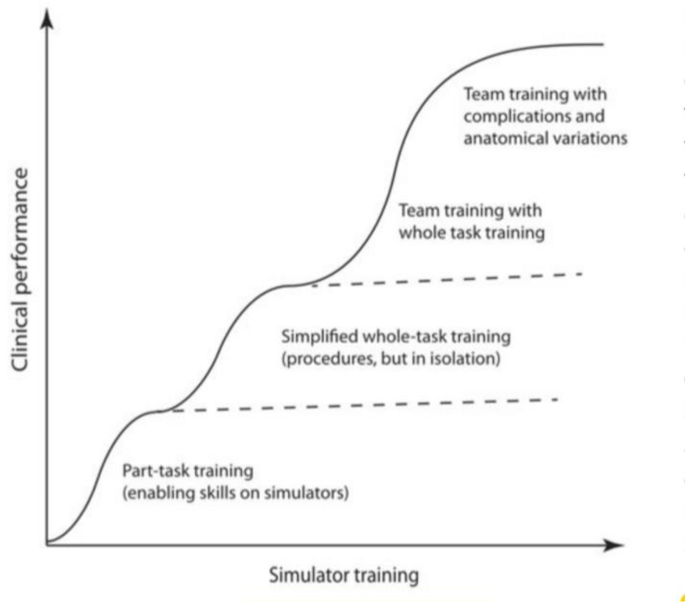


Figure 3-6 Stepwise progression in SBST (Bjerrum et al., 2018)

3.5.2 Typology of simulators

Gary Meller introduced a typology for simulators in 1997, allowing identification and characterisation of critical elements (Meller, 1997).

There are four main elements in this classification.

P1 - The patient and/or the disease process

P2 - The procedure, diagnostic test, or equipment being used

P3 - The physician or paraprofessional

P4 - The professor or expert practitioner

Each simulator element can be passive, active, or interactive, and will be identified using the appropriate letter.

p - passive element

a - active element

i - interactive element.

An ultrasound training simulator (e.g. Ultrasim™) that includes a mannequin, simulation learning software, and automated feedback simulating feedback could be classified as (P_{1i} P_{2i} P_{4i}).

3.5.3 Common characteristics of simulation

Simulation programmes, irrespective of their objectives, share several common characteristics (Issenberg et al., 2005).

Simulation permits trainees to act as they would in the real environment (e.g. tactile feedback[1] on laparoscopic simulators). Trainees can also see cues and consequences like the real environment. (e.g., a laparoscopic VR simulator where bleeding occurs if a blood vessel is injured). Furthermore, trainees can be placed in complex situations through VR simulators that allow changing the complexity of the surgery (e.g. adjusting peritoneal[2] transparency). The training could be high stakes, low stakes, or no stakes (McGaghie & Issenberg, 1999)

3.5.4 Types of surgical simulation

The earliest models used for laparoscopic surgery training were animal and cadaveric. The most significant advantage of these is the tactile sensation, almost like real patients. Legal and ethical issues, as well as concerns of zoonotic infections, have reduced their use. Due to labour and cost concerns, these have been used in short, single-practice sessions (Choy & Okrainec, 2010). This, however, violates the pedagogical principle of distributed practice (see repetition in DP on page 177). Results of Martin et al indicate that live animal practice is not superior to training on benchtop models (Martin et al., 1997). Currently, this mode of simulation is most used in developing new surgical techniques (e.g. Natural Orifice surgery).

Video trainers or box trainers consist of a simple box with a video camera and instrument ports. They are inexpensive, efficient, and easily reproducible (Choy and Okrainec 2010), and therefore are widely used. The activities practised may range from simple tasks (e.g. peg transfer) to complete procedures (Neary et al., 2008). Prior research has identified good transferability of skills to the OT (Scott et al., 2000).

As a computer-based technology, VR can model complete surgical procedures, with anatomic accuracy and pathological diversity. Although the initial cost is high, there are negligible recurrent costs, and adding extra modules is easy. Training instructions and feedback can be programmed into the trainer. Using automated systems like the Imperial College Surgical Assessment Device

[1] E.g. How firm a structure feels
[2] The layer covering organs inside the abdomen

(ICSAD) (Datta et al., 2002; Datta et al., 2001), instantaneous and frequent performance assessments can be made without the presence of a trainer.

VR trainers are valuable assessment tools and can discriminate between novice and skilled surgeons (McDougall et al., 2006). More difficult tasks have the highest discrimination capability. VR simulation training has repeatedly demonstrated the ability to enhance surgical performance and reduce error (Aggarwal et al., 2008; Gurusamy et al., 2008; Willaert et al., 2012). VR training Improves time, accuracy, and number of errors (Rajesh Aggarwal et al., 2007; Ahlberg et al., 2007; Andreatta et al., 2006; Seymour et al., 2002), and decreases operating time, decreases errors (Gurusamy et al., 2009). VR, however, does not produce better outcomes than cadaveric training (Tan et al., 2018). Human feedback combined with VR metrics produces better outcomes than automated metrics alone (Hashimoto et al., 2015).

3.5.5 Need for simulation

The shifts in disease patterns, including more acutely ill patients, and changes in administrative policies leading to shorter inpatient stays have resulted in fewer learning opportunities (Evans & Schenarts, 2016; Issenberg et al., 2005). Furthermore, the reductions in physician reimbursement for teaching and shrinking financial resources constrain the time clinicians can dedicate to teaching (Issenberg et al., 2005). This is exemplified by the results of Roldan et al, that despite evidence that accurate clinical evaluation is a cost-effective diagnostic modality (Roldan et al., 1996), the frequency of direct bedside teaching is decreasing (Issenberg et al., 2005), resulting in a loss of clinical acumen; junior doctors have difficulty identifying common cardiac findings (Mangione & Nieman, 1997). The time in the operating theatre is limited due to logistical reasons, service commitments, and work hour restrictions. It is therefore too valuable to be used for teaching basic technical skills. (Evans & Schenarts, 2016). SBST can move the learning curve out of the OR, and improve learning higher skills in the operating theatre (Meier, 2010).

Introducing new technologies, especially minimally invasive surgery (MIS), demands mastery of new skills. The psychomotor and perceptual skills required for these newer techniques differ from traditional approaches (e.g. mirroring of hand movements in laparoscopic surgery) (Bashankaev et al., 2011). To maximise learning in theatre and minimise harm to patients, they need to develop dexterity on the equipment before proceeding with the steps of surgery (Zendejas et al., 2013). This is particularly important, as newer techniques often have a potential for higher complication rates than traditional surgery (Deziel et al., 1993).

Furthermore, the present generation of surgical trainees was born into the millennial generation. Among other characteristics, they are digital natives, assume technology, and are assimilative learners, and therefore would find SBST technology innately attractive. Supporting this hypothesis, familiarity with video games has been correlated with fewer error rates and faster performance in MIS among trainees (Evans & Schenarts, 2016).

The ability of a training programme to provide standardised experiences for all learners and provide reliable data on outcome measures is an essential component (Issenberg et al., 2000; Issenberg et al., 2002). Simulators offer several opportunities for assessment of competence. All forms of simulation can be permitted to progress through incorrect performance with no risk to patients, permitting accurate assessment of competence. Additionally, simulation can provide an identical assessment for all trainees or a wide range of conditions, depending on the requirement. Furthermore, the inherent ability of specific simulators (e.g. VR) to provide objective performance measures without human supervision permits accurate competence assessment.

SBST for MIS surgery has proven effectiveness in reducing the learning curve and patient morbidity (Köckerling, 2018). Patient safety is heavily reliant on team dynamics. Medical education has often ignored the value of teamwork and the role of safe systems (Helmreich & Schaefer, 2018). The value of this has been exemplified in non-medical fields including commercial aviation, aeronautics and the military (Baker & Salas, 1997). Recognising this importance, the Institute of Medicine asserts, ''health care organisations should establish training... using proven methods*, including simulation*'' (Donaldson et al., 2000).

3.5.6 Feedback

Feedback during SBST enables self-assessment, promotes self-monitoring, improves learning efficacy, and slows skill decay (Issenberg et al., 2005).

Immediate feedback corrects misconceptions (Gibson, 2000), and leads to faster and better learning (Bangert-Drowns et al., 1991; Kulik & Kulik, 1988). This, however, requires the trainee to dedicate their entire attention to feedback, which may reduce skill transfer (Schmidt & Bjork, 1992). Delayed feedback has consistently produced greater retention (Cannon-Bowers et al., 2010; Xeroulis et al., 2007).

The optimal feedback frequency for SBST is unknown (Stefanidis, 2010). Evidence suggests that frequent feedback during simulation training may lead to faster skill acquisition (Cannon-Bowers et al., 2010). Trainers, however, must remain cognizant that fewer feedback interruptions may produce greater retention (McLaughlin et al., 2008; Wickens, 2002).

3.5.7 Advantages and disadvantages of simulation

Surgical skills training in the operating theatre relies on the pattern of patients coming for treatment. Simulation permits the training agenda to be determined by the trainee's needs. The trainee also has the freedom to focus on the whole procedure or specific components (Kneebone, 2003). Simulation also enables objective and reproducible assessment of performance and regular feedback. SBST provides a safe environment, where the trainee has "permission to fail", without risking a patient (Kneebone, 2003). SBST complements, but does not duplicate, education involving real patients in the real environment (Issenberg et al., 2005)

There is a notable tension between the design and evaluation of simulations. For equipment designers, the completion of a product represents the end of their development journey. Conversely, evaluators view this product as the beginning of the assessment process that enhances its effectiveness and usability (Kneebone, 2003). Adopting new technology, therefore, is especially complicated. The emphasis needs to shift from technology to education and clinical practice (Hamdorf & Hall, 2000; Hoffinan, 2000; Torkington et al., 2000). Simulators are only valuable within the context of a curriculum. The role of technology is to support the training objectives (Satava, 2001). Simulation technology, especially high-fidelity equipment, is expensive. In the long run, however, SBST is cost-effective (Issenberg et al., 1999).

3.5.8 Current limitations

3.5.8.1 Limitations in simulation

A primary limitation of published research on SBST is the emphasis on technology rather than pedagogy (Lam et al., 2013). Little emphasis has been placed on pedagogy or instructional design in developing SBST. Evidence is also limited about the best debriefing approach and the minimum number of sessions needed to achieve competence (Bond et al., 2007). The transferability of learned skills (Iqbal et al., 2021), the rate of decay after learning, and the validity of existing tools (Bond et al., 2007) also remain poorly understood. These indicate an immaturity of the field, which prevents the development of recommendations founded on pedagogical principles (Schaefer et al., 2011).

Presently, SBST design is primarily based on educators' personal opinions, and the training content is based on feasibility and availability rather than relevance (Bjerrum et al., 2018). Engaging surgeons in DP and SBST is difficult (Walker et al., 2023). Integrating SBST into competence-based education requires defining specific learning objectives and benchmarks, and the measurements need to have evidence of validity (Cook et al., 2011). Presently, however, there is a lack of measurable objectives (Bjerrum et al., 2018) and many measurements lack evidence on their validity (Borgersen et al., 2018). Without objective evidence on their validity, measurements, goals, and objectives have limited utility (Downing, 2003). This lack of evidence and consensus makes identifying content, learning objectives, and assessment tools time-consuming (Bjerrum et al., 2018). The need for evaluating each procedure or a representative few in evaluating trainees is also unclear (Bjerrum et al., 2018).

While simulation improves the performance, it often follows a sigmoid distribution to reach a plateau eventually. The number of attempts required to achieve this is currently unknown (Podolsky et al., 2018; Valsamis et al., 2018). Non-medical literature has attempted to quantify the training required for expert performance (Ericsson, 2004).

The available evidence had a disproportionate focus on novices and a limited focus on advanced trainees (Scott et al., 2011). Novices, however, show the most significant benefit from SBST, and training novices have the greatest impact on patient safety (Bjerrum et al., 2018).

Despite its theoretical benefits, SBST programs have often failed to deliver the promised learning outcomes. The sole availability of a simulator is inadequate for a meaningful educational experience (Stefanidis, 2010). One potential culprit is suboptimal instructional design (Higgins et al., 2021). Since DP aims at developing expert performance in psychomotor skills, DP-informed SBST should optimise learning outcomes.

3.5.8.2 Limitations in the available evidence

Simulation has been studied extensively, with about a third of the studies focusing on surgery (Issenberg et al., 2005). There are, however, several limitations to the evidence on SBST, both pedagogical and methodological. Of the studies, less than 30% are RCTs, and many are limited by their small sample size, or used unsuitable or heterogeneous participants (often medical students) (Iqbal et al., 2021). In over 75% of the studies, the strength of the evidence was borderline or poor (Issenberg et al., 2005).

Furthermore, although there is some evidence on the effectiveness of simulation as a training tool, evidence is lacking on how to optimise learning through simulation (Cannon-Bowers et al., 2010). Evidence is also limited about the best approach for debriefing, including content and timing, and the minimum number of sessions needed to achieve competence (Bond et al., 2007). The transferability of learned skills (Iqbal et al., 2021), the rate of decay after learning, and the validity of existing tools (Bond et al., 2007) also remain poorly understood. There are many contradictions in the existing literature. Even papers studying the same tool and training have found differences in skill transferability (Shah et al., 2022). A meta-analysis focusing on the effect of trainer type and learning also found contradictory results (Alaker et al., 2016). These inconsistencies often stem from the lack of strict definitions or the ambiguous application (Ericsson & Harwell, 2019).

This study, therefore, attempted to focus on both educational theory and training design (Bond et al., 2007). It also focuses on both surgical trainers and trainees, as competency measures grounded in trainee responses can be reliable and valid outcome data (Issenberg et al., 2005).

3.6 Deliberate practice

We are what we repeatedly do. Excellence, then, is not an act but a habit – Aristotle

3.6.1 What is DP

DP begins with identifying "reproducibly superior performance" (Ericsson 2015) and uses it as an endpoint to achieve EP through four fundamental tenets elaborated below (Table 3.2, left column). When these characteristics are met, educational interventions provide a strong, consistent, and sustained skill and knowledge attainment (McGaghie, 2008), making training highly successful (Bhatti & Ahmed, 2015), progressing beyond "arrested development" otherwise achieved (Figure 3-7).

Combining simulation and DP has been shown to provide gains that are independent of the level of competence of the learner (Leger et al., 2016).

Learner motivation	To attend to the task
	To improve their performance
Task design	Considers pre-existing knowledge.
	Has appropriate levels and sequence
	Demonstrates technique / explicit instructions
	Can be easily understood
Feedback	Provides supervision
	Immediate
	Informative of their performance
	Allows remedial training
Repetition	Allows repetition
	Effort constraint

Table 3.2 Key themes and characteristics of DP (From (Ericsson, 2004))

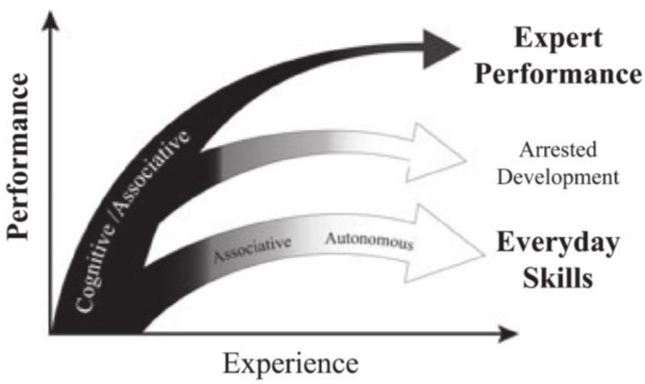


Figure 3-7 The qualitative differences in performance levels (Anders Ericsson, 2008)

3.6.2 Expert performance

The evolution of surgical training is partly grounded in education principles but equally based on changing healthcare, legal, and social paradigms. Beginning with the Halsteadian apprenticeship model and progressing to the cognitive apprenticeship model, there is an increasing demand for competency-based training (Skjold-Ødegaard & Søreide, 2021).

Competence-based training relies on defining the competencies (Entrustable Professional Activities - EPA) and the desired threshold and evaluating them to confirm progression. The threshold is based on Expert Performance (EP). An expert surgeon is someone who can function almost at any time with only minimal preparation (Anders Ericsson, 2008). Reaching this performance level often requires using two closely related approaches, Mastery Learning and DP.

Literature on optimising SBST and the development of EP is limited. This stems from the lack of application of pedagogical principles in SBST and contradictory findings from different studies.

A primary limitation of published research on SBST is the emphasis on technology rather than pedagogy (Lam et al., 2013). Little emphasis has been placed on pedagogy or instructional design in developing simulation training programs. Current literature also indicates an immaturity of the field, which prevents the development of recommendations founded on pedagogical principles (Schaefer et al., 2011).

Multiple factors prevent the adoption of an ideal learning environment (Sharma et al., 2020). Surgical training still follows an apprenticeship-based format (Franzese & Stringer, 2007). Lack of awareness of education principles and existing evidence (Issenberg et al., 2005) also reduces the potential effectiveness. Another limitation is the opportunistic[3] exposure and training. Furthermore, competence and expert performance are arbitrarily defined (Price et al., 2015), indicating the lack of an evidence-based structure. Most surgical training programs are duration-based and ignore the variations in the time taken to achieve competence (McGaghie, 2008). Developing countries have also lagged in embracing pedagogical innovations (Campain et al., 2018).

3.6.3 Core elements of DP

While the DP framework stipulates individual components, no study has looked at the individual effectiveness of each component of DP (Crochet et al., 2011).

3.6.3.1 Motivation

For effective DP, the learner must be motivated to attend to the task and improve. As opposed to "work", providing extrinsic rewards (e.g., remuneration, recognition), and "play", providing intrinsic rewards (enjoyment), DP is neither inherently enjoyable nor immediately rewarding. The

[3] Learning is based on opportunities that arises when a patient with a particular illness is admitted, which is beyond the control of the trainer and the trainee.

learners must, therefore, both understand the importance of prolonged practice and be motivated to improve through training.

This is an essential component for any training, which is often overlooked in course design. Pre-training motivation correlates well with outcomes (Facteau et al., 1995). The belief that training will be helpful to improve satisfaction and transfer (Cannon-Bowers et al., 2010; Lim & Morris, 2006).

3.6.3.2 Task design

DP considers performance an ordered sequence of states, characterised by the increasing complexity of monitoring and directing future improvements (Ericsson, 2015). Additional practice on familiar tasks does not improve accuracy or performance (Ericsson, 2015). The task design must therefore consider the present skill level of the learner. Furthermore, the training task should be easily understood after brief instructions.

A detailed task demonstration allows the trainee to understand the intricacies of the procedure and develop a good mental representation. The use of video for task demonstration is effective in SBST (Jowett et al., 2007; Summers et al., 1999; Takiguchi et al., 2005). Computer-based video instruction has been found to be as effective as expert feedback (Stefanidis,(Stefanidis, 2010). Information on task performance provided before and during the training is superior only providing guidance before (Magill & Anderson, 2024).

Having an appropriate range of difficulties is the 4th most important aspect of simulation. This supports training at progressively higher difficulty levels to accommodate the different ‘learning curves’ of trainees (Issenberg et al., 2005). This ensures that learning will be enhanced with progressively increasing difficulty levels (Issenberg et al., 2005). Transferability of skill due to this strategy, however, has limited evidence (Stefanidis, Korndorffer Jr, Markley, et al., 2007). Skill acquisition is also better when tasks are practiced randomly than in a specific (Kurahashi et al., 2008; Stefanidis, 2010).

3.6.3.3 Feedback

The core component of DP is the feedback on present performance to overcome deficiencies. For maximal benefit, the feedback must be immediate, specific, and informative of their performance (Abraham & Singaram, 2019), and judged against an expert's performance level (Ericsson, 2015), enabling focused practice on weak areas. Informed, non-evaluative feedback on the performance improves learning through reinforcement of the learners’ strengths reinforces strengths (Kruglikova et al., 2010; Stefanidis, 2010).

This prescription provides trainers with a framework for providing feedback. Multiple studies have confirmed that such feedback improves surgical performance (Ericsson, 2015; Hashimoto et al., 2015; Palter & Grantcharov, 2014). Simulation that enhances internal feedback of the performance, like the use of haptic feedback, improves skill acquisition (Cao et al., 2007; Panait et al., 2009; Ström et al., 2006).

3.6.3.4 Repetition

Repetition of activity with successive refinement until reaching EP is the hallmark of DP. Continuous practice improves speed, efficiency, and precision, leading to eventual automaticity and mastery (Tan & Sarker, 2011). Learning may lead to improved technical skills if the task is not repeated (Anastakis et al., 2003; Ericsson, 2006). Repetitive practice was identified as the second most important aspect in SBST in the BEME review on simulation (Issenberg et al., 2005). The common reasons for trainees not practising are the lack of supplies, time, opportunity, mastery of skill, or supervision (Fann et al., 2010).

In addition to the extrinsic feedback, the learner must continuously monitor their performance (internal representation). The number of attempts of a trainee during SBST is related to the final outcome (Tan et al., 2018). Maintaining full attention is effortful and limits the duration of each practice session and is termed "effort constraint" (Ericsson et al., 1993).

3.6.3.5 Mental representation

The key to progress is the ability to self-monitor and correct one's skill by comparing three internal representations (Ericsson, 2015) (Figure 3-8). Initially, the student cannot identify their mistakes (Ericsson, 2015). DP leads to the refinement of mental representations. The role of the trainer is to refine the mental representations through DP, enabling self-evaluation of performance.

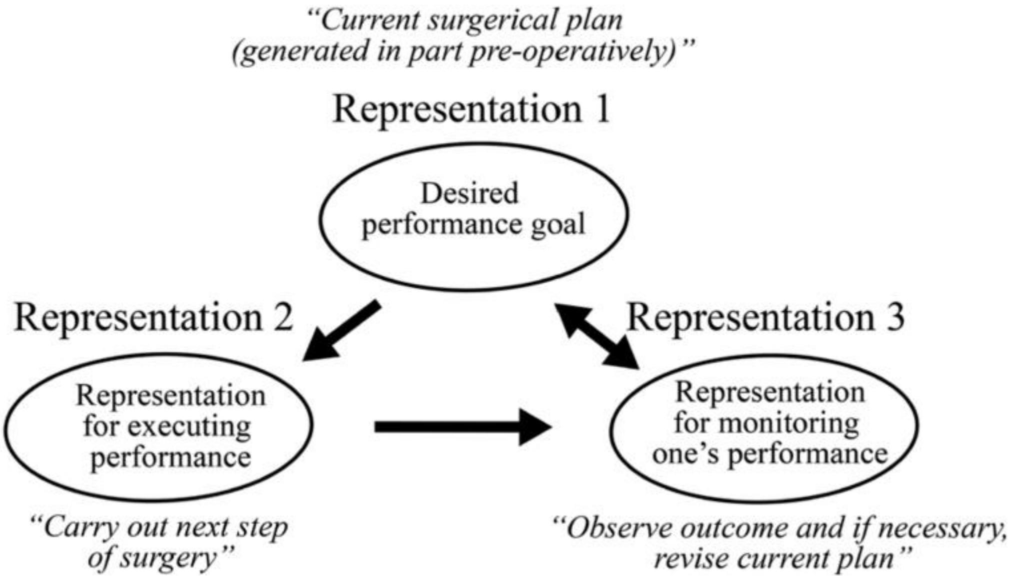


Figure 3-8 Three types of internal representation (Ericsson, 2015)

3.6.4 Benefits of DP for SBST

There are potential benefits in the synergy of Simulation-based surgical training (SBST) and DP. Simulation allows trainees to practice surgical skills without the risks associated with real-world patient care. In contrast, deliberate practice ensures that the training is focused and structured in a way that leads to measurable improvements in performance. SBST, which is guided by DP, can provide trainees with the opportunity to practice specific surgical tasks or procedures repeatedly, receive immediate feedback, and make adjustments to their performance until they achieve a desired level of proficiency (Dawe et al., 2014; Pacilli & Clarke, 2020; Sutherland et al., 2006). When these criteria are met, DP will improve accuracy and speed (Ericsson, 2015; Ericsson et al., 1993; Hashimoto et al., 2015; Palter & Grantcharov, 2014), with the improvement directly proportional to the amount of practice (Ericsson et al., 1993). The performance also becomes effortless and automatic. The skill acquisition is also faster than exposure to routine clinical work (Issenberg et al., 2005).

This approach is particularly valuable in surgical education, where the ability to perform complex technical skills is crucial for patient outcomes. Better training is directly linked to better patient outcomes (Balian et al., 2019; McGaghie et al., 2011b).

3.7 Pedagogy

3.7.1 Differences between DP, Purposeful Practice, and Structured Practice

Despite the extensive literature review, no publications focusing on simulation or surgery were identified. Only a review by Anders Ericsson (2020) provided any pedagogical insight into *purposeful practice*. Ericsson et al (2019) and Hutterman et al (2014) used the term *structured practice* for training that focuses on structured activities but lacks other components of DP.

3.7.2 Current evidence and limitations of DP in medicine

DP is an evidence-based approach grounded in information processing and behavioural theories, with substantial evidence supporting its role in skill acquisition, mastery, maintenance, and improvement of skills (Ericsson, 2004; Ericsson, 2006). It also works for learners of all levels (McGaghie, 2008). Adherence to DP has been shown to reduce error rates and improve scores in surgical procedures (Iqbal et al., 2021).

There have been two broad areas of limitations in using DP in medical research: poor application of principles of DP and the limitations of the DP framework.

3.7.2.1 Poor application of the principles of DP

The overarching limitation of the existing knowledge of DP in surgery is the lack of methodological robustness and attention to individual components. DP has often been poorly implemented in research, and adherence to the original definition is crucial (Ericsson & Harwell, 2019). Furthermore, the alignment of DP with medical education pedagogy requires further attention (McGaghie, 2008).

Published data have failed to focus on the effectiveness of different types of practice in skill development or how each aspect of DP has been used in surgical simulation (**Task design,** see section 6.5.3). Other elements in this category that could benefit from further evidence include the ideal learning environment and skill maintenance/decay.

Additionally, many **feedback** elements (See section 6.5.4) require scientific exploration, including measuring performance and providing feedback. There is often a lack of robust, sensitive, and objective performance measures (McGaghie, 2008). Competency must be defined for each procedure (Bond et al., 2007), but no standard guidelines exist for defining competency targets. Studies that rely on observational assessment of performance mandate rater training and regular calibration, which has often been overlooked (McGaghie et al., 2009; Williams et al., 2003; Woehr & Huffcutt, 1994). Another limitation is using Kirkpatrick level 1-3 endpoints without focusing on the actual results of EP (McGaghie, 2008). After clear competence standards have been defined, objective checklists and expert rating systems will be required (Bond et al., 2007). Guidelines will facilitate their development. Furthermore, using checklists and global scores for feedback has advantages and disadvantages, with evidence lacking on the superiority of either (Bond et al., 2007). With the propagation of video-sharing platforms, the role of feedback on video recordings, including peer feedback, needs to be explored (Bond et al., 2007). How feedback can be individualised for best results also warrants investigation (O'Connor et al., 2008), including preventing negative learning (Bond et al., 2007).

The final component of DP, **repetition** (See section 6.5.4.4), also has several knowledge gaps. It is unclear if the repetition of the training task should be distributed or mass practice. Whether repetition of every step is required or only repeating the key steps is sufficient is also unclear (Bond et al., 2007).

3.7.2.2 Limitations of the DP framework (See also section 0)

DP framework assumes minimal transfer in skills between apparently similar domains (Kirkman, 2013) although several studies have shown good transferability (Hamilton et al., 2002; Loukas et al., 2012). There are contradictory findings on the role of prior preparation (e.g. coordination drills before training (Pearson et al., 2002), basic skills before surgery (Yiasemidou et al., 2017)).

Although mental representation in DP refers to some elements of the thought process, DP does not explicitly focus on the theoretical knowledge and cognitive aspects. Multiple studies (Immenroth et al., 2007; Nickel et al., 2015; Pape-Koehler et al., 2013; Pearson et al., 2002) have identified that cognitive training leads to better learning.

3.8 Theoretical framework

3.8.1 Theory selection

Over recent years, one pedagogical change in medical education has been the use of evidence (Guyatt, 1992; M. Harden, 1999) over intuition, unsystematic experience, or non-scientific rationale. Surgical training, however, has lagged in its adoption, with a poor scientific basis for education programs and outcome measures (Price et al., 2015). The role of SBST has a growing body of evidence (McGaghie et al., 2010; Zendejas et al., 2013), including laparoscopic surgical simulation (Al-Kadi et al., 2012). They, however, often lack scientific evidence in their development and implementation (Blackhall et al., 2019).

DP (Ericsson et al., 1993) has optimised training in many fields. It has been used as a framework for evaluating training and education in medical (Abraham & Singaram, 2019; Gauthier et al., 2015; Wang & Zorek, 2016) and non-medical fields (Jones et al., 2015; Kennedy & Fairbrother, 2019; Motta, 2011). Participants' *reaction* to the learning opportunities provided in training, rather than the intervention per se, is responsible for their changes (Wong et al., 2012). DP is a mechanism to improve this response. DP is the only framework that attempts to achieve *EP* in *all* participants with established effectiveness (Ericsson et al., 1993). DP contrasts with most existing education models, which aim to identify weak candidates for remedial measures. It focuses on exceptionally good performance and is not discriminant or corrective of inferior performance (Bond et al., 2007).

A systematic review conducted on perioperative feedback identified several limitations, including training and feedback being limited to the case at hand, teachable moments being primarily limited to trainee errors, feedback not being solicited by the trainee, and poor-quality, non-specific feedback (Katherine M McKendy et al., 2017). DP has the potential to overcome these limitations. Restructuring the training programmes by promoting DP will produce better outcomes. DP was therefore chosen as the theoretical framework for this study. It will be used to conceptualise the study, explain the findings, and extrapolate the study findings to future practice.

3.8.2 Use of theory in the project

As a surgical trainer, my primary focus in this study was on task design and feedback. The systematic review clarified the relative importance of each component (see methodology. The focus was also limited to DP and SBST as an educational tool, not in assessment. One main prerequisite for effective DP is high-quality and reliable performance measurements (McGaghie, 2008), which will support accurate feedback.

While this study is theoretically anchored in the DP framework as articulated by Ericsson and colleagues, it is important to recognise that the terminology itself was not familiar to many respondents. Instead, participants articulated experiences that embodied the constituent elements of DP—structured repetition, progressive refinement of skills, targeted feedback, and sustained effort—without explicitly identifying these as aspects of DP. Accordingly, the research employs these elements as proxies for the construct, thereby enabling an analysis of how pedagogical practices in surgical education resonate with or diverge from the DP model. This introduces both a theoretical and methodological challenge: the task of interpreting participants' descriptions through the lens of DP requires a degree of conceptual translation, ensuring fidelity to the theoretical model while remaining sensitive to the emic perspectives of respondents. Such an approach foregrounds the complexity of aligning an established theoretical framework with the lived realities of professional training contexts.

4 Methodology

4.1 Overview

The study was conducted in three phases. The findings of each phase were expected to guide the next by providing direction and scope for data collection and analysis.

The first phase is a systematic review of the literature on DP and SBST. The second phase, a quantitative survey, included a large and diverse sample of trainees, trainers, and expert surgeons to examine the current use of DP in SBST. The third phase comprised semi-structured interviews for a deeper exploration of the findings of phase 2. Phase 1 attempted to answer RQ1. Phases 2 and 3 used different approaches to answer the questions raised in RQ2 and RQ3. Phases 2 and 3 were parts of a mixed-methods study.

Since the study used DP, it had the following characteristics. It focused on surgical training, emphasising SBST for laparoscopic surgery. Perceptions of both trainees and trainers were evaluated. As the intended final outcome of DP is the attainment of EP by all participants, no performance ranking was made.

Modern surgical outcomes are already excellent. Identifying improvement in an already excellent system is difficult (Bond et al., 2007). A qualitative analysis was therefore chosen to explore surgical excellence further. Because of the abundance of evidence on simulation and DP, I felt it was essential to focus on the pedagogy of training programmes and the use of DP as an outcome (Bond et al., 2007).

4.1.1 Positionality

The researcher is a Professor in Surgery at the Faculty of Medicine, University of Colombo, Sri Lanka. He was a surgical trainee from 2013 to 2019 and a Consultant Surgeon since 2020. He has a strong interest in surgical training and medical education. He is involved in SBST for trainees in basic and advanced training. He also uses simulation to acquire new skills and maintain existing ones. He, therefore, understands the current limitations of SBST and looks towards DP as a mechanism to improve training further. The conduct of the study will therefore follow this positive outlook on DP.

The investigator, therefore, occupies an insider position within the surgical training ecosystem. This positionality enabled him to engage deeply with both trainers and trainees, drawing on shared language, experiences, and professional norms to facilitate trust and candid dialogue. This proximity, however, carries the risk of bias—particularly the potential to interpret data through the lens of his own beliefs about the value of DP and the limitations of the current training programmes.

To address this, the researcher actively engaged in reflexivity throughout the research process, maintaining a critical awareness of how my assumptions might influence data collection, analysis, and interpretation. Grounded in a constructivist epistemology, the study was approached with the belief that knowledge is not objectively extracted but co-constructed through interaction between the researcher and participants. The qualitative interviews were not merely data-mining exercises but relational encounters where meaning was negotiated in context. Similarly, the integration of quantitative findings was guided not only by statistical significance but by their alignment with the lived realities expressed in the qualitative phase.

The insider-outsider-ness will depend on the participants. Trainees may perceive him as an insider because he, too, was a trainee recently, but also as an outsider because he is currently a trainer. Other surgeons and trainers may consider him an insider. The researcher's perspective, while potentially influencing interpretation, also allowed for greater depth in understanding the complexities of implementing deliberate practice in real-world surgical training. By combining professional expertise with methodological transparency, the researcher has sought to honour the voices of participants and ensure the trustworthiness of the findings.

4.1.2 Mixed methods approach

The research used a sequential mixed-methods design (QUAN+qual) (Schoonenboom & Johnson, 2017) and framed within the pragmatist tradition of mixed methods, aligning with canonical frameworks by Creswell and Plano Clark (2017) and Greene et al (1989). This enabled diverse methods to be combined to address complex questions (e.g. implementation of DP) with both breadth and depth. Greene et al. (1989) emphasize purposes such as triangulation (seeking convergence between methods) and complementarity (using one method to elaborate findings of the other). The primary component was quantitative, with a supplemental qualitative element. A mixed-methods design was chosen to better understand the intricacies of DP and SBST through triangulation and complementarity (Schoonenboom & Johnson, 2017). At each stage, findings from one phase informed the next: for example, the survey was developed based on gaps identified in the literature (connecting data), and interview guides were shaped by quantitative results (explanatory sequential). This design reflects the mixed-methods proposition that combined use of both quantitative and qualitative approaches provides a better understanding of research issues than either approach alone (Palinkas et al., 2011).

Mixed methods research has generated extensive debate in educational research, particularly concerning the philosophical compatibility of quantitative and qualitative paradigms. While pragmatism is often cited as the most common unifying stance, tensions remain around epistemological coherence and the integration of divergent data types (Liu, 2022). In this study, integration was not limited to juxtaposing numerical and thematic results but involved an active synthesis in which quantitative trends informed the focus of qualitative inquiry, and qualitative insights contextualised statistical findings. This bidirectional influence aligns with 'interactive' or 'iterative' mixed methods designs described by Creswell & Plano Clark (2017). The process of integrating themes from different datasets, however, posed challenges, particularly reconciling variations in granularity, ensuring thematic comparability, and preserving the integrity of context-specific narratives while generating a coherent overarching account.

4.2 Phase 1 – Systematic reviews

4.2.1 Materials and methods

Two comprehensive reviews of randomised controlled trials and observational studies, including case-control, cross-sectional, and cohort studies, were conducted on DP-guided SBST, one focusing on open surgery and the other on minimal access surgery. The decision to produce two reviews was based on the preliminary observations on the differences in the SBST programmes in each category,

The search for relevant literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2015). The criteria based on Patient, Intervention, Comparator, and Outcome (PICO) are detailed below.

- Patients – Surgical trainees undergoing simulation-based learning
- Intervention – the use of DP
- Comparator – Other education interventions
- Outcome – Improvement in skill development

The review was registered on PROSPERO (CRD42024536662).

As a systematic review, this did not require approval from the institutional review board.

4.2.2 Literature search

MEDLINE, EMBASE, SCOPUS, ERIC, and Google Scholar were searched from inception to 31st January 2024 without any limitations. The reference lists of the selected articles were searched to identify any further studies.

The search terms used to search MEDLINE are given below. Similar searches were performed on other databases.

<u>For the review of open surgery</u>

1. Deliberate practice OR Purposeful practice OR Mastery
2. Simulation OR Simulation based learning OR Simulation based teaching OR Skills learning
3. Surgery
4. 1 AND 2 AND 3

For the review on minimal access surgery

1. Deliberate practice OR Purposeful practice OR Mastery
2. Simulation OR Simulation based learning OR Simulation based teaching OR Skills learning
3. Laparoscopic surgery OR robotic surgery OR minimal access surgery
4. 1 AND 2 AND 3

4.2.2.1 Study selection

Studies meeting the specified criteria were incorporated in the analysis. These criteria included: 1) Randomized controlled trials and observational studies (such as cross-sectional, case-control, or cohort studies), 2) investigating the impact of DP-informed SBST on enhancing surgical skills, and 3) having surgical trainees as the study participants. The term "Surgical skills" referred to any practical procedure outlined as a fundamental competency in the UK surgical training syllabus (Curriculum, 2017).

Research studies on other specialities like gynaecology and gastroenterology, as well as staff categories such as nurses, were not included in the analysis. The review specifically centred on the impact of DP-informed surgical skills training on surgeons' skill development, so articles addressing non-surgical, non-technical skills, and human factors like teamwork were also omitted.

The search results were uploaded to Rayyan QCRI (https://rayyan.qcri.org/). Two independent reviewers initially screened the titles and abstracts of the identified studies. Subsequently, full-text articles of the chosen studies were perused. All located articles were written in English. No limitations were placed on the type of article, sample size, or educational techniques employed. Reference lists of the included studies were examined to detect additional studies not captured by the initial search strategy (snowball sampling). In cases where multiple publications presented data from the same population, the most recent or comprehensive study was included.

Excluded studies and the reasons for exclusion were recorded. A third reviewer resolved any discrepancies between the initial reviewers.

4.2.2.2 Data extraction and quality assessment

The extracted data comprised the authors' names, publication year, study design, study type, participant characteristics, and Kirkpatrick assessment level (Kirkpatrick & Kirkpatrick, 2016), specific elements of the DP incorporated in the training program, and skill enhancement post-training. Two authors independently performed screening and data extraction. Any discrepancies were addressed by consulting the senior author through discussions.

Elements of DP and their definitions were identified from the publications of Ericsson et al (Ericsson, 2015; Ericsson & Harwell, 2019; Ericsson et al., 1993). The training programme for each article was perused to identify adherence to the original components and definitions.

The quality assessment of the chosen papers was conducted using the Modified Medical Education Research Study Quality Instrument (MMERSQI) (Al Asmri et al., 2023). This instrument comprises 12 items across seven domains, with numerical scoring allocated to each item. The potential scores range from 23.5 to 100.

To evaluate bias in the studies selected, the RoB2 tool was employed for randomised trials (Sterne et al., 2019), while the Risk Of Bias In Non-randomised Studies - of Exposure effects (ROBINS-E) and Risk Of Bias In Non-randomised Studies - of Interventions (ROBINS-I) were used for non-randomised studies (Sterne et al., 2016). The RoB2 tool consists of five scales and an overall bias risk judgment, categorising studies as low risk, some concern, high risk, or no information. On the other hand, the ROBINS-E and ROBINS-I tools assess studies based on seven domains, assigning ratings of low, moderate, serious, critical, or no information.

4.2.2.3 Findings

After the initial literature search, a decision was made to separately collate and analyse studies focusing on open and minimally invasive surgery. This was primarily because of the conceptual differences in psychomotor skills required in each surgical type. The training, therefore, was felt likely to reflect these changes.

Each of these articles have been submitted for publication.

The result of the systematic review is incorporated into the literature review (5.1.1 and 5.1.2).

The two full-text articles are included as an annexure (**Error! Reference source not found.**).

4.3 Phase 2 – Quantitative study

4.3.1 Research site

The investigator is based at the Faculty of Medicine, University of Colombo, Sri Lanka.

Participants for phases 2 and 3 were recruited from multiple training centres in Sri Lanka. The post-graduate surgical training programme in Sri Lanka is uniform and is governed by a single institution (the Post-Graduate Institute of Medicine).

4.3.2 Participants

The participants included surgical trainees of all experience levels, surgical trainers, and expert surgeons. The sample size calculation is described below.

Participants were invited to participate through colleagues of the principal investigator in respective centres. They were encouraged to invite their colleagues (snowball sampling). Expert surgeons were identified based on their surgical skills. Since the study focuses on expert performance, the inclusion was limited to evidence of exceptional surgical skill rather than other attributes like academic excellence. Anders-Ericsson et suggested that the acquisition and maintenance of expert performance (EP) requires sustained DP, and those who consistently exhibit superior performance, rather than those with the most experience, should be identified as experts (Ericsson, 2004).

4.3.2.1 Sample size calculation

As this is an exploratory study, convenience sampling was used.

The following composition was targeted, for a total of 50 participants.

- Trainees – 35
- Trainers – 7
- Expert surgeons – 8

4.3.3 Methods

This was conducted using a self-administered questionnaire. The areas to be explored and questions were derived from the findings of the systematic review (Phase 1).

Three separate questionnaires were used for trainees, trainers, and expert surgeons. All contained identical aspects but were worded appropriately. The data collection form was based on similar tools used in previous studies. These included a tool for feedback scoring based on DP framework developed by Gauthier et al (2015), and later adapted to undergraduate skills teaching by Abraham et a, (2019), systematic reviews on high-fidelity simulation by Issenberg et al (2005), and perioperative feedback by McKendy et al (2017), a questionnaire on feedback developed by Sender Liberman et al (2005), and a review on simulation by Bond et al (2007). These tools had been iteratively developed by the researchers. The scoring system developed by Gauthier et al had good internal consistency and reproducibility (Gauthier et al., 2015).

The questions focused on the following aspects and were distributed via a Google Form based self-administered questionnaire. Data collection forms are included as an annexure (9.1).

- Methods used in training
- The provision of feedback
    - The aspects included in the feedback
    - Extent of feedback
- Self-awareness of principles of simulation and DP
- Learning environment

Additionally, sociodemographic data and data on their prior surgical training were collected.

4.4 Phase 3 – Qualitative study

4.4.1 Participants

The participants included surgical trainees of all experience levels, surgical trainers, and expert surgeons. A representative sample from each participant group was selected and invited for individual interviews.

4.4.2 Sample size calculation

For phase 2, the following composition was targeted from 3 centres for a total of 24 participants.

- Trainees – 4 X 3 = 12
- Trainers – 2 X 3 = 6
- Expert surgeons – 2 X 3 = 8

4.4.3 Methods

I sourced a purposive sample of surgeons, trainers, and surgical trainees in Sri Lanka. They were chosen from the participants of Phase 2. Upon completion of phase 2, participants were asked about their willingness to participate in a qualitative study on surgical training and simulation to explore the findings further. Contact details (phone number and email address) for those who agreed to participate, and demographic details (age and gender) were maintained separately. They were stratified according to the above three types and the approach to DP and simulation.

All participants were considered to be eligible for inclusion in phase 3. From them, an attempt was made to include participants from the entire spectrum of attitudes towards self-guided learning and understanding of the principles of DP.

We emailed information packs containing an invitation letter (to participate in a confidential face-to-face interview), a participant information sheet and a consent form (to be handed over at the interview) to participants of each group. Two weeks after the email was sent, the principal investigator contacted participants to establish their willingness to participate in Phase 3. This led to the final list of potential participants (total n=53; expert surgeons (n=8), trainers (n=7), trainees (n=38)) (Figure 5-53). The principal investigator then followed up with the participants to schedule an interview and finally conducted the interviews. Female participants were only identified among trainees, and two out of the three participated in Phase 3. Participants were unaware of their scoring for self-guided training or deliberate practice, hence their categorisation.

Question in Phase 2	Answers	Code assigned
Stage of training	1- Consultant 2- Trainee	A – Expert surgeon B - Trainer C - Trainee
Self-guided training 1. When I practice, I know what I am doing 2. When I practice, I know what I need to achieve	Coded as percentages	>50% Very often + always – Possess the attribute <50% Very often + always – Lacks the attribute
Understanding of principles of Deliberate Practice 1. How important is repetitive practice to correct errors? 2. How important is feedback for effective learning?	Coded as percentages	>50% Very important + extremely important – Considers it important <50% Very important + extremely important – Doesn't consider it important

Table 4-1 Questions from phase 2

. Data was collected over three months, from July to September 2024. The principal investigator arranged with the participants to conduct in-depth face-to-face interviews using a semi-structured interview guide. The interview guide included open-ended questions with follow-up probing questions (Annexure 9.2). Prior to the interviews, the interview guide was pilot tested with three participants across the different groups to assess the salience and depth of data obtained during interviews. Questions about the design of the guide raised during the pilot testing were resolved through discussion with the supervisor.

Most interviews were conducted at the National Hospital of Sri Lanka, where the participants were employed / training. Some participants who were situated at other hospitals were interviewed in the respective hospitals. All the interviews were in English and lasted for 25 to 40 minutes.

The data was collected as semi-structured interviews. The areas explored were based on the DP framework. The specific areas were guided by the findings of Phases 1 and 2. Attempts were made to elicit more specific information to explore the findings of phase 2.

The interview questions began with a general discussion on surgical training in Sri Lanka and overseas. This was followed by questions exploring the problems they encounter during training, the use of simulation, and how the use of simulation could be improved. Probing questions were also used to elicit their understanding of deliberate practice and other principles of medical education. Then the participants were asked for suggestions for improving the training programme for minimal access surgery. This further expanded the discussion on using DP in improving learning outcomes using SBST. Probes were used wherever the extraction of more relevant information was possible (Annexure 9.2).

4.4.4 Data protection

The collected data was stored on a password-protected computer, accessible only to the investigator.

4.5 Data analysis

4.5.1 Quantitative data

The results of phase 2 were tested for normal distribution, and parametric / non-parametric tests were used appropriately. Findings were described using the mean/standard deviation or median/interquartile range. Correlation coefficient and regression analysis were used to identify the associations between the variables (e.g., correlation between the number of years as a trainee and the extent of DP used in training, using Spearman correlation).

Multi-group comparison was performed using the Kruskal-Wallis test (Kruskal & and Wallis, 1952).

4.5.2 Qualitative data

Interviews were recorded, anonymised, and downloaded/transcribed. During the interview, notes were also taken to ensure all the important information was captured. Some recordings were re-listened to determine nonverbal meaning. The researcher reflected upon what is being conveyed by participants to understand the hidden meanings of statements (Sharkey, 2001). Data was reviewed and coded to uncover general themes (Sohn, 2017) corresponding with elements of DP. A diary was maintained to document observations, experiences, and themes emerging during the interviews. Atlas.ti was used to organise and analyse data. First, the practices of individuals were described, with a subsequent focus on similarities between expert surgeons and differences between them and others. This concentrated on both their own skill development and how they train their trainees. The DP framework was used to analyse the qualitative data.

Coding was conducted in two phases: an initial phase (open coding) and a selective phase (focused coding). In the initial phase, each transcript was read to identify words, sentences, and instances participants used to describe their training, limitations, and suggestions for improvement. Frequent recurring initial codes were collected in the second phase, and different categories centred on DP and SBST were developed. This was followed by the final step of theoretical coding to establish conceptual interrelationships between the categories. Last, axial coding was conducted to relate codes, categories and concepts to each other using inductive and deductive approaches. Codes and findings were discussed with the supervisor to achieve consensus.

Data collection continued until no new data could be generated that advanced, modified, extended, or added to the theory produced from the collected data (Krueger, 2014). Findings were not shared with informants until the completion of the project, since the same person may experience reality differently at different individuals and times (Silverman, 2021).

In their conduct, the researcher refrained from including their own opinions on the topic to prevent influencing the participants' responses.

4.5.2.1 Justification for the study design and alignment with best practices

The methods employed in this phase of the study were carefully chosen to ensure methodological rigor and alignment with established standards in surgical education research. The use of semi-structured interviews as a primary qualitative tool reflects recognized best practices for exploring complex behaviours, perceptions, and cultural influences that are difficult to capture through quantitative measures alone (Brinkman & Kvale, 2014). Given the aim of understanding how DP is perceived and implemented within real-world SBST environments, qualitative inquiry provided the depth and flexibility needed to capture the nuances of trainer and trainee experiences.

The sampling strategy—purposive, stratified to include both trainees and trainers across different stages of training —was employed to enhance the richness and diversity of the data while ensuring theoretical relevance. This approach is consistent with qualitative research norms, which prioritise depth and contextual variety over statistical generalizability (Patton, 2002). The interview guide was informed by the DP framework and developed iteratively, with reference to similar studies in surgical education (e.g. (Gauthier et al., 2015)), ensuring content validity and relevance to the research questions.

Data collection was conducted in a manner consistent with the COREQ (Consolidated Criteria for Reporting Qualitative Research) guidelines, which advocate for transparency, reflexivity, and ethical rigour (Tong et al., 2007). Participants were interviewed in a confidential setting, and steps were taken to ensure psychological safety, particularly given the potential power dynamics between the researcher (a surgeon and trainer) and trainee participants. Transcripts were anonymised and securely stored in compliance with data protection standards.

For data analysis, the study employed systematic text condensation (STC), a pragmatic and widely accepted method in health professions education that allows for thematic synthesis without detaching findings from their empirical context (Malterud, 2012). This method provides a structured yet flexible analytic framework that facilitates the development of rich, practice-relevant themes grounded in participants' narratives. The use of STC allowed the research team to retain proximity to the data while generating actionable insights that inform educational design and institutional policy. This is further discussed below (4.5.2.2)

In line with gold-standard mixed methods practices (Creswell & Clark, 2017), the qualitative data was integrated with findings from earlier quantitative phases using a convergent design. This triangulation enhanced the credibility of the findings and allowed for the identification of points of convergence and divergence, a critical step in understanding the multi-layered barriers to implementing DP in surgical training.

Overall, the methodological decisions in this section reflect a commitment to robust, theory-informed, and context-sensitive inquiry—attributes that define high-quality research in medical education.

4.5.2.2 Systematic Text Condensation

Systematic Text Condensation (STC), as outlined by Malterud (2012), offers a valuable and practical framework for qualitative analysis that was felt to be well-aligned with the objectives and context of this study. This research was designed to investigate the development of expert performance through deliberate practice (DP) and identify the barriers to its implementation, especially in surgical simulation. The emphasis of STC on cross-case thematic analysis makes it particularly effective for examining interview data across the diverse participant groups in this study. By capturing variations in their experiences, STC ensures a coherent analytic structure that enhances understanding of the area explored.

Incorporating STC effectively supports the descriptive and exploratory aims of this study. This approach was instrumental in deepening our understanding of how DP is conceptualised and experienced within surgical training by the participants. Its ability to collate and focus unstructured data enabled valuable insights into how simulation is regarded as a purposeful practice tool, how feedback could be utilised, and the systemic and cultural challenges that may hinder successful implementation. This knowledge can pave the way for meaningful improvements and enhanced practices in the field.

STC's four-step procedure — which includes (1) establishing total impression and (2) meaning units and coding, (3) condensation, and (4) synthesis — offered a clear and structured approach for analysing qualitative data (Malterud, 2012). This also promoted transparency and rigour and fostered a reflective process vital for developing credible and contextually relevant interpretations. The STC method offers a systematic yet adaptable approach that effectively facilitates the analysis of data obtained from semi-structured interviews, even for those who may not have extensive experience with complex philosophical methodologies.

By facilitating the inductive development of themes based on participants' experiences, the method ensures a strong link between the conceptual framework of DP and other areas. STC's focus on setting aside preconceptions at the beginning of the process was particularly beneficial, as the researcher himself is a surgeon and a firm believer in the potential of DP. It allows participants' voices and experiences to come through clearly, aligned with the study's phenomenological approach. As the analysis progressed, incorporating theoretical perspectives on EP and DP enhanced the interpretation of emerging themes, successfully achieving both analytical depth and descriptive validity. Moreover, STC's relevance is further enhanced by its applicability to data from educational, clinical, and training settings (Crabtree & Miller, 1999; Sloth et al., 2023). STC was therefore chosen to supplement the qualitative component of this thesis and generate meaningful insights.

Using STC, similar ideas expressed by participants were grouped together. This combination of ideas enabled the production of sentences which used direct quotations and expressed a coherent idea. Direct quotations were indicated within the sentence. The distribution of participants that contributed to the generated statement was indicated at the end, using their identifiers given in

	Identifier	***Age***	***Self-guided training***	***Considers DP and SBST important***
	ES1	***40***	✔	✔

Expert Surgeons	***ES2***	***47***	✔	✔
	ES3	***48***	✔	✔
	ES4	***54***	✔	✔
	ES5	***61***	✔	***X***
Trainers	***T1***	***46***	✔	✔
	T2	***51***	✔	✔
	T3	***52***	✔	✔
	T4	***61***	✔	***X***
	T5	***67***	✔	***X***
Trainees	***L1***	***37***	✔	✔
	L2	***37***	✔	✔
	L3	***39***	✔	✔
	L4	***34***	✔	***X***
	L5	***34***	✔	***X***
	L6	***38***	✔	***X***
	L7	***30***	***X***	✔
	L8	***31***	***X***	✔
	L9	***37***	***X***	✔
	L10	***31***	***X***	***X***
	L11	***34***	***X***	***X***
	L12	***37***	***X***	***X***

Table 5-13.

4.6 Ethics approval

Approval was sought from the Ethics Review Committees of Lancaster University (EdRes-2024-4164-EdAp-2), and the National Hospital of Sri Lanka, Colombo, Sri Lanka (AAJ/ETH/COM/2024/JAN).

The conduct of insider research introduces several limitations and risks. One is the ethical concern of disclosing information shared with the researcher in the capacity of the insider, which may not have been shared in the sole capacity of a researcher (Burke, 1989; Taylor, 2011). One solution was to seek formal validation of the interpretation from the informant, with permission to disclose the findings (Taylor, 2011). This is particularly important in the surgical fraternity, as these could damage the profession's image. Furthermore, such disclosure may impact future research of the researcher as they might lose acceptance (Geertz, 1973). Though omissions are occasionally necessary in the research output (Taylor, 2011), even if they impede the findings, it was not required in this research.

Additionally, the researcher's relationship with all group participants has the potential to affect the data collection, where the participants may want to please the researcher. This may bias the responses of the participants. To overcome this, participants both known and unknown to the researcher were included, thereby having a mix of participants with "stronger and weaker bonds" (Taylor, 2011). Regardless of this degree of bond, the participants were from the same culture and cohort.

5 Results

The results are presented in three main sections. The first part includes the two systematic reviews. The findings of the mixed methods section are in two sections for the quantitative and qualitative findings.

Error! Reference source not found. Table 5-1 summarises how each research question was addressed in the mixed-methods study and answered in the results and discussion sections.

Research Question	Relevant Section	Key Findings
RQ1: What current evidence supports the use of Deliberate Practice (DP) in simulation-based surgical training (SBST)?	Results: Systematic Review Findings Discussion: Evidence Supporting DP in SBST	Strong support for using DP to improve skill acquisition, retention, and transfer, primarily when feedback and repetition are structured. However, most training lacks consistent implementation of DP principles.
RQ1.1: What is the evidence for each step of DP in surgical simulation?	Results: DP Elements: Feedback, Task Design, Repetition, Motivation Discussion: Evaluation of DP Components	Feedback and repetition are the most commonly implemented elements; motivation and individualised task difficulty are often neglected or inconsistently applied.
RQ1.2: What are the differences in benefits between structured practice, purposeful practice, and DP?	Results: Participant Perceptions of Practice Types Discussion: Comparing Practice Models	Limited evidence in literature. Not reported by any participants during interviews.
RQ2: How is DP currently used in SBST?	Results: Current Integration of DP in Practice Discussion: Improving training	DP is used inconsistently and informally. Most training programs include some elements (e.g., repetition) but lack full adherence to DP methodology.
RQ2.1: How do current training environments adhere to DP principles?	Results: Training Structure and Culture Discussion: *Gaps in DP*	Training environments often prioritise efficiency and service delivery over structured learning. Lack of protected time and feedback mechanisms hinders DP alignment.

RQ2.2: What are the differences in using DP between expert surgeons and trainees?	Results: Trainee vs. Expert Interviews Discussion: Different elements of DP	Experts engage more in reflective practice and structured self-assessment; trainees rely more on opportunistic learning. Cultural and workload differences play a role.
RQ3: What limits the integration of DP into SBST?	Results: Barriers to DP Implementation Discussion: Barriers to DP	Key barriers include limited time, faculty availability, poor understanding of DP, and institutional inertia. Systemic factors often override educational priorities.
RQ3.1: What are the perceived barriers to DP-based simulation in training?	Results: Thematic Barriers from Interviews Discussion: Cultural and Systemic Constraints	Time pressure, lack of faculty training, absence of formal feedback systems, and resistance to change were cited most frequently.
RQ3.2: What are the potential solutions to overcome these barriers?	Results: Improving training Discussion: Recommendations & Future Directions	Suggested solutions include integrating DP into curricula, creating faculty development programs, providing protected training time, and incentivising reflective practice.

Table 5-1 Summary of Research Questions

5.1 Phase 1 – Systematic reviews

There have been several limitations in using DP in medical research. DP has often been poorly implemented in research, and adherence to the original definition is crucial (Ericsson & Harwell, 2019). Furthermore, the alignment of DP with medical education pedagogy requires further attention (McGaghie, 2008). The DP framework also assumes minimal transfer in skills between apparently similar domains (Kirkman, 2013). These affect the utilisation of DP in SBST. Identifying adherence to individual components of DP and subsequent improvement in skills could enable better instructional design for SBST.

These two reviews attempted to collate the available evidence to guide the next phase of the study. This was chosen as the initial phase since it could guide the data collection and analysis of Phase 2. Certain areas (e.g. Details about the current training programme) were exclusively explored in the qualitative study, whereas others (e.g. SBST, DP) were included in both.

The review on open surgery[4] is under review with Simulation in Healthcare (Impact Factor 1.7), and the one on laparoscopic surgery[5] is under review with BMC medical education (Impact factor 2.7).

5.1.1 Systematic review on DP informed SBST for open surgery

The database search identified 585 articles. Three additional articles were identified through the references of the articles. Removal of duplicates identified 211 articles for title and abstract screening. This identified 44 articles for the full-text assessment. Twenty-two were eligible for data extraction and qualitative analysis.

Figure 5-1 shows the PRISMA diagram.

Twelve of the 22 articles were from the USA, while three each were conducted in Canada and Denmark.

Data from the included studies are shown in

	Learner motivation		Task design				Task design				Re
	To attend to the task	To improve their performance	Considers pre-existing knowledge	Appropriate levels and sequence	Demonstrates technique	Can be easily understood	Provides supervision	Immediate	Informative of their performance	Allows remedial training	Allows repetition
Misra et al (2024)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (green)	✗ (red)	✗ (green)	✗ (green)	✗ (green)	✗ (red)	✗ (red)
Li et al (2022)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (green)	✗ (red)	✗ (green)	✗ (green)	✗ (green)	✗ (green)	✗ (green)
Jensen et al (2022)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (green)	✗ (green)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (red)
James et al (2022)	✗ (yellow)	✗ (red)	✗ (red)	✗ (red)	✗ (green)	✗ (red)	✗ (green)	✗ (green)	✗ (green)	✗ (red)	✗ (red)
Saladanha et al (2021)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (green)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (red)
Asselin et al (2021)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✗ (green)	✗ (red)	✗ (green)	✗ (green)	✗ (green)	✗ (green)	✗ (green)

[4] A cut in the abdomen provides access to perform the surgery
[5] Surgery performed with the aid of a camera and multiple instruments inserted through small cuts ("keyhole surgery")

Korte et al (2020)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Hussain et al (2020)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Spratt et al (2019)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green
Long et al (2019)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Andersen et al (2019)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Tan et al (2018)	⊗ red	⊗ red	⊗ yellow	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Petrosoniak et al (2017)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Feins et al (2017)	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Andersen et al (2017)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Leger et al (2016)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Hsu et al (2016)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Rowse et al (2015)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ red	⊗ red	⊗ red	⊗ red
Andersen et al (2015)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Nesbitt et al (2013)	⊗ yellow	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ red
Price et al (2011)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green
Fann et al (2010)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green

Table 5-2 (Elements of DP) and

	Type	Country	Area studied	Overall program
Misra et al (2024)	RCT	USA	Thoracotomy	Single session
Li et al (2022)	Cohort	China	Cardiac surgery	4 weeks, 2 sessions each week
Jensen et al (2022)	Cohort	USA	Vascular anastomosis	2 visits
James et al (2022)	Cohort	UK	Hand surgery	1 visit

Saladanha et al (2021)	Cohort	USA	Cleft-lip surgery	1 visit	
Asselin et al (2021)	Cohort	Canada	Cricothyrotomy	150 minutes of practice, 1 visit, Bootcamp style	D
Korte et al (2020)	Cohort	Germany	Vascular anastomosis	Level 1 - Paper, Level 2 - Chicken leg, Level 3- Bovine heart	D
Hussain et al (2020)	Cohort	USA	Cardiac surgery	2 sessions on 3D printed heart	
Spratt et al (2019)	RCT	USA	Vascular anastomosis	8 weeks, 3 sessions per week, 20-30 min each	D a r
Long et al (2019)	Non-randomized trial	USA	Orthopaedic implant fixation	1 session, 30-min of practising, minimum 3 attempts within that time	
Andersen et al (2019)	Non-randomized trial	Denmark	Mastoidectomy	5 blocks of 3 sessions each	
Tan et al (2018)	RCT	USA	IC tube insertion	1 session of 1 hour	S ar
Petrosoniak et al (2017)	Observational	Canada	Cricothyrotomy	Minimum of 5 attempts	M
Feins et al (2017)	Observational	USA	Cardiac surgery	39 weekly sessions over the training programme	D
Andersen et al (2017)	Cohort	Denmark	Mastoidectomy	12 procedures	
Leger et al (2016)	RCT	France	IC tube insertion	Multiple attempts, minimum 4	
Hsu et al (2016)	Cross-sectional	USA	Knot tying	Multiple attempts, single session	
Rowse et al (2015)	Cross-sectional	USA	Bowel anastomosis	Single session	
Andersen et al (2015)	2x2 RCT	Denmark	Mastoidectomy	12 sessions	
Nesbitt et al (2013)	RCT	USA	Vascular anastomosis	weekly 4-months	
Price et al (2011)	RCT	Canada	Vascular anastomosis	10 sessions over 2 weeks	T fo v a
Fann et al (2010)	Cross-sectional	USA	Vascular anastomosis	Single session of 4-hours	V b t p

Table 5-3 (Other SBST characteristics).

5.1.1.1 Study design, participants, and structure of training

Seven studies were randomised controlled trials, two non-randomised controlled trials and seven cohort studies. Fourteen studies recruited surgical trainees/residents as participants, while the remaining three focused on medical students.

Most (n=6) of studies centred on vascular anastomosis, while three each studied cardiac surgery and mastoidectomy (

	Type	Country	Area studied	Overall program	s
Misra et al (2024)	RCT	USA	Thoracotomy	Single session	
Li et al (2022)	Cohort	China	Cardiac surgery	4 weeks, 2 sessions each week	
Jensen et al (2022)	Cohort	USA	Vascular anastomosis	2 visits	
James et al (2022)	Cohort	UK	Hand surgery	1 visit	
Saladanha et al (2021)	Cohort	USA	Cleft-lip surgery	1 visit	
Asselin et al (2021)	Cohort	Canada	Cricothyrotomy	150 minutes of practice, 1 visit, Bootcamp style	D
Korte et al (2020)	Cohort	Germany	Vascular anastomosis	Level 1 - Paper, Level 2 - Chicken leg, Level 3- Bovine heart	D
Hussain et al (2020)	Cohort	USA	Cardiac surgery	2 sessions on 3D printed heart	
Spratt et al (2019)	RCT	USA	Vascular anastomosis	8 weeks, 3 sessions per week, 20-30 min each	D as re
Long et al (2019)	Non-randomized trial	USA	Orthopaedic implant fixation	1 session, 30-min of practising, minimum 3 attempts within that time	
Andersen et al (2019)	Non-randomized trial	Denmark	Mastoidectomy	5 blocks of 3 sessions each	
Tan et al (2018)	RCT	USA	IC tube insertion	1 session of 1 hour	S ar
Petrosoniak et al (2017)	Observational	Canada	Cricothyrotomy	Minimum of 5 attempts	M
Feins et al (2017)	Observational	USA	Cardiac surgery	39 weekly sessions over the training programme	D
Andersen et al (2017)	Cohort	Denmark	Mastoidectomy	12 procedures	
Leger et al (2016)	RCT	France	IC tube insertion	Multiple attempts, minimum 4	
Hsu et al (2016)	Cross-sectional	USA	Knot tying	Multiple attempts, single session	

Rowse et al (2015)	Cross-sectional	USA	Bowel anastomosis	Single session	
Andersen et al (2015)	2x2 RCT	Denmark	Mastoidectomy	12 sessions	
Nesbitt et al (2013)	RCT	USA	Vascular anastomosis	weekly 4-months	
Price et al (2011)	RCT	Canada	Vascular anastomosis	10 sessions over 2 weeks	T fo v a
Fann et al (2010)	Cross-sectional	USA	Vascular anastomosis	Single session of 4-hours	V b t p

Table 5-3). Nine studies only used a single practice session. All other studies had multiple training sessions, spaced over a few weeks to nine months.

Nine studies used a dry lab, while one each combined dry and wet lab, wet lab and simulator, and wet lab and real surgery. Four studies each used a wet lab and virtual reality (VR).

Most studies evaluated learning at Kirkpatrick levels 1 and 2 (Change in attitudes or knowledge), often in combination. Li et al (2022) used a Kirkpatrick level 4a evaluation.

PRISMA 2009 Flow Diagram

Identification

Records identified through database searching

Additional records identified through other sources

Records after duplicates removed (n = 211)

Screening

Records screened (n = 211)

Records excluded (n = 167)

Full-text articles excluded, with reasons

Figure 5-1 PRISMA diagram

	Learner motivation		Task design				Task design				Repetition		Total score
	To attend to the task	To improve their performance	Considers pre-existing knowledge	Appropriate levels and sequence	Demonstrates technique	Can be easily understood	Provides supervision	Immediate	Informative of their performance	Allows remedial training	Allows repetition	Effort constraint	
Misra et al (2024)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (green)	5
Li et al (2022)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	7
Jensen et al (2022)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	1
James et al (2022)	⊗ (yellow)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (red)	4
Saladanha et al (2021)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	1
Asselin et al (2021)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	7
Korte et al (2020)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	7
Hussain et al (2020)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (red)	6
Spratt et al (2019)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	6
Long et al (2019)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	7

Andersen et al (2019)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	7
Tan et al (2018)	⊗ (absent)	⊗ (absent)	⊗ (unclear)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	7
Petrosoniak et al (2017)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (absent)	6
Feins et al (2017)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	7
Andersen et al (2017)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	7
Leger et al (2016)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (absent)	6
Hsu et al (2016)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	6
Rowse et al (2015)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	3
Andersen et al (2015)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	7
Nesbitt et al (2013)	⊗ (unclear)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (absent)	⊗ (present)	7
Price et al (2011)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	7
Fann et al (2010)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (absent)	⊗ (present)	⊗ (absent)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (present)	⊗ (absent)	6

Table 5-2 Adherence to DP principles

Key: ⊗ = Element present; ⊗= Element absent; ⊗= Unclear; Scores indicate the number of DP elements present.

	Type	Country	Area studied	Overall program	Form of simulation	Outcome measure (Kirkpatrick)	MMERSQI score
Misra et al (2024)	RCT	USA	Thoracotomy	Single session	Dry lab	1,2	77
Li et al (2022)	Cohort	China	Cardiac surgery	4 weeks, 2 sessions each week	Dry lab	4a	64
Jensen et al (2022)	Cohort	USA	Vascular anastomosis	2 visits	Dry lab	1	61
James et al (2022)	Cohort	UK	Hand surgery	1 visit	Wet lab	1	45
Saladanha et al (2021)	Cohort	USA	Cleft-lip surgery	1 visit	Dry lab	1,2	51
Asselin et al (2021)	Cohort	Canada	Cricothyrotomy	150 minutes of practice, 1 visit, Bootcamp style	Dry and wet lab	1,2	43
Korte et al (2020)	Cohort	Germany	Vascular anastomosis	Level 1 - Paper, Level 2 - Chicken leg, Level 3- Bovine heart	Dry and wet lab	1,2	57
Hussain et al (2020)	Cohort	USA	Cardiac surgery	2 sessions on 3D printed heart	Dry lab	2	67
Spratt et al (2019)	RCT	USA	Vascular anastomosis	8 weeks, 3 sessions per week, 20-30 min each	Dry lab, final assessment, real surgery	2,3	87
Long et al (2019)	Non-randomized trial	USA	Orthopaedic implant fixation	1 session, 30-min of practising, minimum 3 attempts within that time	Dry lab	1,2	64
Andersen et al (2019)	Non-randomized trial	Denmark	Mastoidectomy	5 blocks of 3 sessions each	VR	1,2	67
Tan et al (2018)	RCT	USA	IC tube insertion	1 session of 1 hour	Simulation and Cadaver	1,2,3	65

Petrosoniak et al (2017)	Observational	Canada	Cricothyrotomy	Minimum of 5 attempts	Mannequin	1,2	57
Feins et al (2017)	Observational	USA	Cardiac surgery	39 weekly sessions over the training programme	Dry lab and simulator	1,2	74
Andersen et al (2017)	Cohort	Denmark	Mastoidectomy	12 procedures	VR	1,2	64
Leger et al (2016)	RCT	France	IC tube insertion	Multiple attempts, minimum 4	Wet lab	1,2	74
Hsu et al (2016)	Cross-sectional	USA	Knot tying	Multiple attempts, single session	Dry Lab	1,2	63
Rowse et al (2015)	Cross-sectional	USA	Bowel anastomosis	Single session	Dry lab	1,2	45
Andersen et al (2015)	2x2 RCT	Denmark	Mastoidectomy	12 sessions	VR	1,2	81
Nesbitt et al (2013)	RCT	USA	Vascular anastomosis	weekly 4-months	Wet lab	2	69
Price et al (2011)	RCT	Canada	Vascular anastomosis	10 sessions over 2 weeks	Task trainer for practice, wet lab for assessment	1,2	84
Fann et al (2010)	Cross-sectional	USA	Vascular anastomosis	Single session of 4-hours	Wet lab for bootcamp, task trainer for practising at home	1,2	63

Table 5-3 Characteristics of the included studies

5.1.1.2 Elements of DP in SBST

There was a wide variation in the implementation of DP in skills training in the studies (

	Learner motivation		Task design				Task design				Re
	To attend to the task	To improve their performance	Considers pre-existing knowledge	Appropriate levels and sequence	Demonstrates technique	Can be easily understood	Provides supervision	Immediate	Informative of their performance	Allows remedial training	Allows repetition
Misra et al (2024)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)
Li et al (2022)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Jensen et al (2022)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)
James et al (2022)	⊗ (yellow)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)
Saladanha et al (2021)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)
Asselin et al (2021)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Korte et al (2020)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Hussain et al (2020)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Spratt et al (2019)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)
Long et al (2019)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Andersen et al (2019)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Tan et al (2018)	⊗ (red)	⊗ (red)	⊗ (yellow)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Petrosoniak et al (2017)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Feins et al (2017)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Andersen et al (2017)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Leger et al (2016)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Hsu et al (2016)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)

Rowse et al (2015)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)
Andersen et al (2015)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Nesbitt et al (2013)	⊗ (yellow)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (red)
Price et al (2011)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
Fann et al (2010)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)

Table 5-2).

5.1.1.2.1 Learner motivation

The DP model emphasises the importance of the learner's motivation to both attend to the task and improve their skill. Their explicit measurement is therefore essential in implementing DP.

Nesbitt et al (2013) recruited students who had expressed an interest in surgery. None of the other studies assessed the motivation of participants.

5.1.1.2.2 Task design

Tan et al (2018) assessed learners' prior experience and used it to assign participants into groups. They, however, did not use this information to structure the training. None of the other studies assessed prior experience.

Korte et al (2020) designed multiple difficulty levels, but all participants started their training at the same level. In the study by Feins et al (2017), participants first performed individual tasks before performing the complete procedure. None of the other authors had different levels in their training activities.

Feins et al (2017) focused on a range of procedures in cardiothoracic surgery but did not indicate if the study included explicit instructions or demonstrations of the tasks. Hsu et al (2016) also failed to provide explicit instructions to participants. Their study, however, focused on tying knots, a basic surgical skill. All other studies provided clear descriptions of the expected task. There were several methods used in teaching the skill, including videos (Asselin et al., 2021; Jensen et al., 2022; Rowse et al., 2015; Tan et al., 2018), reading material (James & Fawdington, 2022; Tan et al., 2018), lectures (Andersen et al., 2015; Asselin et al., 2021; Fann et al., 2010; Leger et al., 2016; Petrosoniak et al., 2017), and hands-on demonstrations (Korte et al., 2020).

Although the learning task was explicitly described in most studies, most authors did not evaluate the ease of understanding the instructions. Jensen et al (2022) provided videos of the procedure before the programme, and an in-person demonstration before beginning the task. None of the other studies indicated the ease of understanding.

5.1.1.2.3 Feedback

There were several types of feedback provided. These included human feedback from a tutor, self-assessment, or automated feedback. Automated feedback was always immediate, while tutor feedback could be given immediately or later.

In 15 studies, the feedback was provided by a tutor and was immediate. One study (Spratt et al., 2019) provided feedback on video recordings but at a later date. Three studies used feedback provided by the simulator (Andersen et al., 2017; Hsu et al., 2016; Long et al., 2019). In the studies that encouraged self-assessment as a form of feedback, it was guided by either video (Andersen et al., 2019) or a checklist (Andersen et al., 2015; Tan et al., 2018).

Automated feedback from the simulators was also indicative of their performance. Three studies (Jensen et al., 2022; Rowse et al., 2015; Saldanha et al., 2021) did not state the nature of the feedback. In other studies, the feedback provided was indicative of the participants' performance.

Most studies provided the opportunity for remedial training following feedback, but several studies did not allow this (James & Fawdington, 2022; Jensen et al., 2022; Misra et al., 2024; Rowse et al., 2015; Saldanha et al., 2021).

5.1.1.2.4 Repetition

Most studies, except the ones that did not permit remedial training (James & Fawdington, 2022; Jensen et al., 2022; Misra et al., 2024; Rowse et al., 2015; Saldanha et al., 2021) and the study by Nesbitt et al (2013) did not allow the opportunity for subsequent practice.

Most studies limited the duration of these sessions based on the effort constraint. The session duration ranged from 20 minutes (Misra et al., 2024) to four hours (Feins et al., 2017). Some studies did not limit the training duration, permitting practice up to the entire day (James &

Fawdington, 2022). Furthermore, studies attempted to ensure adequate gaps between sessions to prevent fatigue (Andersen et al., 2015; Feins et al., 2017).

5.1.1.2.5 Effect of DP in improving learning outcomes

All studies identified better learning following DP-informed simulation. Common outcome measures used included objective rating scales (Andersen et al., 2015; Hussein et al., 2020; Li et al., 2022; Nesbitt et al., 2013; Price et al., 2011; Spratt et al., 2019), custom rubrics (Jensen et al., 2022; Korte et al., 2020), surveys and self-assessments (Andersen et al., 2017; Asselin et al., 2021; Saldanha et al., 2021), and speed (Leger et al., 2016; Petrosoniak et al., 2017). The study by Misra et al failed to identify an improvement in knowledge (2024), but Li et al (2022) noted knowledge improvement.

Overall, the improvements in skill reported did not show a direct correlation with the number of items of DP implemented. Several studies (Misra et al., 2024; Rowse & Dearani, 2019; Tan et al., 2018) reported skill retention as well. The study by Petrosoniak et al (2017) assessed transfer validity.

Multiple studies (James & Fawdington, 2022; Li et al., 2022; Price et al., 2011) identified that the early introduction of SBST is better.

Most studies measured the skill before and after the training to assess improvement. Some studies measured the skill at intermediate time points (Fann et al., 2010; Feins et al., 2017; Spratt et al., 2019) and others measured the performance at every attempt, long(Andersen et al., 2015; Andersen et al., 2017; Long et al., 2019).

5.1.1.3 Study quality and bias assessment

Four of the six RCTs had a low risk of bias according to the ROB2 score, while the remaining two had some concerns. There was a wide variation in the bias in the non-RCTs. Five studies had some *concerns, while eight had a high risk of bias (*

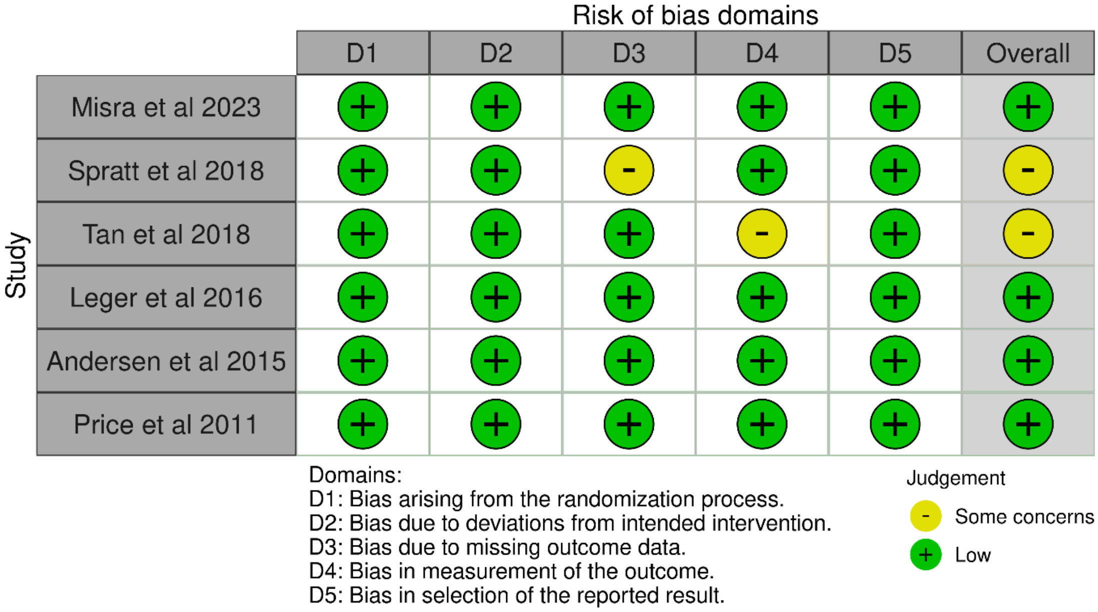


Table 5-4,

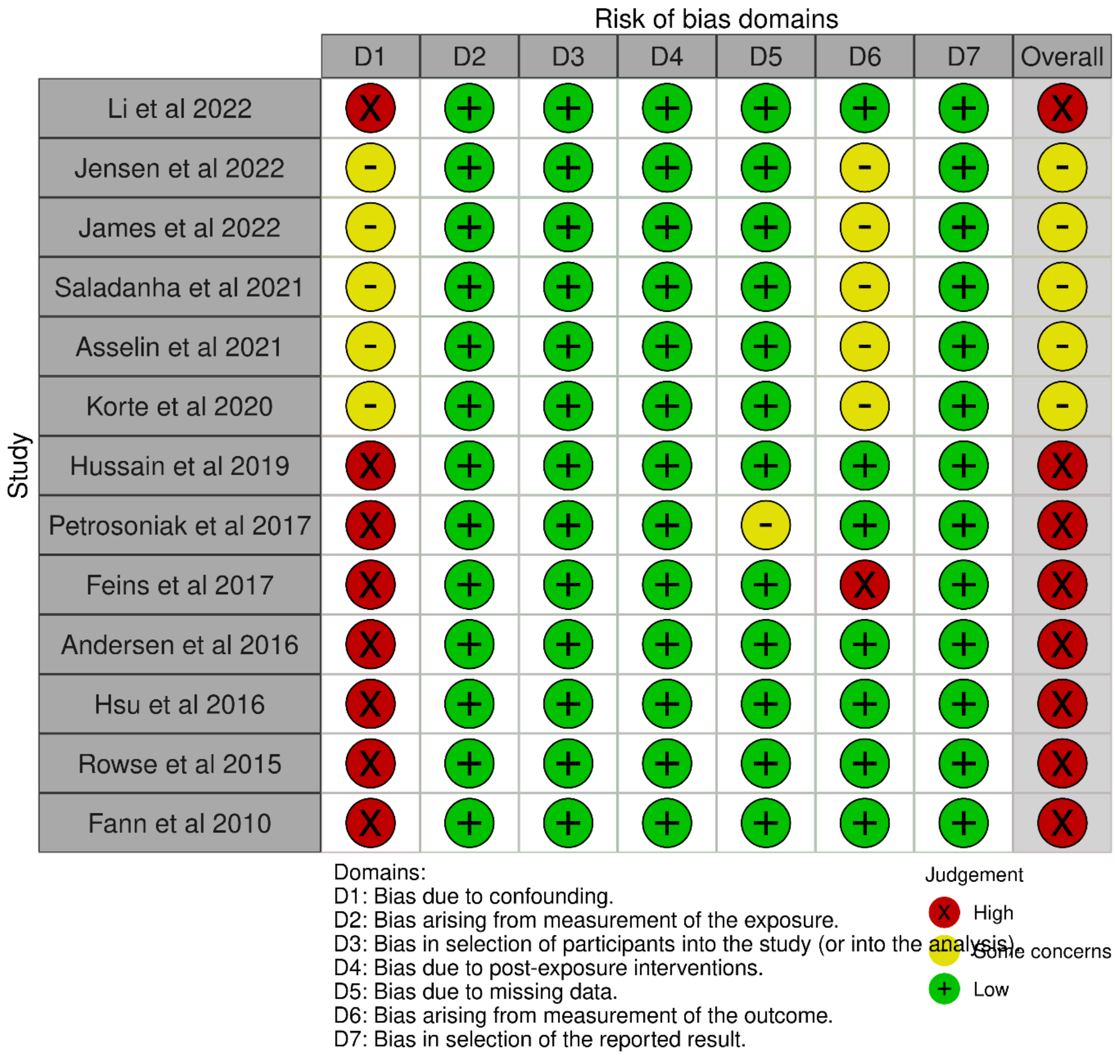


Table *5-5,*

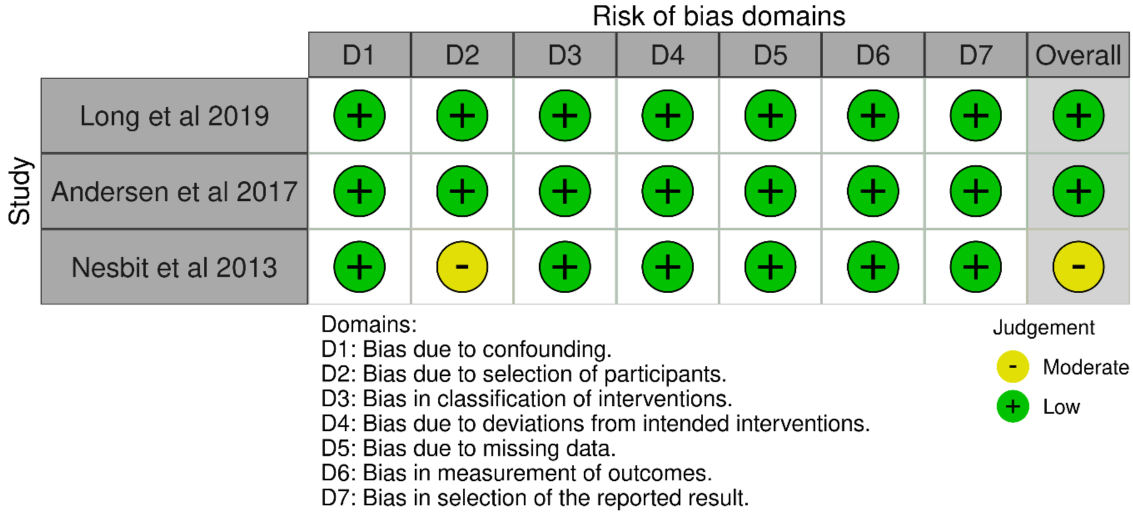


Table 5-6).

The quality of the studies, measured by (MMERSQI), ranged from 43 to 87, with RCTs consistently having higher scores (

	Type	Country	Area studied	Overall program	s
Misra et al (2024)	RCT	USA	Thoracotomy	Single session	
Li et al (2022)	Cohort	China	Cardiac surgery	4 weeks, 2 sessions each week	
Jensen et al (2022)	Cohort	USA	Vascular anastomosis	2 visits	
James et al (2022)	Cohort	UK	Hand surgery	1 visit	
Saladanha et al (2021)	Cohort	USA	Cleft-lip surgery	1 visit	
Asselin et al (2021)	Cohort	Canada	Cricothyrotomy	150 minutes of practice, 1 visit, Bootcamp style	D
Korte et al (2020)	Cohort	Germany	Vascular anastomosis	Level 1 - Paper, Level 2 - Chicken leg, Level 3- Bovine heart	D
Hussain et al (2020)	Cohort	USA	Cardiac surgery	2 sessions on 3D printed heart	
Spratt et al (2019)	RCT	USA	Vascular anastomosis	8 weeks, 3 sessions per week, 20-30 min each	D a r
Long et al (2019)	Non-randomized trial	USA	Orthopaedic implant fixation	1 session, 30-min of practising, minimum 3 attempts within that time	
Andersen et al (2019)	Non-randomized trial	Denmark	Mastoidectomy	5 blocks of 3 sessions each	

Tan et al (2018)	RCT	USA	IC tube insertion	1 session of 1 hour	S ar
Petrosoniak et al (2017)	Observational	Canada	Cricothyrotomy	Minimum of 5 attempts	M
Feins et al (2017)	Observational	USA	Cardiac surgery	39 weekly sessions over the training programme	D
Andersen et al (2017)	Cohort	Denmark	Mastoidectomy	12 procedures	
Leger et al (2016)	RCT	France	IC tube insertion	Multiple attempts, minimum 4	
Hsu et al (2016)	Cross-sectional	USA	Knot tying	Multiple attempts, single session	
Rowse et al (2015)	Cross-sectional	USA	Bowel anastomosis	Single session	
Andersen et al (2015)	2x2 RCT	Denmark	Mastoidectomy	12 sessions	
Nesbitt et al (2013)	RCT	USA	Vascular anastomosis	weekly 4-months	
Price et al (2011)	RCT	Canada	Vascular anastomosis	10 sessions over 2 weeks	T fo v a
Fann et al (2010)	Cross-sectional	USA	Vascular anastomosis	Single session of 4-hours	V b t p

Table 5-3).

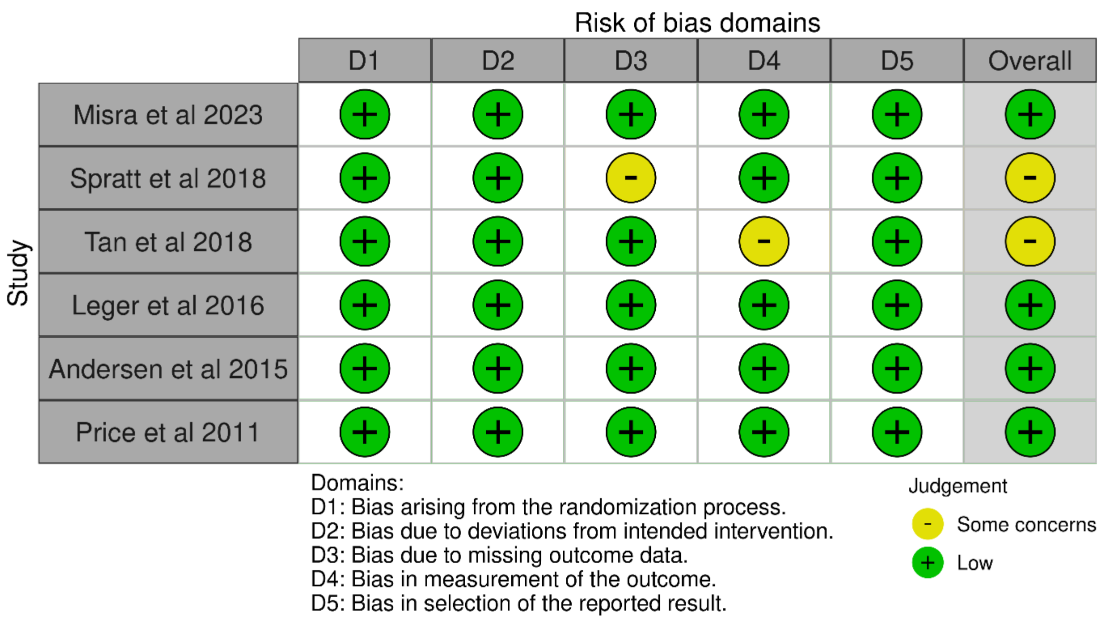


Table 5-4 ROB2 classification

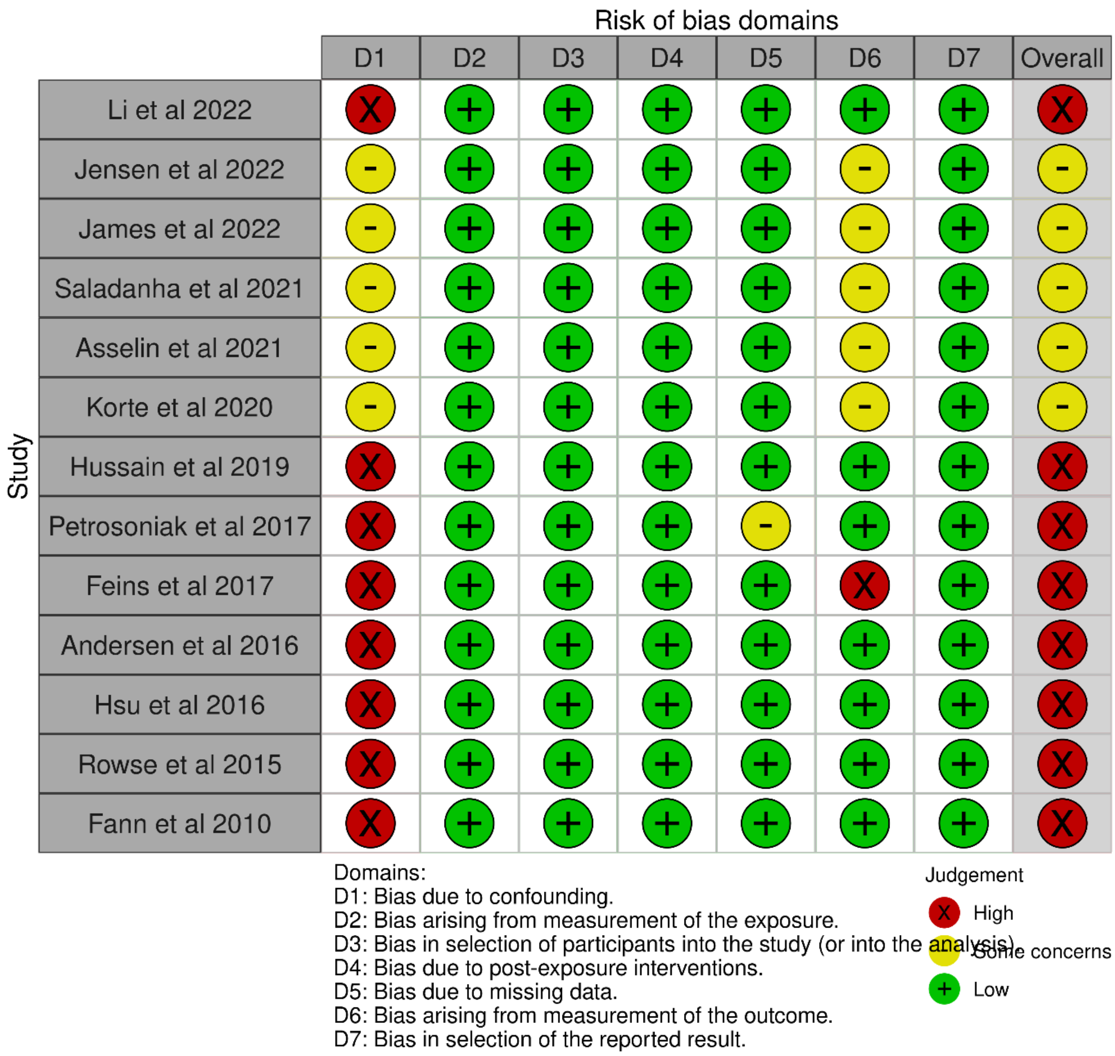


Table 5-5 Risk Of Bias In Non-randomised Studies - of Exposure effects (ROBINS-E)

Risk of bias domains

Study	D1	D2	D3	D4	D5	D6	D7	Overall
Long et al 2019	+	+	+	+	+	+	+	+
Andersen et al 2017	+	+	+	+	+	+	+	+
Nesbit et al 2013	+	-	+	+	+	+	+	-

Domains:
D1: Bias due to confounding.
D2: Bias due to selection of participants.
D3: Bias in classification of interventions.
D4: Bias due to deviations from intended interventions.
D5: Bias due to missing data.
D6: Bias in measurement of outcomes.
D7: Bias in selection of the reported result.

Judgement
- Moderate
+ Low

Table 5-6 Risk Of Bias In Non-randomised Studies - of Interventions (ROBINS-I)

5.1.1.4 Conclusions and recommendations for SBST design

This systematic review attempted to explore the utility of DP-informed SBST in developing open surgical skills. In summary, our results confirm that DP is an effective tool for designing SBST curricula. In summary, there was a wide variation in the implementation of DP in simulation training, with learner motivation being the least emphasised and demonstration of the technique being the best emphasised. Most studies were confined to Kirkpatrick level 1 or 2 assessments. Most studies analysed the skill before and after the intervention, while some measured the skill throughout the training. Learning with DP-informed SBST was better than control groups, but the improvement was not proportionate to the adherence to the framework. The study quality varied significantly, even among RCTs. The strength of the findings is most affected by this. These findings are similar to the findings of the systematic review on DP-informed simulation for laparoscopic training by the authors (Article under review).

Of the main domains of DP, learner motivation was universally ignored. Pre-training motivation predicts learning outcomes (Burke & Hutchins, 2008). The correlation between motivation and learning was reported to be 0.45 by Facteau et al (Facteau et al., 1995). Motivation could be extrinsic and intrinsic. For continued practice in DP in SBST, intrinsic motivation is mandatory (Stefanidis, 2010). The lack of emphasis on learner motivation could be one reason for the poor correlation observed between components of DP and outcomes.

Task design is also a key component of DP. Of its sub-components, providing a starting level appropriate for individual trainees' competence was universally ignored. Only Feins et al (2017) provided training which had multiple difficulty levels. All others had training of the same difficulty.

Most studies provided an explicit demonstration of the expected tasks, some in multiple forms. The authors did not, however, state if the participants easily comprehended these instructions.

DP-informed SBST differs from standard training in providing feedback, allowing for reflection on their performance for improved performance (Kneebone, 2003). Human feedback is superior to automated VR feedback metrics (Hashimoto et al., 2015), but human resource limitations, such as high instructor commitment and expensive equipment, make it challenging to implement DP-informed SBST in existing training programs. There are several potential solutions for this (Article under review). Introducing DP early in training can improve learning outcomes (De Win et al., 2013), as it encourages effective mental representation for self-directed practice (Ericsson & Harwell, 2019). Providing intensive supervision early in training can be cost-effective and enable learners to use VR systems effectively. Video recording of student training can reduce tutor time commitment (Charokar & Modi, 2021). The third option is the provision of an explicit objective tool for self-assessment.

Unlike minimal access surgery, open surgery is not routinely videoed. Despite this, several studies used video recording for participant assessment (Fann et al., 2010; Misra et al., 2024; Spratt et al., 2019). While collating these videos from multiple trainees minimises training programmes' time and resource commitments, they violate the DP principle of immediate feedback. Another alternative for minimising tutor resources is the use of peer feedback. Peer feedback for surgical training has been used successfully (McGann et al., 2021; Sheahan et al., 2019; Vaughn et al., 2016). The results of Vaughn et al (2016) indicated that peer feedback produced a better outcome than faculty feedback.

Self-assessment during SBST has been utilised earlier (Andersen et al., 2019), and existing evidence suggests that learners can accurately identify their mistakes (MacDonald et al., 2003). Moorthy et al identified a good correlation between self and expert assessment (Moorthy et al., 2006). Self-assessment accuracy improves with experience (Moorthy et al., 2006). Guided simulation without feedback is ineffective (Brydges et al., 2015; Tejos et al., 2021). Empowering learners with a guided self-assessment tool, in contrast, results in improved learning outcomes (Andersen et al., 2023).

Only one study (Hsu et al., 2016) in this series evaluated general surgical skills. All other studies focused on intermediate skills (e.g. bowel anastomosis (Rowse et al., 2015)) or surgical subspecialties (e.g. cardiac surgery). The studies on cardiac and vascular surgery often recruited senior trainees or consultant Surgeons. Existing evidence indicates that early introduction to SBST provides better outcomes (De Win et al., 2013). These results contrast with DP-informed SBST in laparoscopic surgery (Article under review). Furthermore, compared to our findings on training in minimal access surgery, there was a greater emphasis on whole-task training in the included studies.

As a systematic review, these findings are limited by the strength and quality of the included publications. The heterogeneity of the quality of the papers, as reflected in the bias, is a significant limitation of this study. Additionally, I limited the scope to developing psychomotor skills in surgical procedures and purposely ignored other domains of expertise, like clinical decision-making and communication. Furthermore, there was significant heterogeneity in the participant characteristics, learning outcomes, and training orchestration.

In summary, DP is a valuable tool for designing and delivering surgical training through simulation. The included studies confirm the effectiveness of DP-informed SBST for open surgery, with consistently better learning outcomes compared to standard educational techniques. The variable adoption of the elements of DP in number and definition into SBST remains the most significant confounder in interpreting the existing evidence. Future researchers should therefore pay careful attention to the instructional design of their training programmes, with strict adherence to the original definitions of the elements of DP.

5.1.2 Systematic review on DP-informed SBST for Laparoscopic surgery

The database search identified 585 articles. Three additional articles were identified through the references of the articles. Removal of duplicates identified 211 articles for title and abstract screening. This identified 115 articles for the full-text assessment. Ten articles were eligible for data extraction and qualitative analysis.

shows the PRISMA diagram.

Five of the ten articles were from North America, while four were from Europe.

Data from the included studies are shown in

	Learner motivation		Task design				Task design				Re
	To attend to the task	To improve their performance	Considers pre-existing knowledge	Appropriate levels and sequence	Demonstrates technique	Can be easily understood	Provides supervision	Immediate	Informative of their performance	Allows remedial training	Allows repetition
(Charokar & Modi, 2021)	green	green	red	green	green	amber	green	green	green	green	green
(Sinitsky et al., 2020)	red	red	green	green	green	green	green	green	green	green	green
(Baumann & Barsness, 2018)	red	red	red	red	green	amber	green	green	amber	red	red
(El-Beheiry et al., 2017)	green	green	red	red	green	red	red	red	green	green	green
(Aho et al., 2015)	green	green	red	red	green	amber	green	green	green	green	green
(Teitelbaum et al., 2014)	red	red	red	red	green	red	green	green	green	green	green
(Hashimoto et al., 2015)	red	red	red	green	green	green	green	green	green	green	green
(Palter & Grantcharov, 2014)	red	red	green	green	green	amber	green	green	green	green	green
(De Win et al., 2013)	red	red	red	green	green	amber	green	green	amber	green	green
(Crochet et al., 2011)	red	red	red	green	green	amber	green	green	green	green	green

Table 5-7 and

uthor	Country	Form of simulation	Outcome measure (Kirkpatrick)	Area studied	Overall program
kar & Modi, 2021)	India	Box-trainer	3	Laparoscopic surgery - generic and procedure-specific skills	12-week, structured training on box trainers, direct supervision
et al., 2020)	UK	VR	3	Laparoscopic appendicectomy - general and procedure specific	10 sessions
umann & ess, 2018)	USA	Not specified, likely VR	2	Laparoscopic paediatric surgery	3-hour didactic, 4-hour hands-on

heiry et al., 2017)	Canada	VR - LAPSIM	1	Laparoscopy general skills - camera, peg transfer, clipping	1-day a week, 5 months
t al., 2015)	USA	VR - Simsurgery, Lapsim Dry lab - Box trainer	3	General laparoscopic skills	6 weeks
baum et al., 2014)	USA	Box-trainer with simulated biliary system	2	Procedure specific - Common bile duct exploration	2 months
moto et al., 2015)	UK	VR - Lapmentor	3	General and procedure-specific skills	Not stated
alter & harov, 2014)	USA	VR - LAPSIM	4a	General and task-specific, also complete procedure	3-months
et al., 2013)	Belgium	Box trainer	3	General skills, procedure-specific skills	6-months
t et al., 2011)	UK	VR - LapMentor	3	General skills, procedure-specific skills, complete cholecystectomy procedure	6 weeks

Table 5-8.

5.1.2.1 *Study design, participants, and structure of training*

Five studies were randomised controlled trials, three were cohort studies, and two were cross-sectional studies. Eight studies recruited surgical trainees/residents as participants, while the two remaining studies focused on surgeons and medical students.

The majority (n=7) of studies centred on generic laparoscopic skills, while two (Crochet et al., 2011; Teitelbaum et al., 2014) and one (Sinitsky et al., 2020) respectively studied procedure-specific skills of appendicectomy and cholecystectomy. Only one study (Baumann & Barsness, 2018) had a single session "boot camp" style program. All other studies had multiple training sessions, spaced over a few weeks to six months.

Three studies (Charokar & Modi, 2021; De Win et al., 2013; Teitelbaum et al., 2014) used box trainers while others used virtual reality simulators for skills training.

Most studies evaluated learning at Kirkpatrick level 3 (Change in learning behaviour). One study (El-Beheiry et al., 2017) evaluated at Kirkpatrick level 1, while Palter et al (Palter & Grantcharov, 2014) used a Kirkpatrick level 4a evaluation.

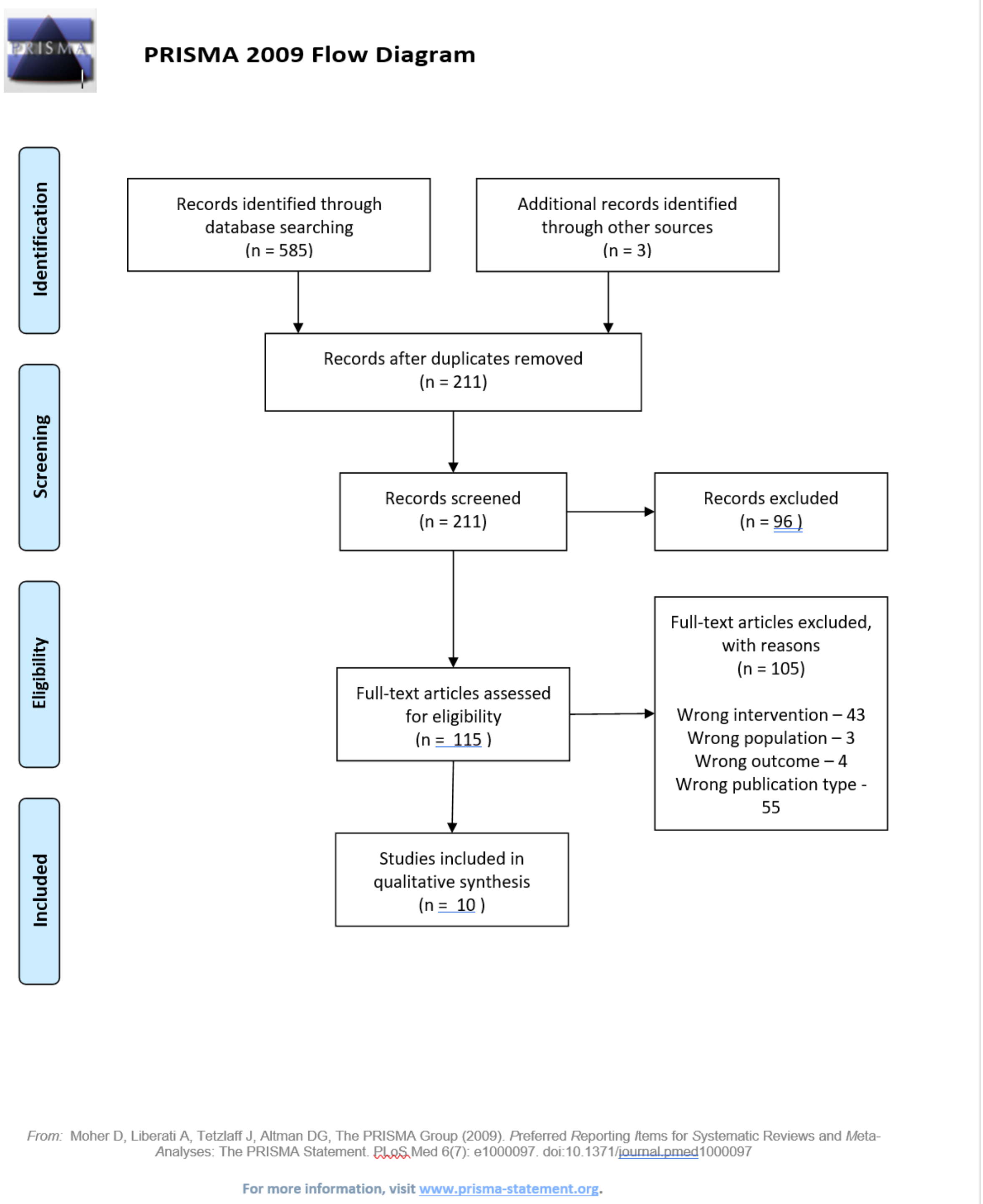


Figure 5-2 PRISMA flow diagram

	Learner motivation		Task design				Task design				Repetition		Total score
	To attend to the task	To improve their performance	Considers pre-existing knowledge	Appropriate levels and sequence	Demonstrates technique	Can be easily understood	Provides supervision	Immediate	Informative of their performance	Allows remedial training	Allows repetition	Effort constraint	
(Charokar & Modi, 2021)	⊗ green	⊗ green	⊗ red	⊗ green	⊗ green	⊗ yellow	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	10
(Sinitsky et al., 2020)	⊗ red	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	10
(Baumann & Barsness, 2018)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ yellow	⊗ green	⊗ green	⊗ yellow	⊗ red	⊗ red	⊗ red	3
(El-Beheiry et al., 2017)	⊗ green	⊗ green	⊗ red	⊗ red	⊗ green	⊗ red	⊗ red	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	7
(Aho et al., 2015)	⊗ green	⊗ green	⊗ red	⊗ red	⊗ green	⊗ yellow	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ red	⊗ red
(Teitelbaum et al., 2014)	⊗ red	⊗ red	⊗ red	⊗ red	⊗ green	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	7
(Hashimoto et al., 2015)	⊗ red	⊗ red	⊗ red	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ yellow	8
(Palter & Grantcharov, 2014)	⊗ red	⊗ red	⊗ green	⊗ green	⊗ green	⊗ yellow	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	9
(De Win et al., 2013)	⊗ red	⊗ red	⊗ red	⊗ green	⊗ green	⊗ yellow	⊗ green	⊗ green	⊗ yellow	⊗ green	⊗ green	⊗ yellow	6
(Crochet et al., 2011)	⊗ red	⊗ red	⊗ red	⊗ green	⊗ green	⊗ yellow	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	⊗ green	8

Table 5-7 Adherence to DP in laparoscopic surgical training

Key: ⊗ = Element present; ⊗= Element absent; ⊗= Unclear; Scores indicate the number of DP elements present.

Author	Country	Form of simulation	Outcome measure (Kirkpatrick)	Area studied	Overall program	MMERSQI total
(Charokar & Modi, 2021)	India	Box-trainer	3	Laparoscopic surgery - generic and procedure-specific skills	12-week, structured training on box trainers, direct supervision	63
(Sinitsky et al., 2020)	UK	VR	3	Laparoscopic appendicectomy - general and procedure specific	10 sessions	85
(Baumann & Barsness, 2018)	USA	Not specified, likely VR	2	Laparoscopic paediatric surgery	3-hour didactic, 4-hour hands-on	50
(El-Beheiry et al., 2017)	Canada	VR - LAPSIM	1	Laparoscopy general skills - camera, peg transfer, clipping	1-day a week, 5 months	64
(Aho et al., 2015)	USA	VR - Simsurgery, Lapsim Dry lab - Box trainer	3	General laparoscopic skills	6 weeks	67
(Teitelbaum et al., 2014)	USA	Box-trainer with simulated biliary system	2	Procedure specific - Common bile duct exploration	2 months	67
(Hashimoto et al., 2015)	UK	VR - Lapmentor	3	General and procedure-specific skills	Not stated	88
(Palter & Grantcharov, 2014)	USA	VR - LAPSIM	4a	General and task-specific, also complete procedure	3-months	84
(De Win et al., 2013)	Belgium	Box trainer	3	General skills, procedure-specific skills	6-months	77
(Crochet et al., 2011)	UK	VR - LapMentor	3	General skills, procedure-specific skills, complete cholecystectomy procedure	6 weeks	74

Table 5-8 Characteristics of the SBST

5.1.2.2 Elements of DP in SBST

There was a wide variation in the implementation of DP in skills training in the studies (

	Learner motivation		Task design				Task design				Re
	To attend to the task	To improve their performance	Considers pre-existing knowledge	Appropriate levels and sequence	Demonstrates technique	Can be easily understood	Provides supervision	Immediate	Informative of their performance	Allows remedial training	Allows repetition
(Charokar & Modi, 2021)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
(Sinitsky et al., 2020)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
(Baumann & Barsness, 2018)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (red)	⊗ (red)
(El-Beheiry et al., 2017)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)
(Aho et al., 2015)	⊗ (green)	⊗ (green)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
(Teitelbaum et al., 2014)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
(Hashimoto et al., 2015)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
(Palter & Grantcharov, 2014)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)
(De Win et al., 2013)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)
(Crochet et al., 2011)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)

Table 5-7).

5.1.2.2.1 Learner motivation

The DP model states the importance of the learner's motivation to 1) attend to the task and 2) improve their skill, and therefore the utility of their explicit measurement.

Only one study (Charokar & Modi, 2021) explicitly assessed learner motivation. Two others used motivation as a part of the intervention. El-Beheiry et al (2017) used gamification as a motivator, while Aho et al (2015) used mentoring as an intervention to improve motivation.

5.1.2.2.2 Task design

Only two studies (Palter & Grantcharov, 2014; Sinitsky et al., 2020) considered the pre-existing skill level when designing the training. Crochet et al (2011) and Hashimoto et al (2015) assessed prior experience but did not use it to structure the training.

Five studies (Crochet et al., 2011; De Win et al., 2013; Hashimoto et al., 2015; Palter & Grantcharov, 2014; Sinitsky et al., 2020) enabled stepwise progression during the training, while the results of Charokar et al (2021) identified the importance of stepwise progression in a skills training programme.

All training programs provided explicit instructions and demonstrated techniques to be followed. There was a wide range of formats used for this purpose, including video (Teitelbaum et al., 2014), simulator (Aho et al., 2015; El-Beheiry et al., 2017), and direct supervision (Baumann & Barsness, 2018; Sinitsky et al., 2020). Most, however, did not state whether participants found the instructions easy to follow.

5.1.2.2.3 Feedback

Two primary forms of feedback were provided in the studies, and some used a combination of the two. For the intervention group, six studies (Baumann & Barsness, 2018; Charokar & Modi, 2021; Crochet et al., 2011; De Win et al., 2013; Hashimoto et al., 2015; Teitelbaum et al., 2014) used feedback from the supervisors/mentors. Three studies (Aho et al., 2015; El-Beheiry et al., 2017; Sinitsky et al., 2020) used automated feedback from the simulators, while the study by Palter et al (2014) used a combination of human feedback and metrics from the simulator.

In all three studies where the system automatically provided the feedback, it was immediate. Except in the study by Hashimoto et al (2015), studies with human feedback did not explicitly state the timing of the feedback but was most likely immediate.

Automated feedback from the simulators was also indicative of their performance. Two studies (Baumann & Barsness, 2018; De Win et al., 2013) did not state the nature of the feedback. In other studies, the feedback provided was indicative of the participants' performance.

The study by Bauman et al (2018) did not provide an opportunity for remedial training after feedback. All other studies provided opportunities for remedial training, while in two studies (Aho et al., 2015; El-Beheiry et al., 2017) the intervention promoted this remedial training.

5.1.2.2.4 Repetition

Repetition of the learned task in their own time and pace was allowed by all studies except the study by Baumann et al (2018). This repetition was promoted as a part of the intervention by some studies (Aho et al., 2015; El-Beheiry et al., 2017).

Many studies limited the duration of these sessions based on the effort constraint. The session durations ranged from 20 minutes (Crochet et al., 2011) to 1 hour (Charokar & Modi, 2021; Palter & Grantcharov, 2014; Teitelbaum et al., 2014). Furthermore, studies attempted to ensure adequate gaps between sessions to prevent fatigue (El-Beheiry et al., 2017; Sinitsky et al., 2020). The study by Hashimoto et al (2015) did not state the duration of each session, but it appears likely to be the longest of all included studies, as it had multiple components.

5.1.2.2.5 Effect of DP in improving learning outcomes

All studies identified better learning following DP-informed simulation. Common outcome measures used included accuracy (Aho et al., 2015; El-Beheiry et al., 2017; Hashimoto et al., 2015), speed (Aho et al., 2015; El-Beheiry et al., 2017; Hashimoto et al., 2015), confidence (Baumann & Barsness, 2018; Teitelbaum et al., 2014), and objective skills rating (Crochet et al., 2011; Hashimoto et al., 2015; Palter & Grantcharov, 2014). Overall, the improvements in skill reported did not show a direct correlation with the number of items of DP implemented.

Several studies identified improvement in skills in the control group (Crochet et al., 2011; De Win et al., 2013; Hashimoto et al., 2015). Compared to the intervention (DP) arm, a primary characteristic of this improvement is that they reached the peak sooner and remained at a lower level (Crochet et al., 2011; Hashimoto et al., 2015). In measuring outcomes, most studies used objective measures (Crochet et al., 2011; De Win et al., 2013; El-Beheiry et al., 2017; Hashimoto et al., 2015; Palter & Grantcharov, 2014; Teitelbaum et al., 2014), although subjective measurements were also made by some authors (Baumann & Barsness, 2018). Several studies measured the skills before and after the intervention (De Win et al., 2013; El-Beheiry et al., 2017; Palter & Grantcharov, 2014; Sinitsky et al., 2020; Teitelbaum et al., 2014), while some others made measurements throughout the training period (Aho et al., 2015; Crochet et al., 2011; De Win et al., 2013; El-Beheiry et al., 2017; Hashimoto et al., 2015). Only one study (De Win et al., 2013) assessed skill decay.

5.1.2.3 Study quality and bias assessment

Four of the five RCTs had a low risk of bias according to the ROB2 score, while the remaining one had some concerns. There was a wide variation in the bias in the non-RCTs. Three studies had some concerns, while two had a high risk of bias (

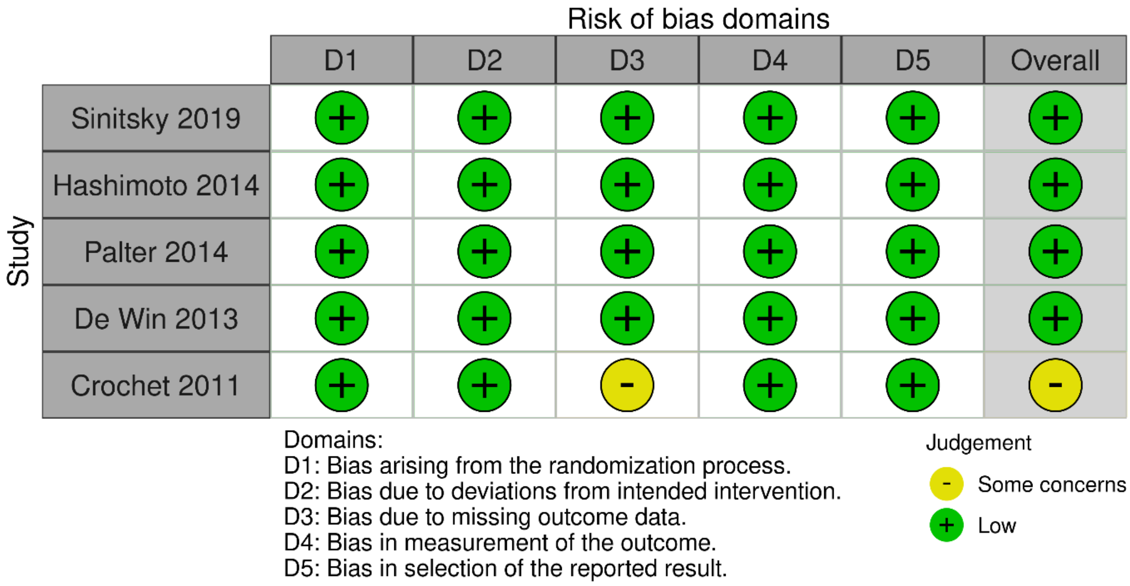


Table 5-9 and

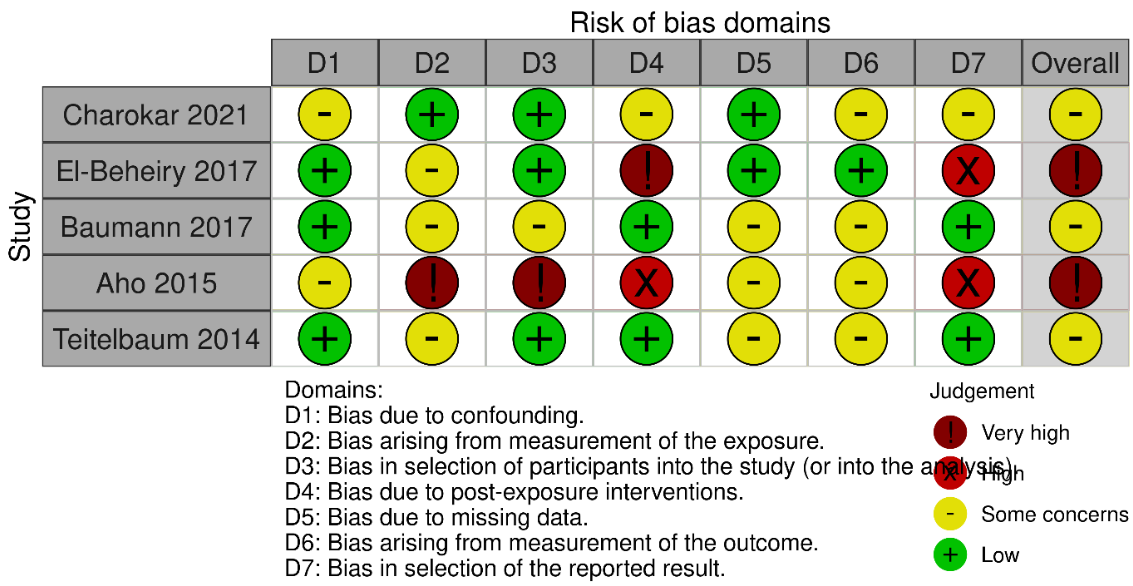


Table 5-10).

The quality of the studies, measured by (MMERSQI), ranged from 50 to 88, with RCTs consistently having higher scores (

	Learner motivation		Task design				Task design				Re
	To attend to the task	To improve their performance	Considers pre-existing knowledge	Appropriate levels and sequence	Demonstrates technique	Can be easily understood	Provides supervision	Immediate	Informative of their performance	Allows remedial training	Allows repetition
(Charokar & Modi, 2021)	Green	Green	Red	Green	Green	Yellow	Green	Green	Green	Green	Green
(Sinitsky et al., 2020)	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green
(Baumann & Barsness, 2018)	Red	Red	Red	Red	Green	Yellow	Green	Green	Yellow	Red	Red
(El-Beheiry et al., 2017)	Green	Green	Red	Red	Green	Red	Red	Red	Green	Green	Green
(Aho et al., 2015)	Green	Green	Red	Red	Green	Yellow	Green	Green	Green	Green	Green
(Teitelbaum et al., 2014)	Red	Red	Red	Red	Green	Red	Green	Green	Green	Green	Green
(Hashimoto et al., 2015)	Red	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green
(Palter & Grantcharov, 2014)	Red	Red	Green	Green	Green	Yellow	Green	Green	Green	Green	Green

(De Win et al., 2013)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)
(Crochet et al., 2011)	⊗ (red)	⊗ (red)	⊗ (red)	⊗ (green)	⊗ (green)	⊗ (yellow)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)	⊗ (green)

Table 5-7).

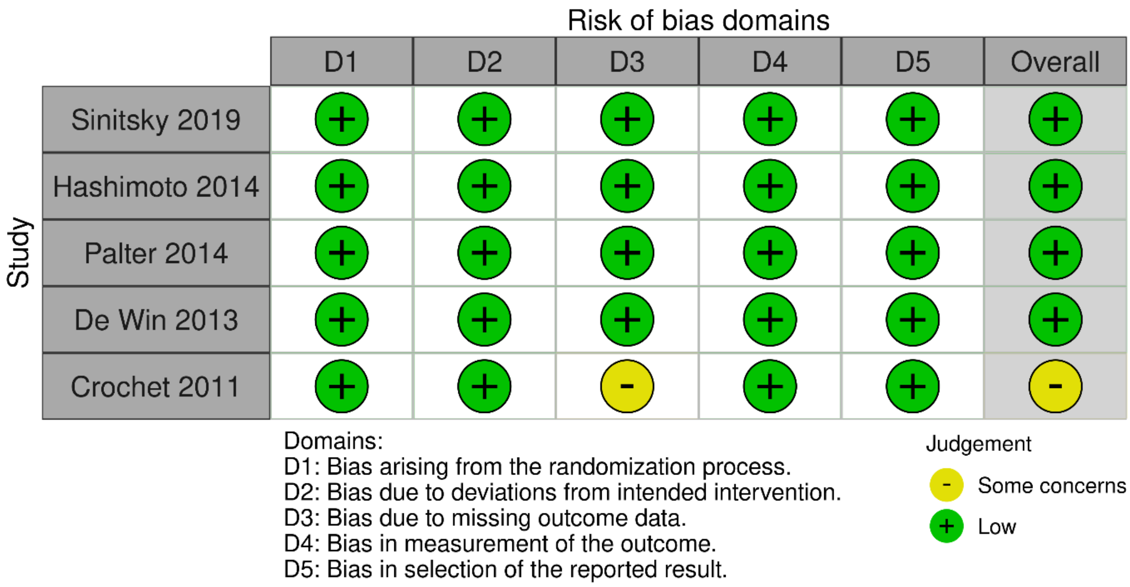


Table 5-9 ROB2 classification

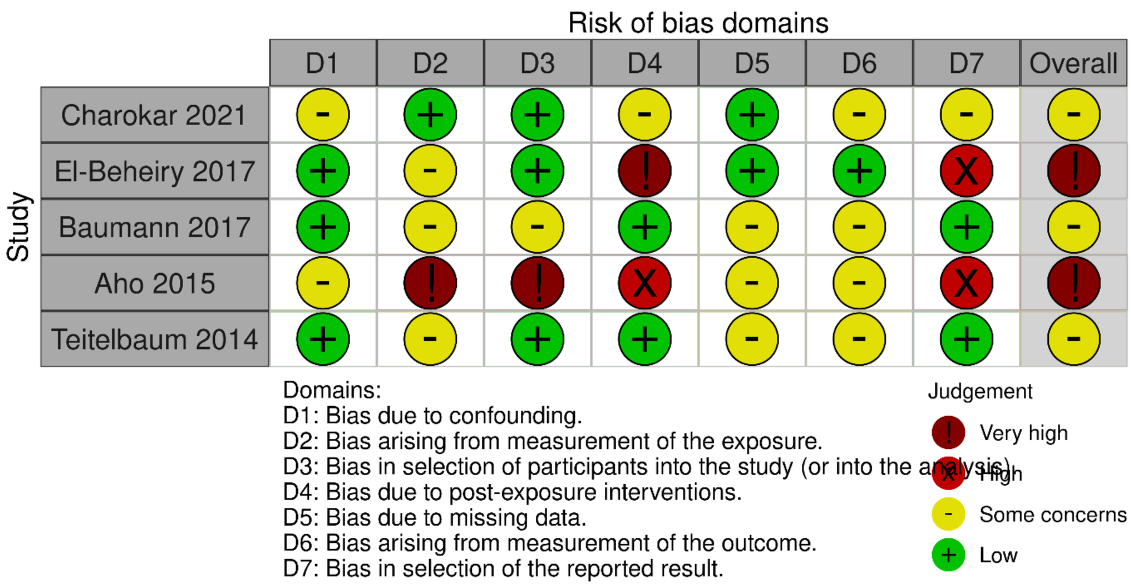


Table 5-10 Risk Of Bias In Non-randomised Studies - of Exposure effects (ROBINS-E)

5.1.2.4 Conclusions and recommendations for SBST design

This systematic review aimed to identify the effectiveness of DP-informed SBST in developing laparoscopic surgical skills. The findings indicate that DP is an effective tool to guide SBST design. Most studies analysed the skill before and after the intervention that was based on DP, while some assessed the skill at multiple points during the training. One study looked at skill retention after the initial learning. The study quality varied significantly, even among RCTs, and bears the most significant impact on the strength of the findings.

Surgical training has historically followed a Halstedian approach (McGaghie et al., 2011a), where junior surgeons work as apprentices with a more senior surgeon and receive progressively increasing responsibility and autonomy in operating. Although time-tested, this approach has been met with resistance more recently due to work hour restrictions limiting training opportunities (de Montbrun & Macrae, 2012), and concerns about ethics and patient safety on "practising" a procedure on patients (Bond et al., 2007). SBST was welcomed as a solution to all these limitations. Results of SBST, however, do not consistently demonstrate better learning. One explanation for this is the inefficient instructional design of the existing SBST, which does not maximise the potential for learning (Higgins et al., 2021). DP aims to develop expert performance in all participants and provides an explicit prescription in its application. DP-informed SBST should, therefore, optimise the learning outcomes from SBST.

Repetition has consistently proven to improve psychomotor skills (Higgins et al., 2021), and this is the most likely explanation for the improvements observed in the control groups in the included studies. One characteristic of the improvement in the control groups, however, is that it remained lower than the DP group, and the peak was achieved earlier (Crochet et al., 2011). This is a classic example of performance plateauing described in the DP framework, aptly termed “arrested development” (Anders Ericsson, 2008). DP remains the best tool for overcoming this.

One dominant difference between DP and standard training is the feedback provided. The opportunity to reflect on errors is essential for improving future performance (Kneebone, 2003). Even in studies that focused on both automated feedback from the VR systems and human feedback, human feedback was superior to VR feedback metrics alone (Hashimoto et al., 2015). Human resources are likely the most significant limitation to the ideal implementation of DP-informed SBST. The required instructor commitment in the included studies is phenomenal, especially the ones with a tutor: student ratio of 1 (Higgins et al., 2021). Unless significant financial and policy changes are made, this requirement will unlikely be accommodated within the existing training programmes outside the research setting. Even replacing human feedback with automated metrics from VR would require expensive equipment capable of real-time metrics.

Two solutions could overcome this. Even in studies informed by DP, better learning outcomes were noted when DP was introduced early (De Win et al., 2013). This is consistent with the DP framework, where effective mental representation (Ericsson & Harwell, 2019) is essential for a learner to identify their own mistakes and take corrective action. Therefore, providing intensive supervision early in the training to develop a mental representation adequate for subsequent self-directed practice may provide the most cost-effective option for human resource allocation. This would empower learners to optimally use VR systems' automated feedback to develop their skills. Another option available is video recording of student training, for tutors to review later and provide feedback, which has been attempted previously (Charokar & Modi, 2021). This significantly reduces the time commitment of tutors. This asynchronous feedback, however, is against the DP principle of “immediate feedback” (Ericsson et al., 1993). Unlike open surgery, MIS will always have a video camera focusing throughout the procedure on the operative steps. MIS, therefore, yields well to video-based feedback.

The DP framework attempts to develop "expert performance" in all participants. Application of this to psychomotor skill training in surgery is not straightforward. Unlike sports and music, fields with extensive evidence on the use of DP, surgery lacks both an explicit definition of expert performance and a demand for all surgeons to perform at the same level of expertise. The performance level expected from a certified surgeon is far below the competency of the best surgeons. Only the study by Sitinsky et al (2020) used expert performance as a benchmark. DP, therefore, may not be ideally aligned with the principles of surgical training.

The opportunity to reflect and practice following feedback is another key component of DP. All studies except one (Baumann & Barsness, 2018) enabled this. A recent Best Evidence in Medical Education (BEME) review identified a dose-response relationship between hours of practice and learning outcomes (Issenberg et al., 2005). Without direct observation and feedback, training risks becoming a tick-box exercise (Shalhoub et al., 2017).

Psychomotor skills needed for MIS are more complex than those needed for open surgery. Studies have also shown that 8% will be incapable of learning MIS skills, despite adequate training (Grantcharov & Funch-Jensen, 2009). DP, perhaps, could be the solution to their training. Our findings, however, indicate that among the included studies, reported skill gains did not mirror the number of items of DP adhered to. The most likely explanation for this is that the extent to which each item was incorporated into the training program is challenging to quantify. Ericsson et al have repeatedly emphasised the importance of adhering to the original definitions of the DP framework in research (Ericsson & Harwell, 2019). The review focused entirely on psychomotor skill development. EP in surgery extends beyond psychomotor skills. Decision-making remains an important aspect. This is ignored in most of the included studies, as they were confined to performing a single task ("task trainers") (Aho et al., 2015; El-Beheiry et al., 2017). A pedagogically valid assessment of this complexity is difficult. Furthermore, the results of this review are limited by the scope of the included studies. Most included studies had small sample sizes. No study assessed long-term retention of skills.

In summary, DP is a valuable instructional design tool for structuring and orchestrating SBST. DP informed SBST consistently provided better psychomotor skill learning compared to standard training. The most significant limitation of existing literature on DP-informed SBST is the variable adoption of its elements, both in number and form. Strict adherence to DP, however, is likely to produce superior training results than conventional training.

5.2 Phase 2 – Quantitative study

The findings of this phase will be discussed in the subsections of surgical training, simulation in surgical training, and DP.

5.2.1 Demographics

There were 53 participants, which included eight surgeons, 7 trainers, and 38 trainees. Fifty participants were males. The mean age of the group was 36.0 (SD – 9.8) years. The age, sex, and experience distribution of subgroups are indicated below.

Group	Age	Sex	Years as a surgeon
Expert surgeons	46 (±6.8) years Range 40-61	8 males	12.9 (±7.1) years Range 4-25
Trainers	60 (±8.1) years Range 44-67	7 males	26.3 (±12.5) years Range 8-40
Trainees	34 (±2.3) years Range 30-39	Male: Female 35:3	3.7 (±1.9) years Range 1-7

Table.5-11 Demographics of the participants

5.2.2 Simulation-based surgical training (SBST)

This section focuses on the availability and usage of simulation training.

More ES employed simulators for skills training and assessment (greater than 75%) than trainees (

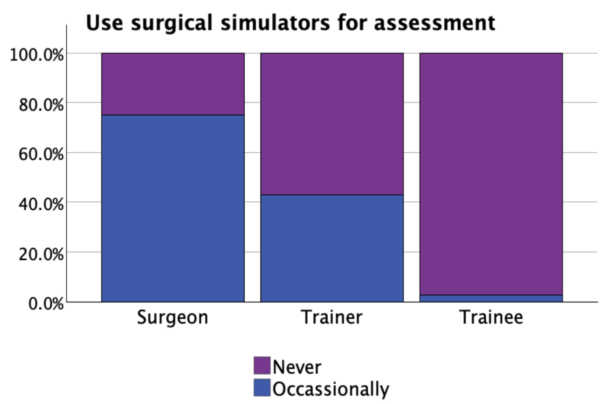


Figure 5-3 and

Figure 5-4). Even the ES, however, used it occasionally.

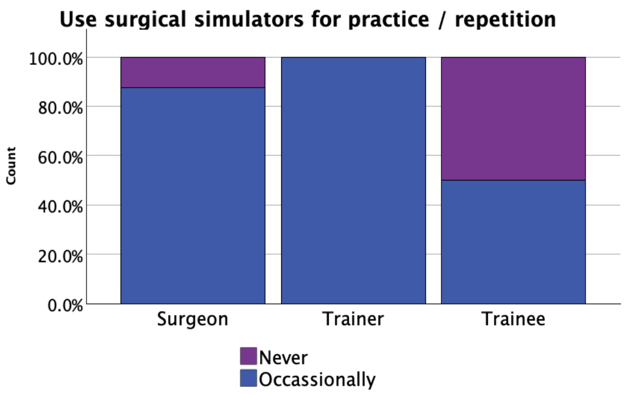


Figure 5-3 Use of simulators for practice

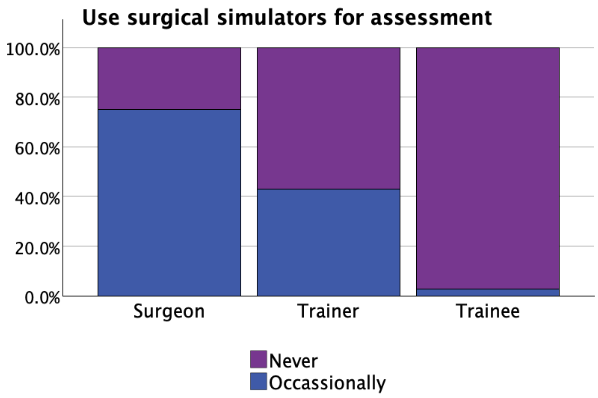


Figure 5-4 Use of simulators for asessment

While nearly 40% of ES utilised simulators for formative feedback (Figure 5-5), trainees have yet to adopt this practice.

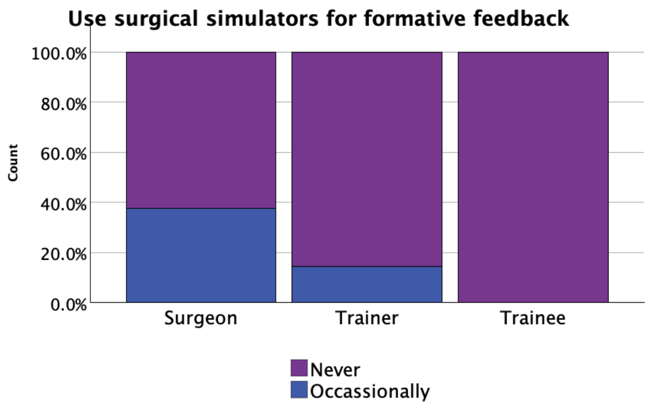
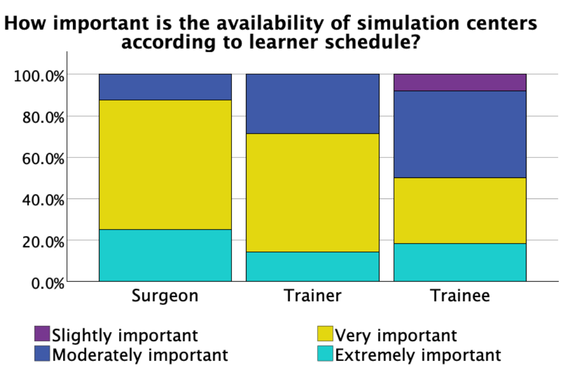


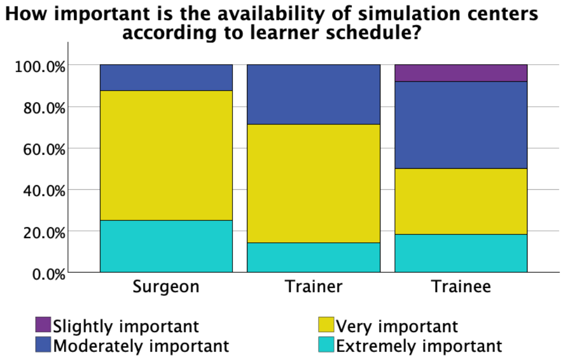
Figure 5-5 Use of simulators for formative feedback

Over 90% of ES felt the availability of a simulation centre was important, while only 50% of the



trainees stated this was important (

Figure 5-6). In establishing a simulation centre, 2/3rd of ES and trainers felt the location was important, but only a



minority of trainees shared this view (

Figure 5-6).

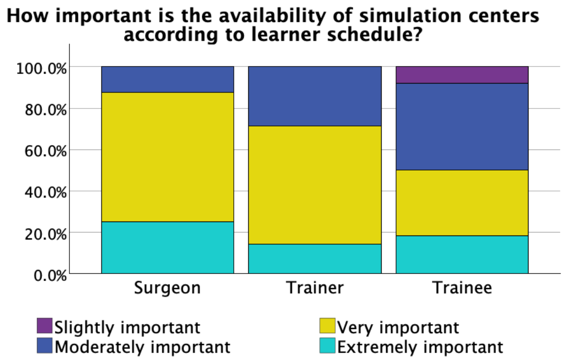


Figure 5-6 Importance of availability of simulation centers according to learner schedule

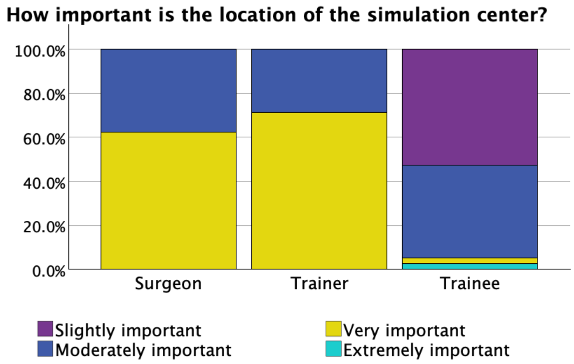


Figure 5-7 Importanec of location of the simulation center

Although all three groups agreed that integrating the simulation training into the existing programme was important, this was expressed by a disproportionately higher percentage of trainers than other groups (Figure 5-8).

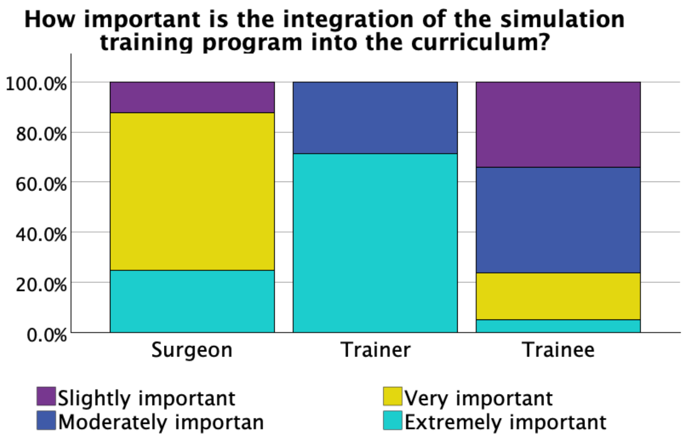
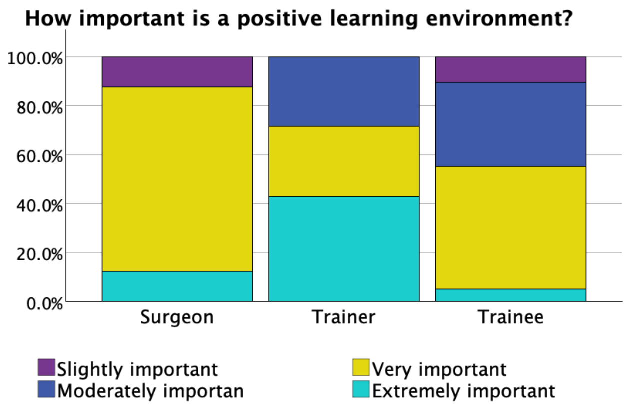


Figure 5-8 Importance of intergation of the simulation training

Using objective measures and a positive learning environment were felt to be important to all three groups (Figure 5-9 Importance of objective performance measures). A greater significance was attributed to a positive environment by ES, with trainers and trainees attributing less



importance (

Figure 5-10).

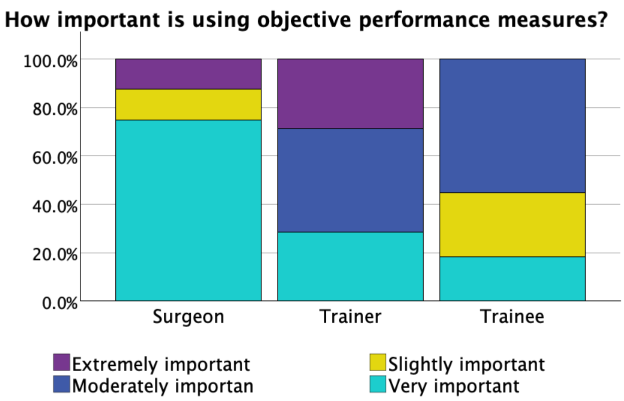


Figure 5-9 Importance of objective performance measures

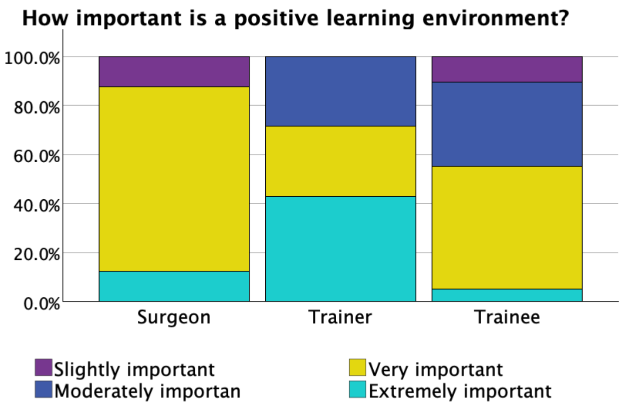
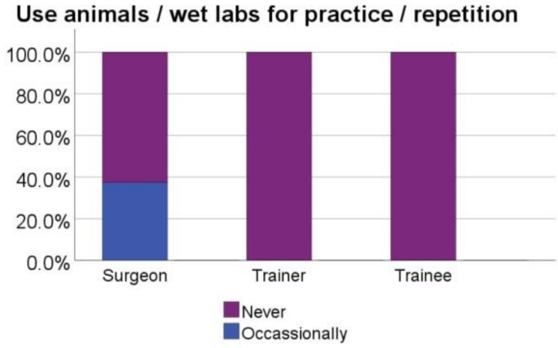


Figure 5-10 Importance of a positive learning environment

ES occasionally engaged with simulators (over 85%) and cadavers (more than 60%) for practice, compared to their



trainee counterparts (Figure 5-11 and

Figure 5-12). The participation, however, was still very low.

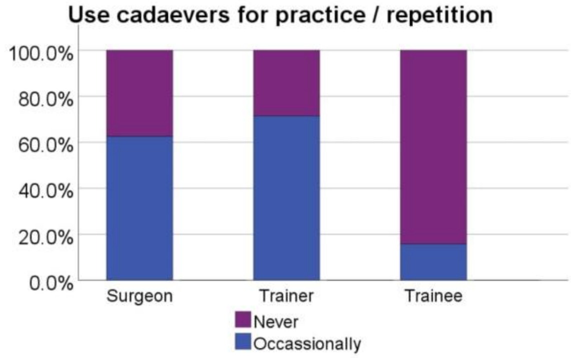


Figure 5-11 Use of cadavers for practice

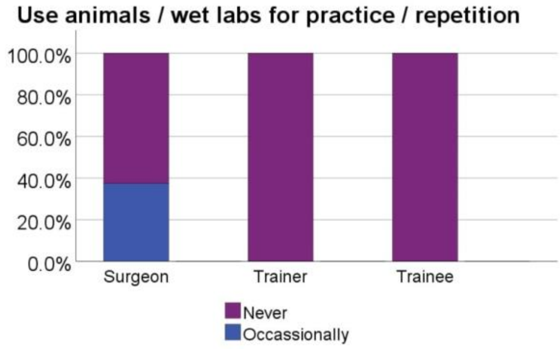


Figure 5-12 Use of animals for practice

5.2.3 Deliberate practice

This section focuses on each element discussed in the literature review section 3.6.3.

5.2.3.1 Learner motivation

The median self-reported usual level of motivation by trainees was 80% (±11.1), measured on a visual analogue scale of 0-100. The value reported by expert surgeons (when they were in training) was 83.8% (10.6). Trainers, however, reflected that their trainees ' motivation was 25% (±11.8).

There was a significant difference in the motivation levels between groups (Kruskal-Wallis test, Test statistic 12.04, p=0.002). This was due to the difference between the self-reported values of trainees and the perceived levels of motivation by trainers (p<0.001). There was no difference between expert surgeons and trainees.

Purpose	Surgeon	Trainer	Trainee
Improve my identity, autonomy and independent practice	78.8 (15.3)	68.6 (13.4)	74.5 (12.9)
Develop my self-confidence and personality	75 (17.7)	84.3 (7.9)	75.5 (9.5)
Gain confidence in my potential	77.5 (16.7)	78.6 (9)	73.9 (10.0)
Acquire skills to be a more responsible and autonomous surgeon	83.8 (10.6)	78.6 (10.7)	74.2 (10.8)

Table 5-12 Motivation of trainees

The level of experience had different effects on the motivation. ES showed a decline in motivation with increasing experience (Spearman Rho -.73, p=0.038), while trainers indicated an increasing motivation (rho 0.95, p<0.001). No change was seen among trainees.

In summary, ES were more motivated than trainees. Furthermore, trainers felt that trainees were less motivated than their self-claims in some respects. While trainees' motivation for SBST was constant among all aspects, ES were more motivated to pursue SBST to learn a new skill.

5.2.3.2 Task design

Availability of SBST tasks with a range of difficulties to suit the competence of the trainer was felt to be important by all three groups, and in nearly identical proportions (

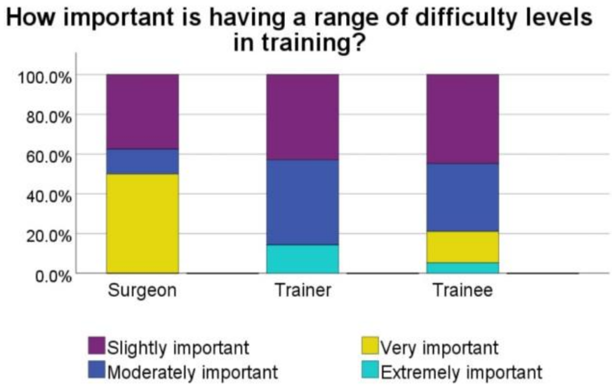


Figure 5-13). The range of clinical variation in the available training tasks was felt to be less important by all groups (

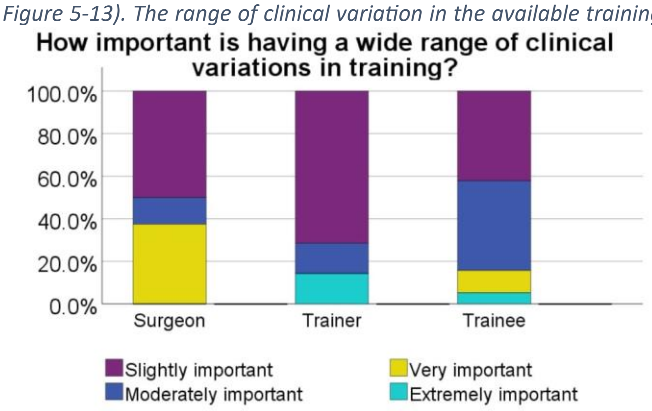


Figure 5-14).

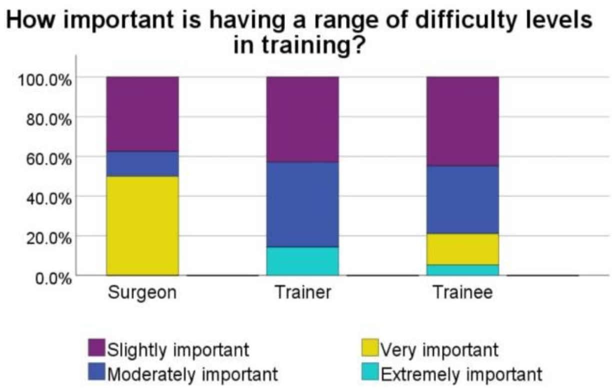


Figure 5-13 Importance of having a range of difficulty levels

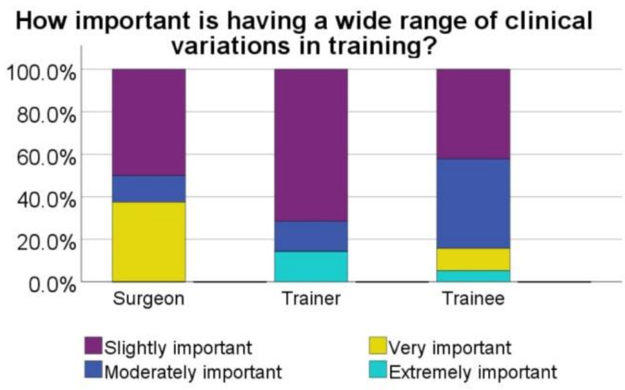


Figure 5-14 Importance of having a range of clinical variation

Training that was individualised to the competence level and learning styles of each participant was felt to be very important by trainers, but by fewer ES and trainees (

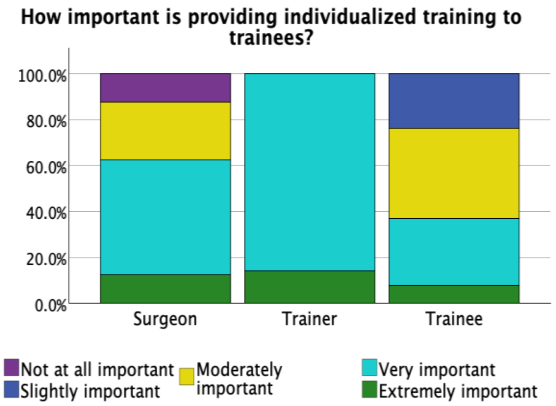


Figure 5-15).

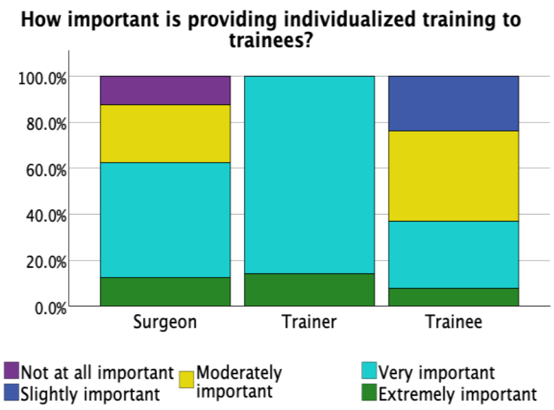


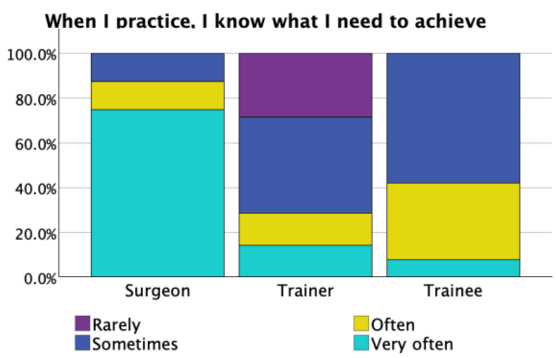
Figure 5-15 Importance of individualized training

5.2.3.3 Feedback

The feedback trainers provided, and the trainees and expert surgeons had received, showed significant differences. The results have been grouped as content of feedback and self-assessment.

5.2.3.3.1 Self-evaluation

The study highlighted several key insights into the training practices of Expert Surgeons (ES) compared to current trainees. Notably, ES reported a strong understanding of their training objectives, with nearly 90% of their practice time focused on clear goals. In contrast, fewer than 50% of trainees reported feeling the same way, and trainers felt this figure to be even lower (25%) (



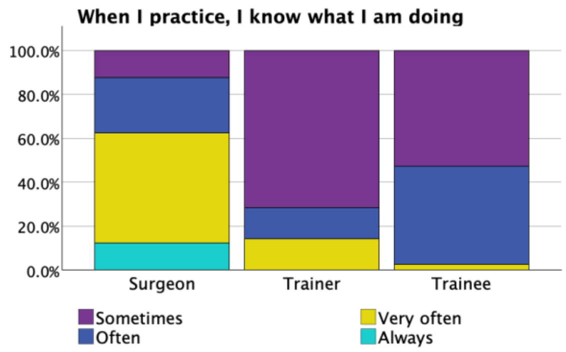


Figure 5-16 and

Figure 5-17).

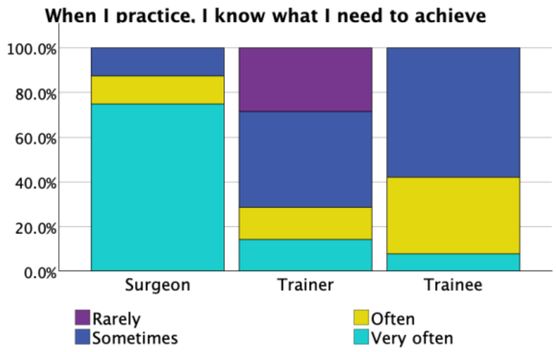


Figure 5-16 When I practice, I know what to achieve

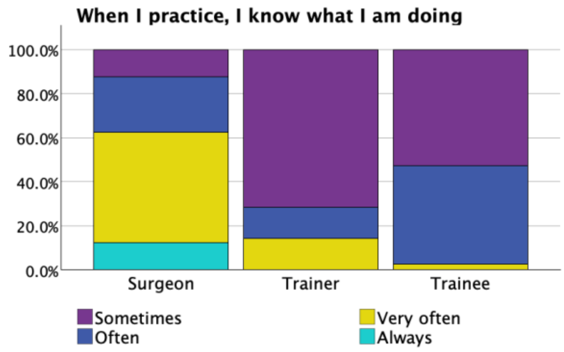


Figure 5-17 When I practice, I know what I am doing

Furthermore, ES claimed that, as trainees, they effectively utilised each training session as part of a long-term practice plan (nearly 90% of the time), while only 20% of trainees reported doing the same. Like previous findings, Trainers felt this practice was less common among trainees than they claimed (

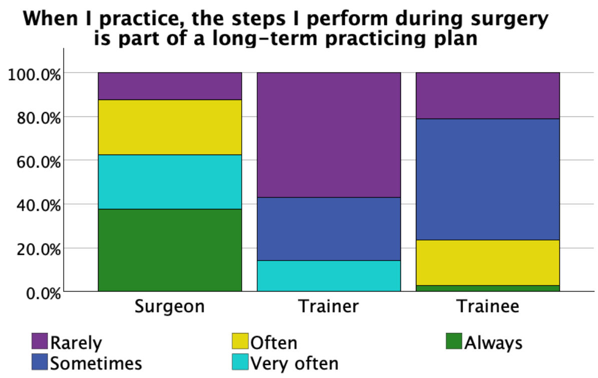


Figure 5-18).

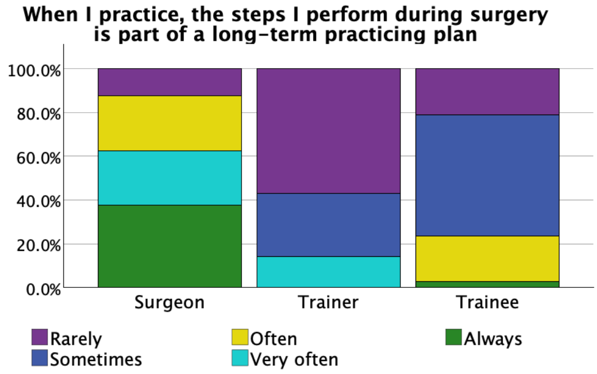
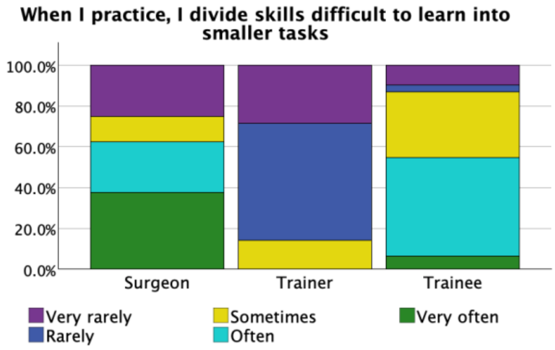


Figure 5-18 The steps I practice are a part of a long term practicing plan

Both ES and current trainees claimed breaking down complex tasks into smaller, manageable



components when they practice (

Figure 5-19). This was done during any skills that are difficult to master (

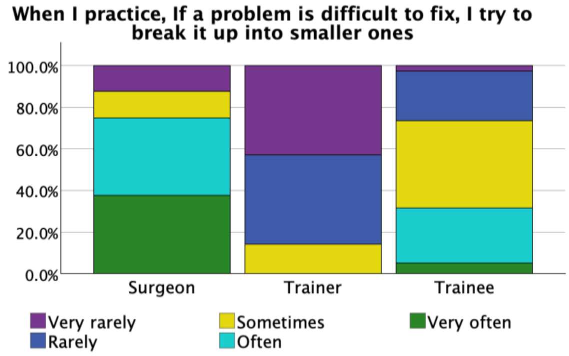


Figure 5-20), as well as in deconstructing a surgical procedure into sequential elements for learning (

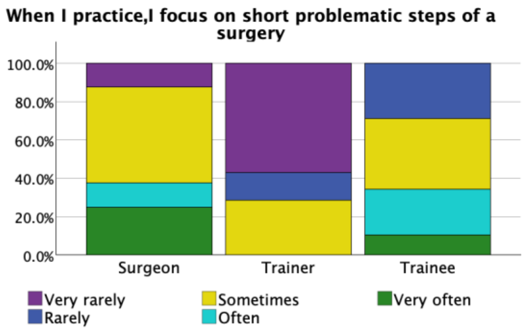


Figure 5-21).

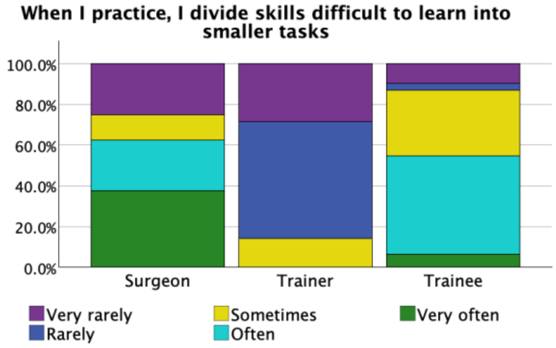


Figure 5-19 I divide the skills difficult to learn into smaller tasks

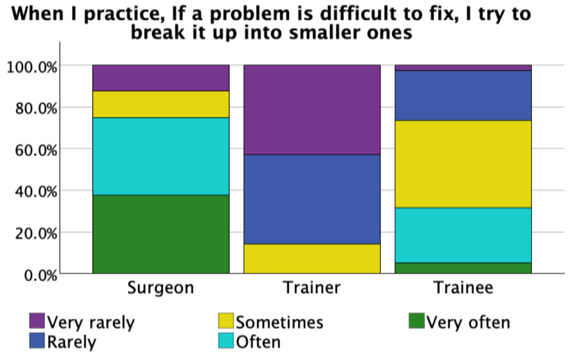


Figure 5-20 If a problem is difficult to fix, I try to break it up into smaller ones

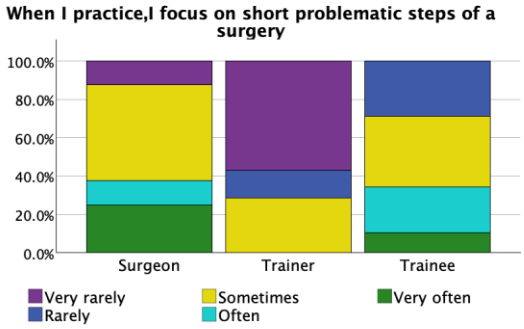


Figure 5-21 Focus on short problematic steps

However, ES claimed to be significantly more proactive in addressing technical issues encountered during practice, with over 75% analysing technical problems frequently, compared to around 25% for trainees (

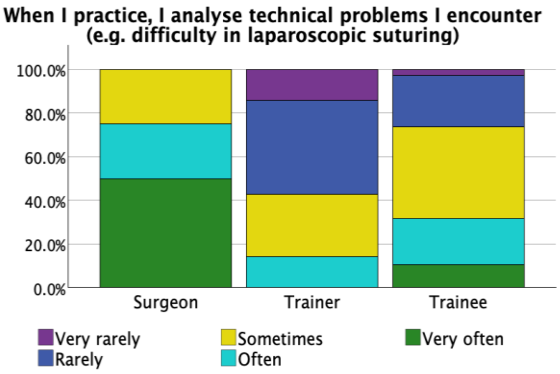


Figure 5-22).

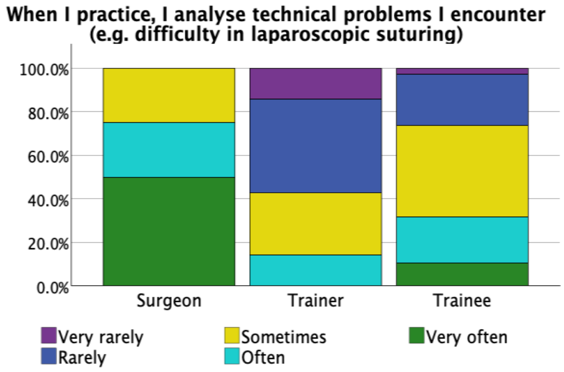


Figure 5-22 Analyse technical problems encountered

Moreover, ES consistently evaluated the effectiveness of their techniques, while trainees did so less often (

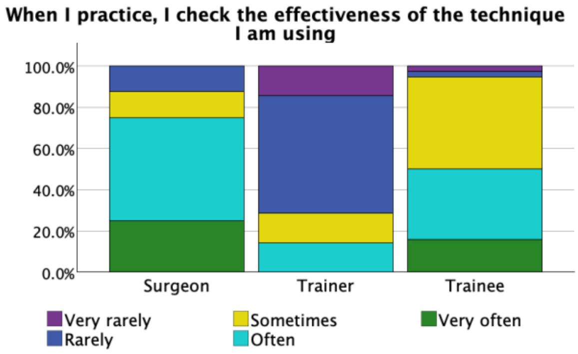


Figure 5-23). This dedication to understanding training challenges was evident, with 80% of ES recognising the need for specific planning and thinking when faced with problems, a perspective not widely shared by trainees (

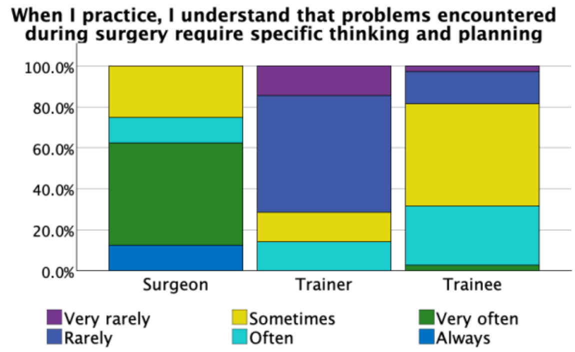


Figure 5-24). Similar trends were observed in analysing skills-related challenges (

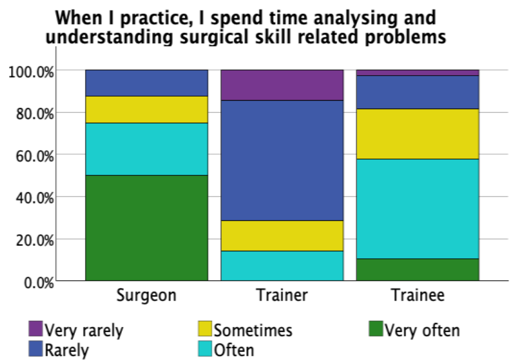


Figure 5-25). In all three aspects, the trainers stated they observed the desirable characteristics less frequently than claimed by trainees.

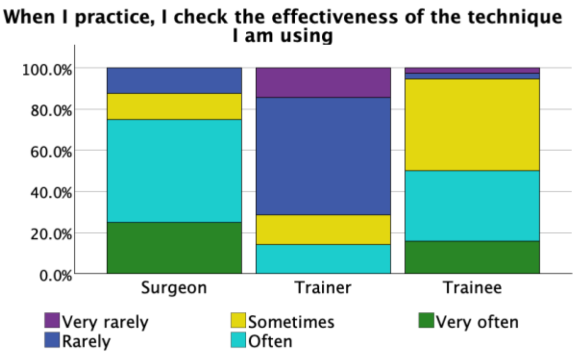


Figure 5-23 I check the effectiveness of the technique I use

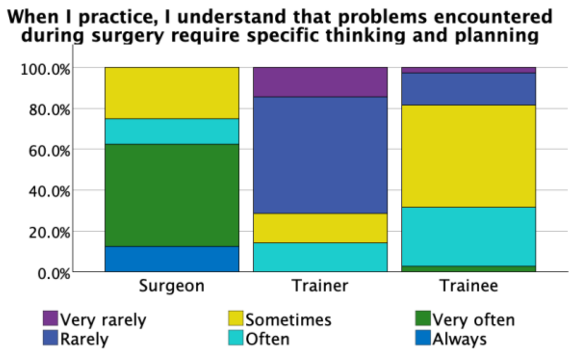


Figure 5-24 I understand the problems require specific thinking and planning

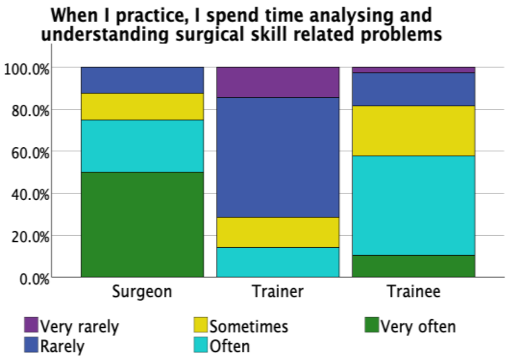
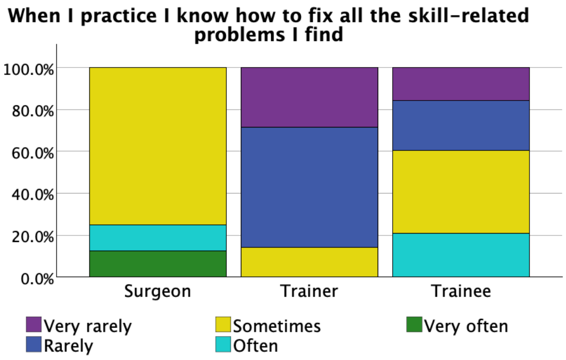


Figure 5-25 I spend time analysing and understanding surgical skill related problems

ES also declared greater independence in resolving skill-related issues during their training (



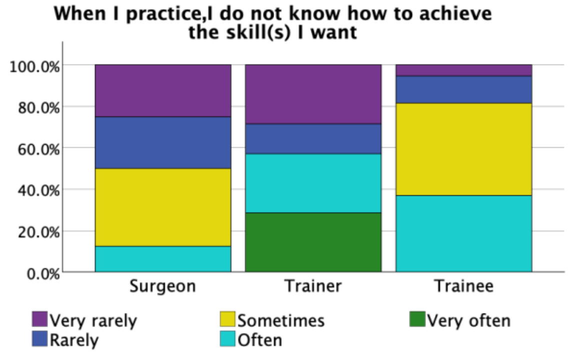


Figure 5-26 and

Figure 5-27). Reflecting on their past experiences as trainees, ES also claimed that they evaluated the effectiveness of their practice more consistently than present trainees did (

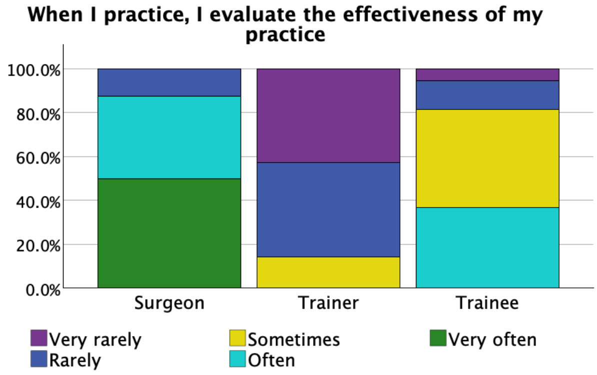


Figure 5-28). The trainers again stated that they observed the desirable characteristics less frequently than claimed by trainees.

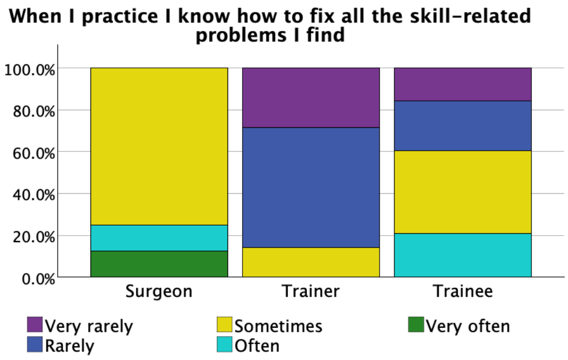


Figure 5-26 I know how to fix skill related problems

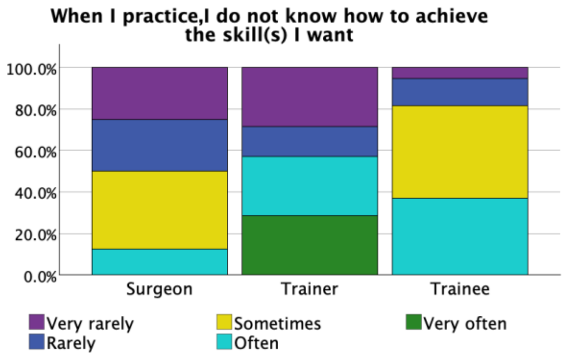


Figure 5-27 I do not know how to achieve the skills I want

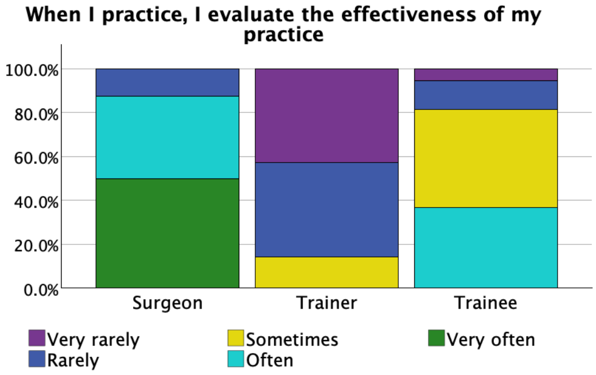
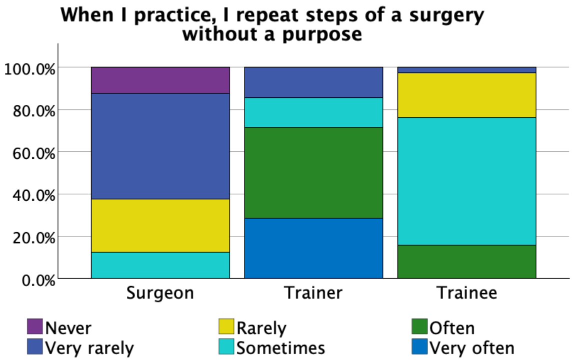


Figure 5-28 I evaluate the effectiveness of my practice

Additionally, ES modified their approaches more readily when faced with challenges (Figure.5-38) and were less likely to engage in mindless repetition (Figure 5-53), practice without a clear goal (



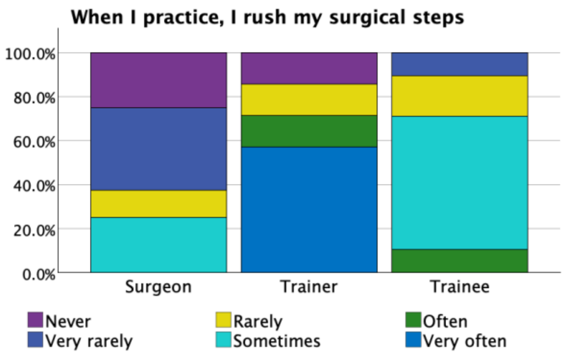


Figure 5-31), or rush through steps (

Figure 5-32).

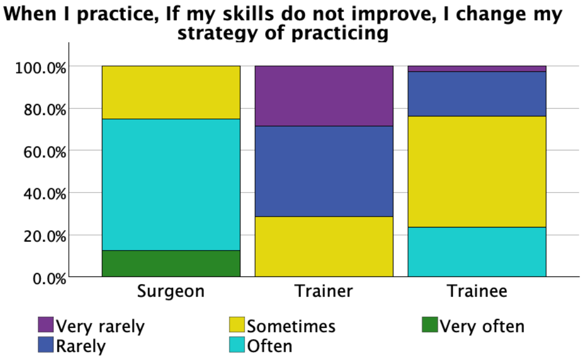


Figure 5-29 I change my strategy of practice if skills don't improve

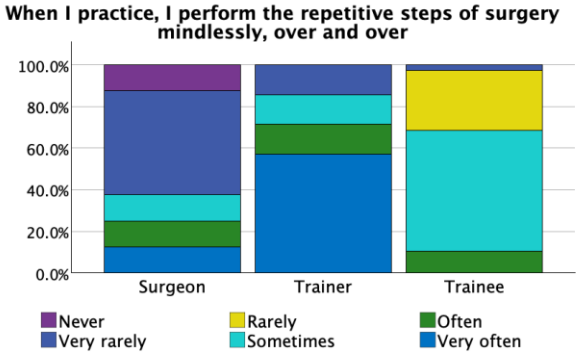


Figure 5-30 I perform the repetitive steps of surgery mindlessly

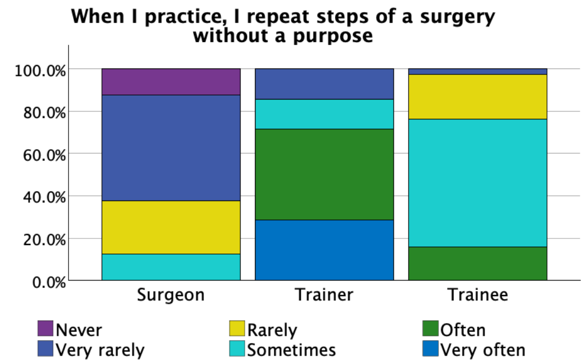


Figure 5-31 I repeat steps of a surgery without a purpose

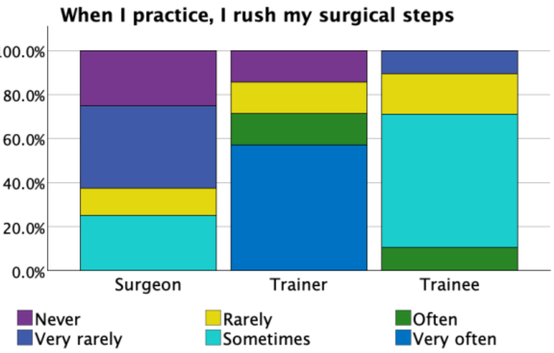


Figure 5-32 I rush my surgical steps

On the other hand, Trainees stated they repeat mistakes without making efforts to correct them. This, too, was noted by trainers more frequently than acknowledged by the trainees. This issue was minimally observed among ES (

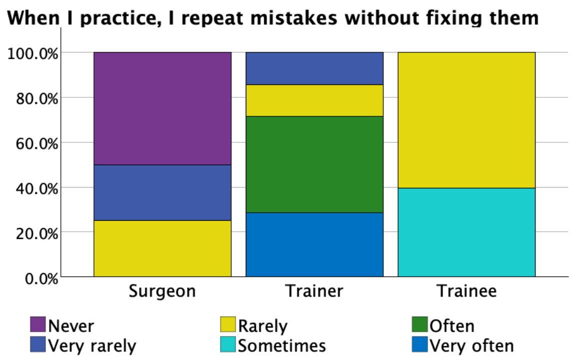


Figure 5-33).

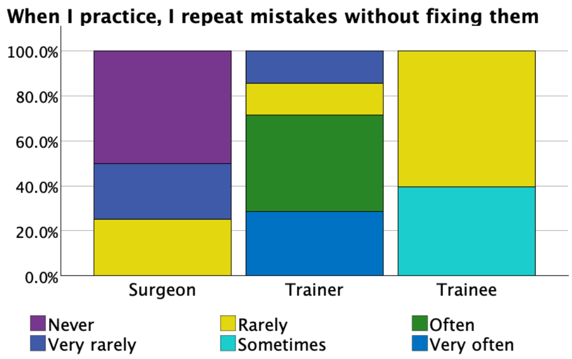
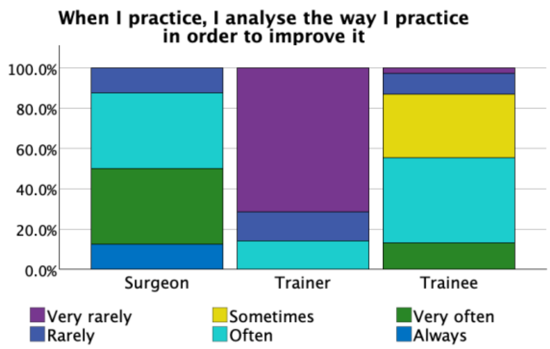


Figure 5-33 I repeat mistakes without fixing them

Compared to current trainees, a higher proportion of ES claimed they engaged in analysing their



practice sessions for continuous improvement (

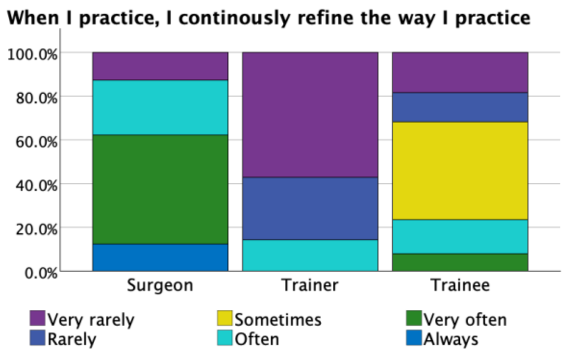


Figure 5-34) and refined their practice methods regularly (

Figure 5-35) as trainees.

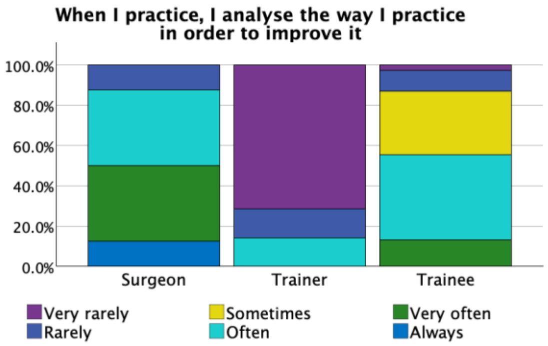


Figure 5-34 I analyse the way I practice

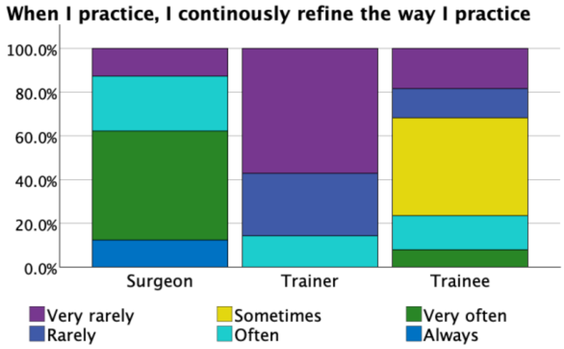


Figure 5-35 I continuously refine the way I practice

ES also claimed to access academic literature on surgical techniques more often (

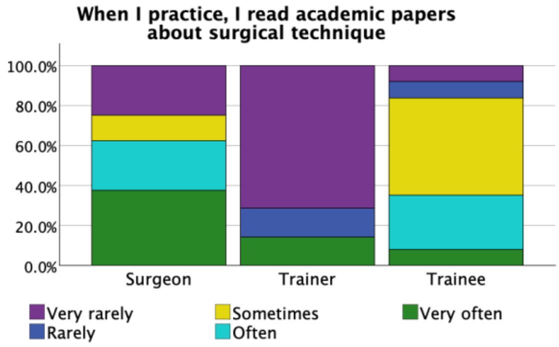


Figure 5-36) and declared a greater understanding of how to optimise ergonomics (

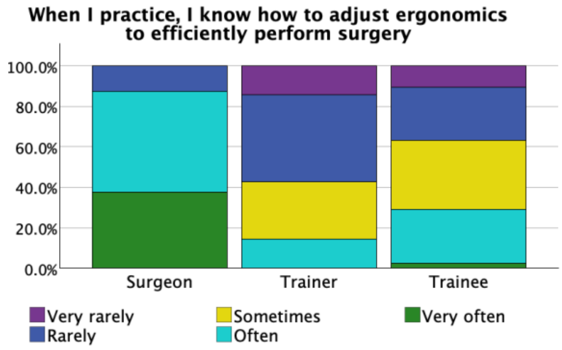


Figure 5-37).

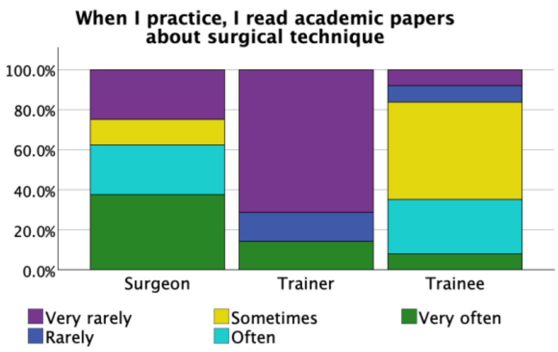


Figure 5-36 I read academic papers about surgical technique

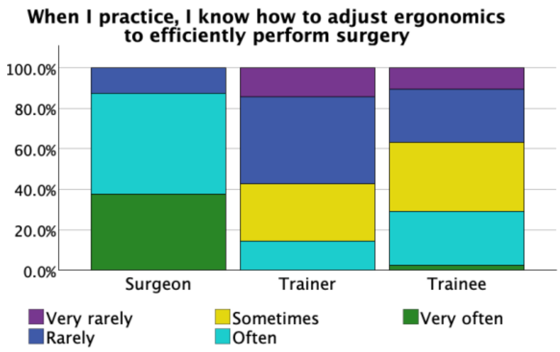


Figure 5-37 I know how to adjust ergonomic

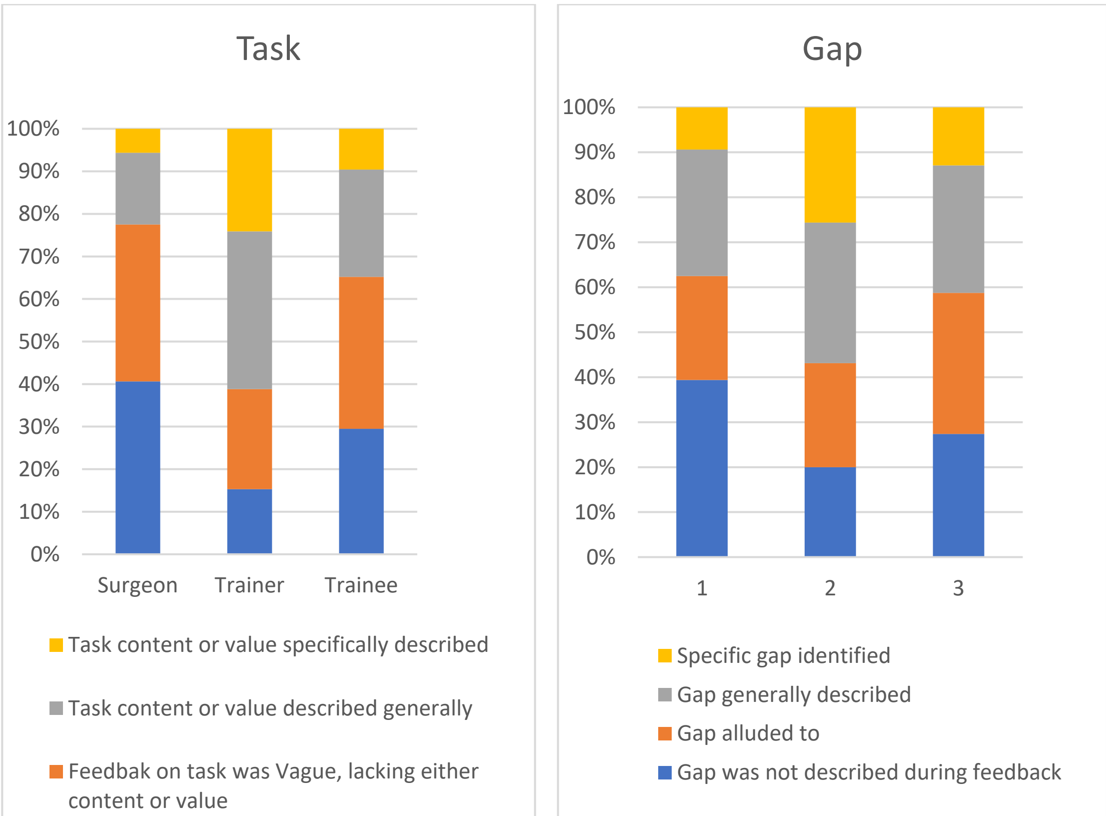
In summary, the findings indicate that, compared to current trainees, ES exhibited more effective and reflective practice attributes as trainees. In all explored areas, trainers observed the desirable practices less frequently than trainees reported them, indicating a significant reporting bias. These findings have identified room for improvement in several areas.

5.2.3.3.2 Content

Both expert surgeons and trainees reported that the feedback either did not describe the element or provided vague feedback. This was common to all three components (task, gap, learning goal). Description of the task was the worst, with over 75% of the feedback either not described or described vaguely. Gap and learning goal received poor feedback in over 60% of the time.

The trainers, however, felt that they provided general or specific feedback in over 50% of the time, in all three areas (Table 9-1 , and Figure.5-38)

There were statistically significant differences between the groups in the perceived feedback received/ given (Kruskal-Wallis test). Like the results described above, the trainers reported providing better feedback than the trainees reported as receiving (Table 9-2).



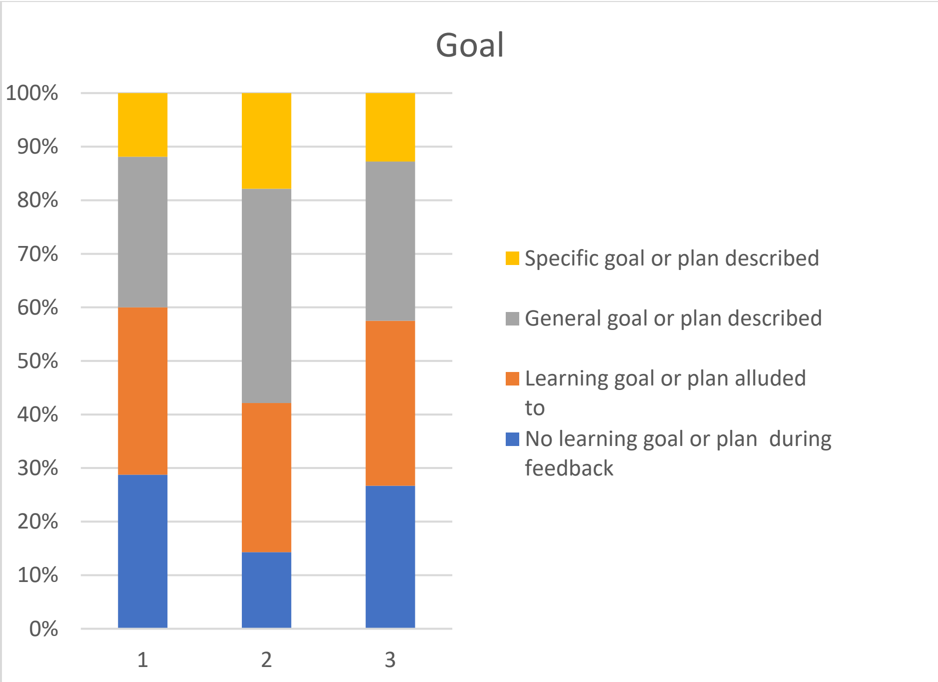
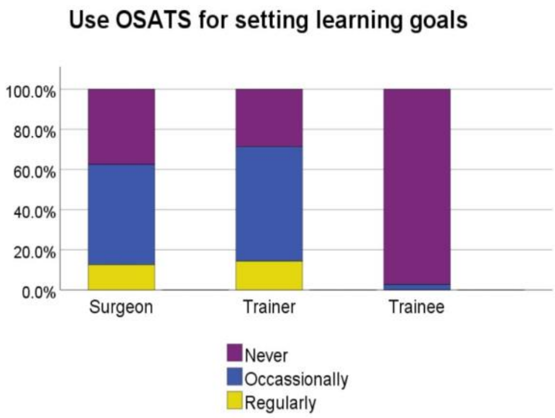


Figure.5-38 Feedback provided / receive

Self-directed learning presents a valuable opportunity for further development among trainees, as expert surgeons emphasise the importance of using objective measures such as OSATS (Objective Structured Assessment of Technical Skills) for setting learning goals (over 60%), establishing milestones (over 60%), and providing assessments and feedback (50%). Interestingly, trainers reported even higher engagement with these measures in structuring training. It seems, however, that trainees are not consistently utilising these tools, indicating a potential area for growth (



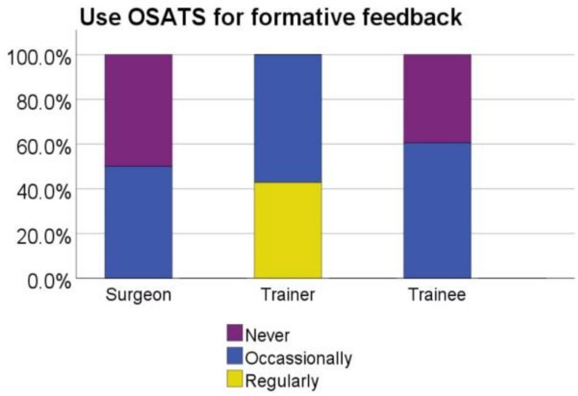


Figure 5-42).

Figure 5-39 to

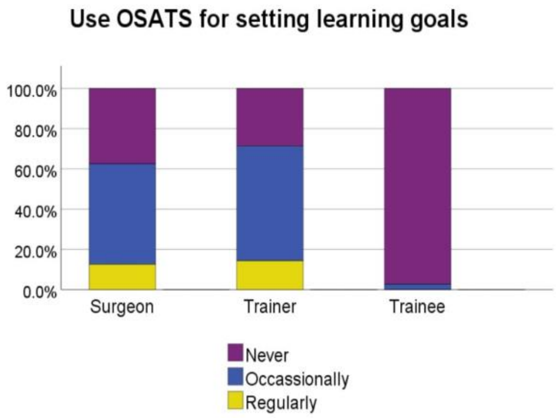


Figure 5-39 Use OSATS for setting learning goals

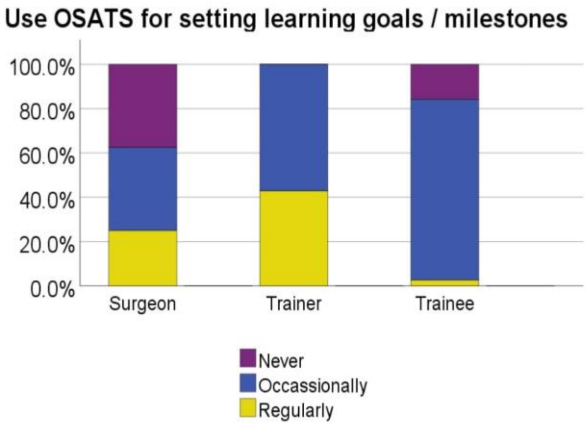


Figure 5-40 Use OSATS for setting milestone

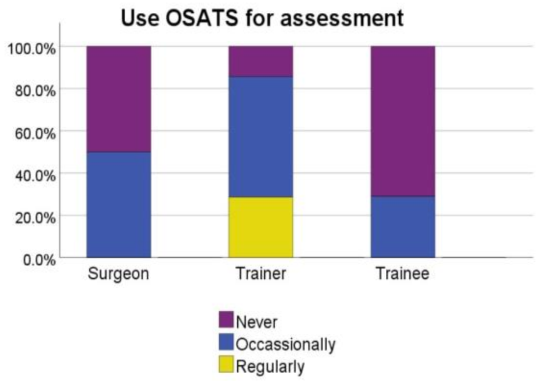


Figure 5-41 Use OSATS for assessment

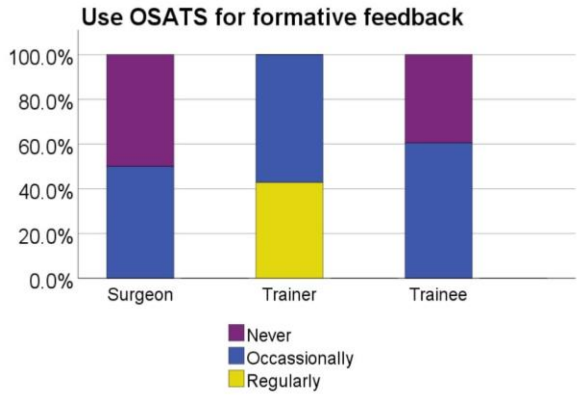


Figure 5-42 Use OSATS for formative feedback

Similar trends were observed in the use of OSCE (Objectively Structured Clinical Assessments) as well (

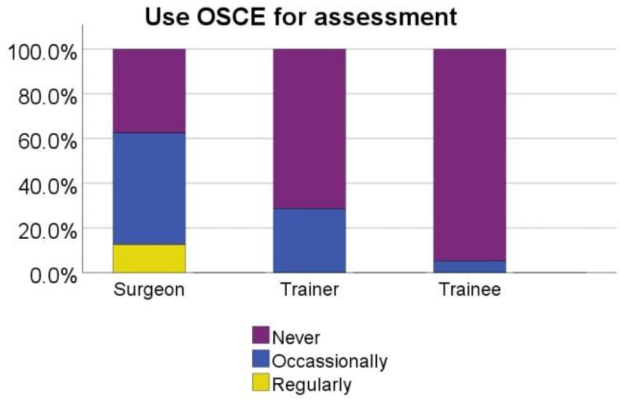


Figure 5-43).

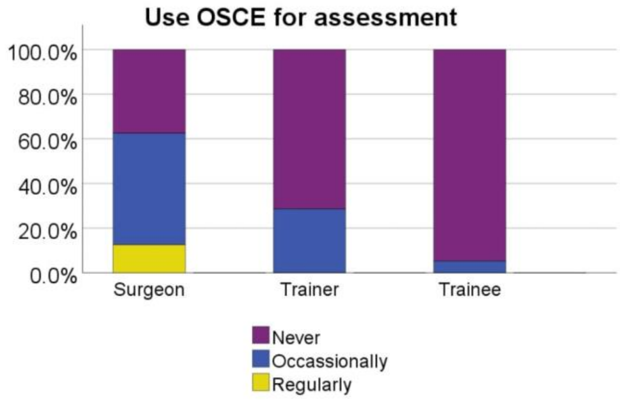
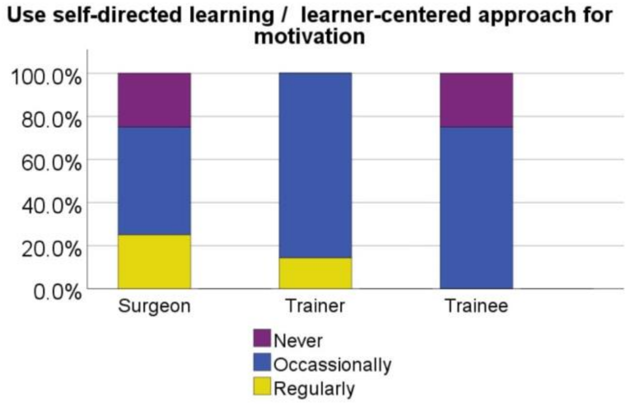


Figure 5-43 Use OSCE for assessment

This underscores the need for trainees to explore and incorporate self-directed learning methods to enhance their



development (

Figure 5-44).

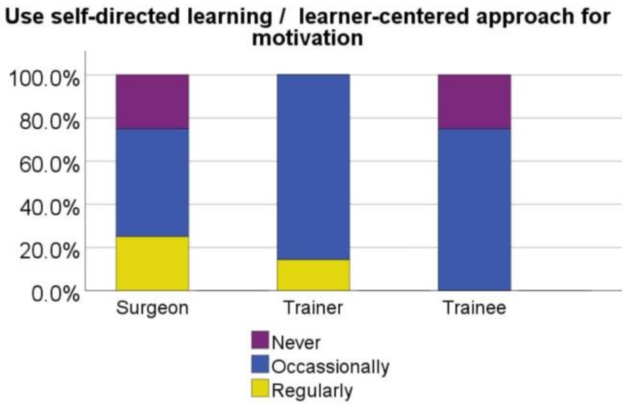


Figure 5-44 Use self-directed learning for motivation

5.2.3.4 Repetition

Repetitive practice is viewed as extremely or very important for error correction by nearly 90% of ES, highlighting its significance in skill development. In contrast, only 40% of trainees share this perspective, indicating an opportunity for further education on the benefits of practice (Figure 5-45).

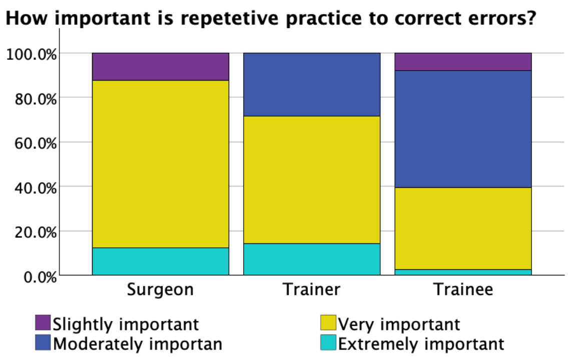


Figure 5-45 Importance of repetitive practice to correct errors

Similar trends were observed regarding the role of feedback in enhancing performance (

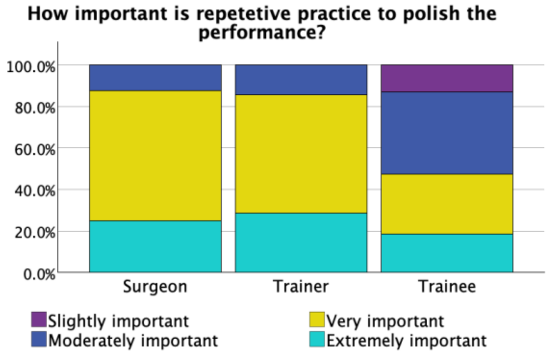


Figure 5-46) and in making skills more effortless and automatic (

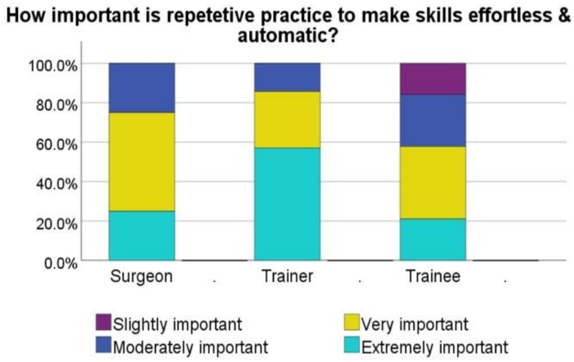


Figure 5-47).

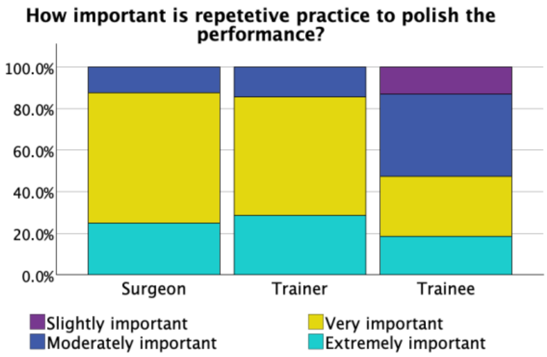


Figure 5-46 Importance of repetitive practice to polish the performance

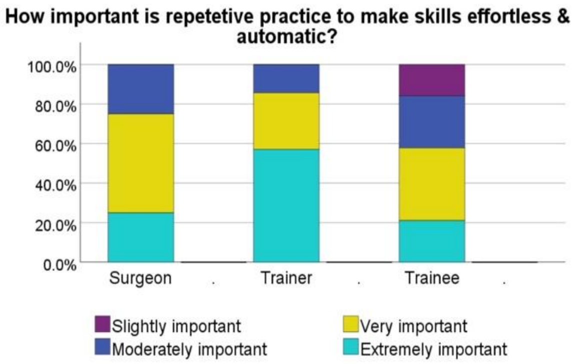


Figure 5-47 Importance of repetitive practice to make skills effortless

Almost 60% of both ES and trainees acknowledged that repetitive practice could accelerate skill acquisition (

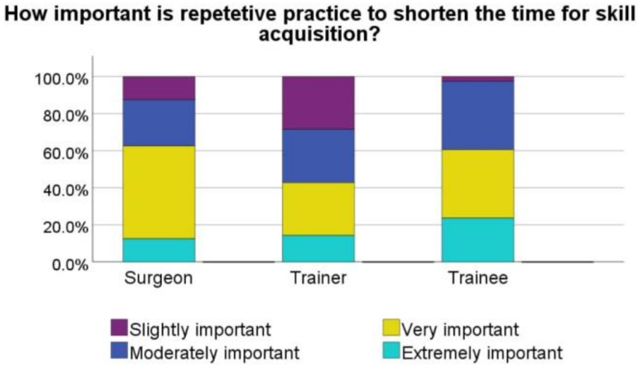


Figure 5-48).

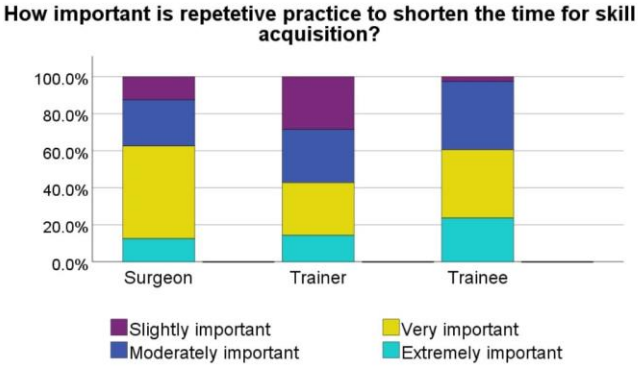
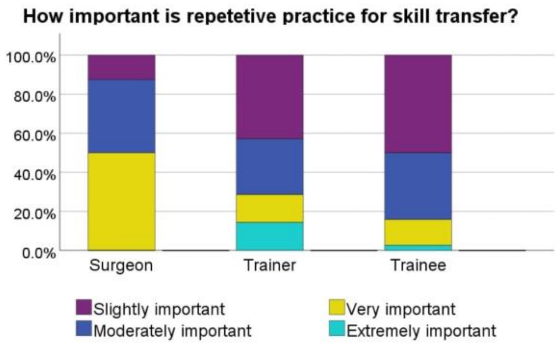


Figure 5-48 Importance of repetitive practice to shorten time for skill acquisition

While nearly 90% of ES believe that repetitive practice is essential for effective skill transfer, only



about 50% of trainees expressed this view (

Figure 5-49).

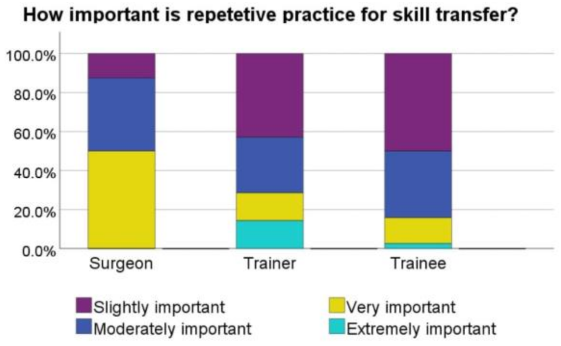


Figure 5-49 Importance of repetitive practice for skill transfer

These insights suggest a need for more targeted training and discussions to bridge the gap in understanding the value of repetitive practice among trainees.

5.2.3.5 Perceived importance of feedback

More than 80% of ES and trainers felt feedback was "extremely important" or "very important" for effective learning, while only about 50% of trainees expressed this (

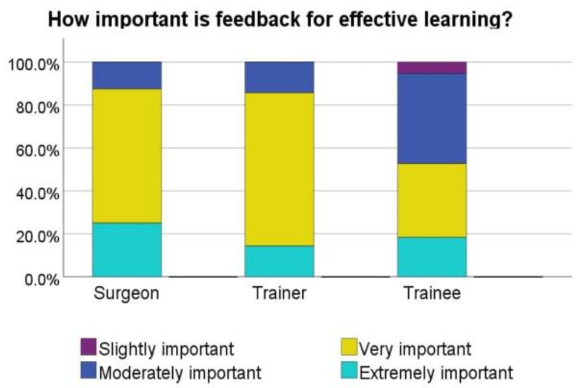


Figure 5-50). Similar perceptions were held regarding the importance of feedback to slow decay (

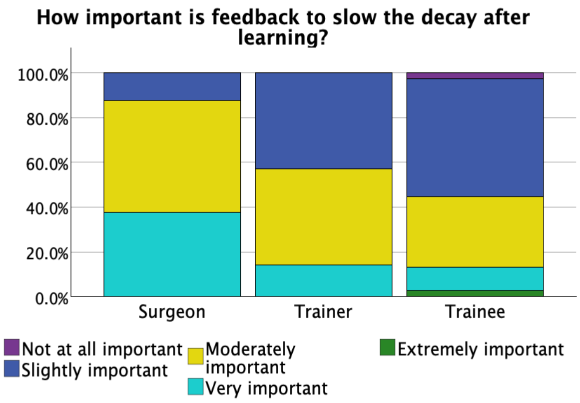


Figure 5-51).

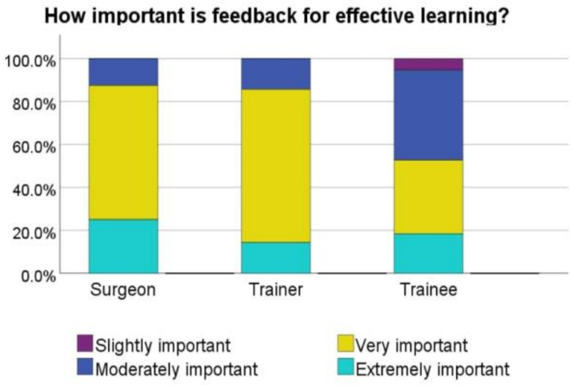


Figure 5-50 Importance of feedback for effective learning

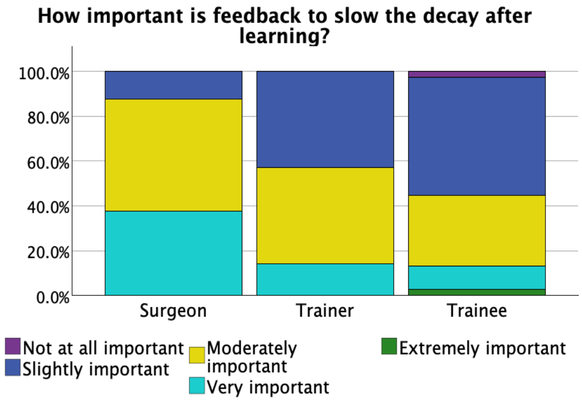


Figure 5-51 Importance of feedback to slow decay

All groups agreed on the importance of feedback to monitor progress (

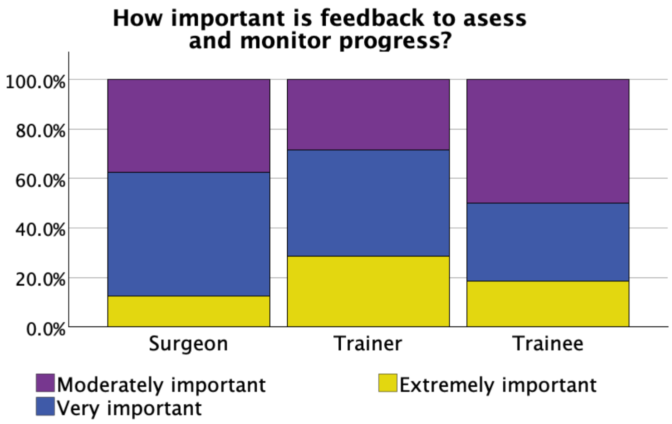


Figure 5-52).

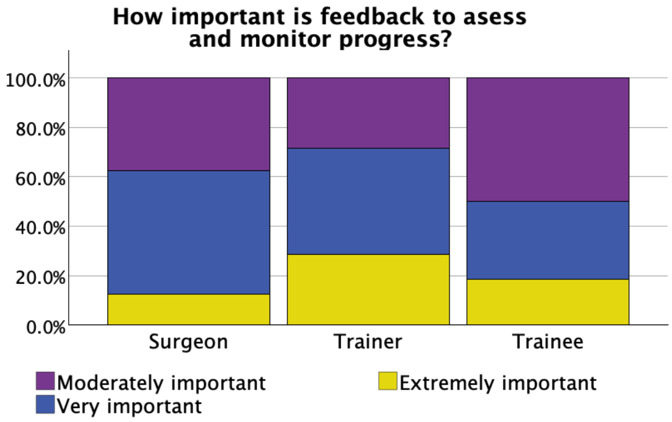


Figure 5-52 Importance of feedback to assess and monitor progress

5.2.4 Participant suggestions for training improvement

The feedback from the three groups at the end of the questionnaire highlighted valuable insights into enhancing training methods. ES emphasised the importance of exposure to a variety of techniques, stating that this approach significantly contributes to effective training. They also pointed out that regular simulator practice, accompanied by constructive feedback, plays a crucial role in skill development. Conversely, they noted that repetitive practice without feedback or reflection is not as beneficial.

Trainers also echoed these sentiments, recognising that both reflection and repetition under supervision enhance skill acquisition. They underscored the importance of providing feedback and actively assisting in correcting techniques to foster improvement.

Among the trainees, opinions were divided regarding the significance of practice quantity. Some expressed that having a higher practice volume is vital, suggesting that "the numbers are important" and that increased quantity might improve quality. Others argued that the focus should be on practice quality, asserting that exposure to high-quality training is equally critical. One trainee aptly noted, "While quantity helps with muscle memory and speed, quality enhances efficiency and reduces the learning curve." A trainer added that both quantity and quality are essential for effective training, emphasising a balanced approach to skill development.

5.3 Phase 3 – Qualitative study

The findings of this phase will also be discussed in the subsections of surgical training, simulation in surgical training, and DP.

5.3.1 Participants

A total of 22 in-depth interviews were conducted as indicated in Figure 5-53 . All participants spoke English. The characteristics of the participants are shown below (

	Identifier	***Age***	***Self-guided training***	***Considers DP and SBST important***
Expert Surgeons	***ES1***	***40***	✔	✔
	ES2	***47***	✔	✔
	ES3	***48***	✔	✔
	ES4	***54***	✔	✔
	ES5	***61***	✔	***X***
Trainers	***T1***	***46***	✔	✔
	T2	***51***	✔	✔
	T3	***52***	✔	✔
	T4	***61***	✔	***X***
	T5	***67***	✔	***X***
Trainees	***L1***	***37***	✔	✔
	L2	***37***	✔	✔
	L3	***39***	✔	✔
	L4	***34***	✔	***X***
	L5	***34***	✔	***X***
	L6	***38***	✔	***X***
	L7	***30***	***X***	✔
	L8	***31***	***X***	✔
	L9	***37***	***X***	✔
	L10	***31***	***X***	***X***
	L11	***34***	***X***	***X***
	L12	***37***	***X***	***X***

Table 5-13).

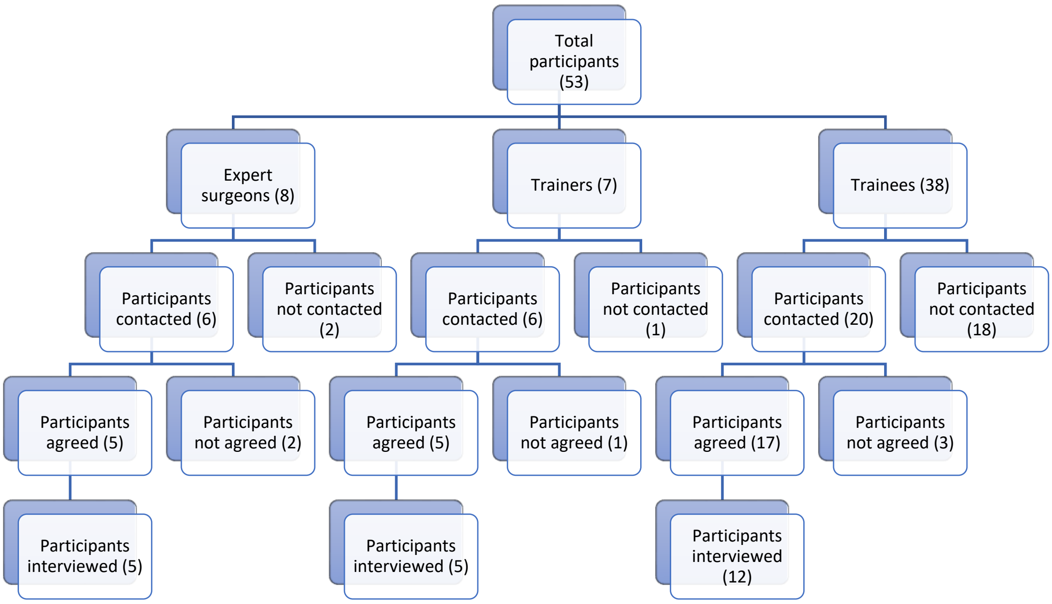


Figure 5-53 Sampling for the qualitative phase

	Identifier	*Age*	*Self-guided training*	*Considers DP and SBST important*
Expert Surgeons	*ES1*	*40*	✔	✔
	ES2	*47*	✔	✔
	ES3	*48*	✔	✔
	ES4	*54*	✔	✔
	ES5	*61*	✔	*X*
Trainers	*T1*	*46*	✔	✔
	T2	*51*	✔	✔
	T3	*52*	✔	✔
	T4	*61*	✔	*X*
	T5	*67*	✔	*X*
Trainees	*L1*	*37*	✔	✔
	L2	*37*	✔	✔
	L3	*39*	✔	✔
	L4	*34*	✔	*X*
	L5	*34*	✔	*X*
	L6	*38*	✔	*X*
	L7	*30*	*X*	✔
	L8	*31*	*X*	✔
	L9	*37*	*X*	✔
	L10	*31*	*X*	*X*
	L11	*34*	*X*	*X*
	L12	*37*	*X*	*X*

Table 5-13 Characteristics of the participants

The descriptions of each column and the selection of participants are explained in

Question in Phase 2	Answers	Code assigned
Stage of training	3- Consultant 4- Trainee	A – Expert surgeon B - Trainer C - Trainee
Self-guided training 3. When I practice, I know what I am doing 4. When I practice, I know what I need to achieve	Coded as percentages	>50% Very often + always – Possess the attribute <50% Very often + always – Lacks the attribute
Understanding of principles of Deliberate Practice 3. How important is repetitive practice to correct errors? 4. How important is feedback for effective learning?	Coded as percentages	>50% Very important + extremely important – Considers it important <50% Very important + extremely important – Doesn't consider it important

Table 4-1.

5.3.2 Results overview

All participants provided detailed accounts of their training programs, covering both local experiences in Sri Lanka and international opportunities in the UK, Singapore, and Australia.

The three conceptual groups of participants were designed to explore training from diverse perspectives, allowing for a comprehensive triangulation of the findings. This included ES, who have successfully navigated the existing system; trainers, who serve as the educators within that system; and trainees, who represent the learners' perspective.

Additionally, the statements reflect the participants' ages, adding valuable context to the discussions. A summary of the domains, themes, and categories can be found in

Domain	Theme	Category
Surgical training	Early laparoscopic era	Lack of expertise
		No structured training
	Present laparoscopic training	Structure
		Approach to Laparoscopic training
		Supervision and feedback
		Competence-based education
		Learning on patients
		Resource limitations
		Training outside Sri Lanka
	Pedagogy of surgical training	Regular practice
		Individua variation
		Self-evaluation
	Limitations of the current training programme	Clinical demands
		Training opportunities
		Inherent problems with MIS
	Suggestions for improvement	Curriculum design and implementation
		Competence-based learning
		Self-learning
		Elective training
		SBST
Simulation	Current state of SBST	
	Role of simulation in surgical training	Basic skills
		Advanced skills
		Other
	Intended outcomes	Learning outcomes
		Patient outcomes
	Infrastructure	Type of simulators
		Access to simulators
	Content and delivery	Basic training

		Advanced training
		Remedial training
	Attitudes	Of trainees
		of trainers
		About SBST
	Limitations affecting broader SBST use	Curriculum
		Cultural factors
		Time
	Improving SBST	Structure and integration
		Competence-based learning
		Orchestration
Deliberate practice	Understanding of DP	Unaware
		Incorrect
		Superficial
		Deep
	Mental representation	
	Motivation	
	Task design	Overall task design
		Stepwise approach
	Feedback	Supervision
		Timing of feedback
		Content
		Remedial training
	Application of DB in SBST	
	Suggestions for better adoption of DP	

Table 5-14.

Domain	Theme	Category
Surgical training	Early laparoscopic era	Lack of expertise
		No structured training
	Present laparoscopic training	Structure
		Approach to Laparoscopic training
		Supervision and feedback
		Competence-based education
		Learning on patients
		Resource limitations
		Training outside Sri Lanka
	Pedagogy of surgical training	Regular practice
		Individua variation
		Self-evaluation
		Clinical demands

	Limitations of the current training programme	Training opportunities
		Inherent problems with MIS
	Suggestions for improvement	Curriculum design and implementation
		Competence-based learning
		Self-learning
		Elective training
		SBST
Simulation	Current state of SBST	
	Role of simulation in surgical training	Basic skills
		Advanced skills
		Other
	Intended outcomes	Learning outcomes
		Patient outcomes
	Infrastructure	Type of simulators
		Access to simulators
	Content and delivery	Basic training
		Advanced training
		Remedial training
	Attitudes	Of trainees
		of trainers
		About SBST
	Limitations affecting broader SBST use	Curriculum
		Cultural factors
		Time
	Improving SBST	Structure and integration
		Competence-based learning
		Orchestration
Deliberate practice	Understanding of DP	Unaware
		Incorrect
		Superficial
		Deep
	Mental representation	
	Motivation	
	Task design	Overall task design
		Stepwise approach
	Feedback	Supervision
		Timing of feedback
		Content
		Remedial training
	Application of DB in SBST	
	Suggestions for better adoption of DP	

Table 5-14 Domains, themes, and categories

5.3.3 Early laparoscopic era

Present ES and trainers have witnessed the introduction of laparoscopy to Sri Lankan surgery at the turn of the millennium. The absence of expertise, equipment, and structured training characterised this period.

The trainers of the present ES lacked the expertise to supervise and guide them, and the training had been unstructured and opportunistic. This was true for all subspecialities of surgery.

> ***Before 2000, "only about 10% of surgeons were doing laparoscopic surgery". Only a limited number of "simple procedures like cholecystectomies" were performed, with more complex surgeries being routinely performed as open surgery. "Trainers themselves were just getting trained" in laparoscopy. "I think that's not good enough for me to learn" from someone who is still learning (Text condensate from 6 participants ES3, ES4, ES5, T3, T4, T5)***

This period was also characterised by the regular contributions from foreign resource persons for training surgeons.

> ***"The team members came (from the UK) to train my boss, actually. I also observed. And after that, I assisted my consultant" - T4***

The absence of a structured training programme characterises the early laparoscopic period of Sri Lanka. Both ES and trainers had learnt by assisting a more experienced local or overseas surgeon who often had begun as a camera assistant.

> ***"There was no formal training", "we never had training on a beetle". First exposure to laparoscopic training occurred when I was a senior registrar. Even there, "it was opportunistic learning and holding the camera" (Text condensate from 5 participants – ES4, ES5, T3, T4, T5).***

They had then started to perform these surgeries independently, during their placement at other stations, and learnt through independent practice. As a result, they reflect that their skill level as trainees was inferior to that of the present generation of trainees.

> ***"During the peripheral appointment, I was able to perform laparoscopic cholecystectomies". But as a registrar, I would say I was probably way "below the skill levels of the current trainees"***
> ***(Text condensate from 3 participants – ES2, ES3, T3).***

There had not been any simulation training for basic skills during this period, nor was there a structure for exposure. The training had been directly on patients, without any structured stepwise training[6]. Restricting the types of surgeries (e.g. only performing appendicectomy or cholecystectomy) or restricting it to uncomplicated situations (e.g. early cancers) was the hallmark of this period, to ensure patient safety.

> ***"Good selection of patients, Low threshold for conversion", and doing with people who were good assistants (Text condensate from 3 participants – ES4, T4, T5).***

Some others had not had any laparoscopic training while in Sri Lanka and were introduced to it during their overseas training. Subsequently, upon returning to Sri Lanka, they started MIS with minimal supervision and mentorship.

> ***I had "zero exposure to laparoscopic surgery or training during local training". "All my training was after I came back and worked here". "Even at that time, the consultants here were not very familiar". "As time went on and then our senior registrars also took part in surgery and training" (Text condensate from 4 participants ES1, ES3, T4, T5).***

5.3.4 Present laparoscopic training

5.3.4.1 Structure of the training programme

All three groups perceived the training program as needing more structure and organisation, both from their experiences as trainees and their current roles as trainers. The current training program does not have a prescribed structure for surgical skills training. This results in variation in exposure among trainees, resulting in variation in competence. ES highlighted the importance of a standardised curriculum incorporating DP into the training. The Post Graduate Institute of Medicine (PGIM) serves as the central regulatory body for the training program in Sri Lanka and outlines essential competencies; however, there is potential for improving how these competencies are integrated into the training process by providing more consistent guidelines for trainers.

> ***There's a "lack of standardised training program". "Although the PGIM prospectus lists the competencies, the training programmes are conducted by different Universities and societies, each doing things differently". Additionally, a curriculum that "incorporates deliberate practice is essential" (Text condensate from 5 participants ES2, T3, T5, L2).***

[6] Training in MIS proceeds stepwise, with basic training in the skills lab to familiarize oneself with the instruments, followed by easy tasks during surgery

Additionally, there is room to enhance the allocation of training centres. One trainer suggested allocation based on the laparoscopic volume, while keeping the process adaptable to ensure optimal training experiences for all participants. This could produce better skill development.

> ***There are many "who could train", and we should objectively assess their units based on their operative audit. "We can allocate trainees to a unit for a specific component". That is the structure and organisation we need (Text condensate from 4 participants ES4, T2, T3, T5).***

Other areas highlighted included the reliance on learning through observation without prior simulation, the occurrence of opportunistic learning moments, and inconsistent supervision due to varying levels of training experience. Additionally, there was a strong focus on hands-on training, with trainers noting that much of the educational value comes from assisting in surgeries, even if the trainee's role is primarily as a cameraman.

> ***I had "few months observing, but very little formal training". It was a "hit or miss opportunistic way of training, mostly holding the camera. "Some people do not understand how to train juniors and it's difficult to ensure everyone gets similar training" (Text condensate from 5 participants ES1, T2, T3, L4, L9).***

There was an obvious improvement in training over time, with the present generation of trainees having more training opportunities and a better structure.

> ***"Present day trainees are doing much better than people who trained 10 years ago". There are "basic skills courses", where "fundamental techniques like camera navigation, tissue manipulation, and suturing" are taught step by step. Then you can gradually perform surgeries. The best one to "start off is the laparoscopic appendectomy" (Text condensate from 6 participants – ES3, T4, L4, L10, L16).***

Despite the lack of guidance from the governing body, some trainers attempted to incorporate SBST within the existing curriculum. It was also highlighted that, as training often begins with real patients, careful consideration of patient and case selection is crucial. However, there was a lack of agreement on what constitutes a good training case. While some surgeons deemed laparoscopic appendicectomy suitable for training, others had differing opinions. This indicates an opportunity for further dialogue and consensus-building to enhance the training experience.

> ***"I try to adhere to the training program, but it is not structured". We have a beetle, so when a trainee faces difficulties while operating, "I ask him to work at least 10 hours before next theatre session". Initially "I do not allow them to do laparoscopic***

> ***appendicectomy because most happen as emergencies and are unsupervised" (Text condensate from 3 participants T2. T5, L12).***

While mentorship from trainers was not a focal point of discussion, trainees expressed a strong commitment to mentoring their junior colleagues.

> ***My role involves not only continuing my own training but also mentoring junior trainees. When mentoring junior trainees, I emphasise the importance of these training methods – Trainee***

Trainers also highlighted the importance of assessing the competence of surgical skills. Currently, operative volume is the most used metric in this assessment. This, however, is insufficient in competence-based education.

> ***"We do not check whether they have done their work. We just look at the logbook and the number of surgeries performed. How they perform, the outcome is not known" – T1***

5.3.4.2 Approach to laparoscopic training

The training approach utilised by ES and trainers emphasises two key areas: a comprehensive understanding of diseases and effective clinical decision making. Trainers focused more on understanding the disease processes, and other areas like learning theories, biomechanics of laparoscopy, and using simulation to prime learners for practical skills were largely ignored. Notably, only one ES highlighted the significance of mastering the mechanics of laparoscopy as a crucial aspect of pre-learning.

> ***When they come to the theatre, they must know the diagnosis, "indications, contraindications", "problems of pneumoperitoneum, physiological changes". There are enough articles to read and online modules.***
> ***"Structure development of laparoscopic skills starting from the ability to understand what you see, and the mechanics of laparoscopy. One of the first things is to get them to understand how the 30^0 camera work" (Text condensate from 6 participants ES2,ES3, ES5, T2, T4, T5).***

ES acknowledged that observing various surgical techniques from their peers plays a vital role in their training. Trainees expressed a preference for interactive sessions that include problem discussions as an effective method for learning surgical skills. Moreover, trainers emphasised the importance of trainees' abilities to select appropriate patients and recognise when to halt a procedure if it becomes challenging. This points to a potential area for growth, highlighting the need for more simulation opportunities alongside real patient training.

> ***We "discuss the case and study the images, to try to anticipate the difficulties, especially by studying the vascular anatomy". Trainees highly value these problem-based interactive sessions.***
> ***Because they are learning on patients, they need a "good clinical sense". They must recognise when it's "no longer safe to proceed and when to bail out". I have had a "couple of people who only call after they done irreversible damage" (Text condensate from 5 participants ES4, T2, T3, T4, T5).***

Additionally, trainers noted that their training methods have evolved over time, particularly as their competence increased, permitting support to trainees in challenging situations. This progression is a positive sign of the commitment to enhancing the learning experience for all involved.

> ***"The freedom I allow my trainees had evolved because I am more confident in my own laparoscopic skills" - T1***

5.3.4.3 Supervision and feedback

There was a range of perspectives on the supervision of trainees during surgical procedures. Some trainers and ES advocated for the presence of trainers within the operating theatre, believing it could enhance learning opportunities. Others suggested that trainers might remain outside the theatre, available for assistance if needed, citing concerns about performance anxiety arising from a trainer's presence. Interestingly, some ES felt that supervision could even be effectively provided by someone more junior, if they possessed adequate laparoscopic experience.

> ***"I don't believe that being there like a hawk can improve their training". I give them instructions, but I don't scrub in. "My own performance goes down by about 30-40% at any point of time, if I know that I am being scrutinised". "I allow them to operate on their own. I see if they call me when they're in trouble"; one key criterion to assesses their ability to judge themselves (Text condensate from 5 participants- ES1, ES3, T4, T4, T5)***

> ***"I'll be there with them throughout the procedure, waiting to take over when something goes wrong" – T2***

A common theme among all three groups was the significance of training for trainers, emphasising the need for effective supervision and meaningful feedback. This point underscores the variability in preferences regarding whether trainers should be present in the theatre.

> ***"I think some people don't understand how to train juniors", so a training programme to train the trainer is essential. "My motto is that there are no bad trainees but only bad trainers". Incorporating a structured mentorship would improve confidence and competence. "Having good mentors is essential", to discuss and call for help at any time, even "somebody who can bail them out" (Text condensate from 4 participants- ES1, T2, L11, L17)***

The diversity of opinions appears to be influenced by the absence of structured SBST and the current reliance on learning through patient interactions. Additionally, it was noted that there is no formal feedback process in place during training—this includes aspects such as content, timing, and structure, which may have contributed to the differing views among trainees concerning supervision.

> ***I don't think we use simulation adequately. We should encourage them, "especially when the resources are available inhouse". We also need to move away from opportunistic feedback based on what we see and introduce a structured feedback system. One quality we must inculcate is self-reflection (Text condensate from 3 participants- ES2, T2, T4).***

Overall, fostering constructive dialogue about these issues could enhance the training experience for all involved.

5.3.4.4 Competence-based education

During the interviews, several important aspects of competence-based education emerged. Interestingly, none of the trainees highlighted these points. Both educators and trainers recognised the lack of a universal standard for defining acceptable levels of competence and the methods for measuring it.

Currently, the system is primarily based on the number of procedures completed, which are documented by trainees and verified by trainers. While there was a discussion regarding certification at the end of the training program, it became clear that such certification primarily signifies participation rather than skill level. ES also emphasised the importance of a certification process that accurately reflects skill competency.

> ***"Benchmarking is something we must follow", but unfortunately, there are no benchmarks for the number of cases needed for proficiency. "Once someone assists me for about 15 to 20 cases", I grant increasing independence. Once someone reaches the first milestone, you can allow them to progress to the next level. I try to develop the basic competencies before the end of the first year, "but our training programme***

> ***duration of 2 years is too short" (Text condensate from 6 participants – ES2, ES3, T1, T2, T4, T5).***
>
> ***"We give them a certificate of participation", but that's not an assessment of competence. "Certification I feel must involve checking if they have achieved a certain skill level even at the basic course" (Text condensate from 3 participants – ES1, ES5, T2).***

Some trainers suggested that the pre-board certification assessment represents a valuable opportunity for evaluating competence. Since this assessment occurs at the end of the training program, it doesn't allow for ongoing evaluation throughout the training process. To support trainees who may not meet the expected competence level, trainers proposed extending training duration and offering additional surgical opportunities. It's worth noting that discussions around skill assessment were not prominent, indicating a potential area for improvement. Overall, addressing these gaps could enhance the effectiveness of competence-based education.

> ***Pre-board certification assessment is the best place to check their competence. If they haven't had sufficient exposure or reached the expected standard, extending the training programme would be quite useful. We should not hesitate to guide them to further training (Text condensate from 4 participants – ES5, T2, T4, T5).***

5.3.4.5 Learning on patients

During the interviews, several constructive themes emerged regarding the lack of SBST and its impact on learning through patient interactions. These included the reasons for reliance on training on patients, how it affects patient outcomes and safety, and the potential solutions within the existing limitations.

Currently, a significant portion of surgical training occurs directly with patients, a practice recognised by all three groups involved. Both limited SBST opportunities and the high demands of the workload influence this trend.

All participants concurred that considerable training happens in the operating room, often including first-time surgeries performed on patients. This scenario introduces additional considerations for both patient care and educational experiences. In some cases, surgeries may need to shift from laparoscopic to open techniques when the complexity exceeds the surgeon's skill level. While this ensures patient safety, it can impede the ideal of graded exposure and corrective practice, essential for effective learning. Moreover, aligning trainee competence with patient complexity remains challenging, making graded exposure difficult to implement.

> ***My learning was straight away on real patients. Unfortunately, even now, most of the training opportunities are during surgery, and that's "often out of necessity due to high patient volumes". "We got a beetle rather late" (Text condensate from 7 participants T2, T3, L3, L8, L11, L12).***

The safety of patients is closely linked to trainees' self-assessment of their skills. Some trainees may be operating at what is termed "unconscious incompetence," which poses risks to patient safety. This necessitates the presence of trainers throughout procedures, a requirement that, while crucial for oversight, can inadvertently impact the trainees' performance. Trainers noted that while there is valuable learning through trial and error, they believe a more structured approach would be preferable.

> ***I have seen several incidences where they have caused irreversible damage. Part of the training is "learning from mistakes". "I think it's very unfair for the patient, because their first time should not be surgery on a live patient" (Text condensate from 6 participants – ES1, ES2, T1, T2, T4, T5).***

Several proactive measures have been integrated to enhance patient safety within the current training model. These include avoiding laparoscopic procedures in cases anticipated to be complex and opting for early conversion to open surgery. While these strategies prioritise patient safety, they limit experiential learning opportunities.

> ***If the tumour was "close to major vessels, we straight away went with open surgery because our priority was cancer clearance" and patient safety. If a trainee were operating, "I would always be there for the procedure" (Text condensate from 3 participants- ES2, T2, T3).***

Attributes such as patience and determination have emerged as vital for trainees' success. One trainer emphasised that implementing SBST could significantly reduce patient morbidity associated with the learning process. By focusing on these constructive changes, the training program can better balance the needs for both patient safety and effective learner development. There was, however, scepticism about the inability of SBST to develop decision-making.

> ***"Morbidity may improve with simulation". Until then, it "doesn't matter if you convert". Determination, patience and patient safety are the key elements. While simulation can provide a controlled environment for skill development, hands-on experience is crucial for developing clinical judgment and decision-making abilities (Text condensate from 5 participants – ES2, ES4, T3, T6, L4).***

5.3.4.6 Resource limitations

Even in the current training programme, resource limitations affect training. An ES highlighted the lack of experts for supervision, especially with training in education.

The other factor that was highlighted was how administrative matters affect training. As skills training often happens during live surgery, any factor reducing operating theatre access will adversely affect training. These may include other specialities (e.g. anaesthesia) or staff categories (e.g. nurses).

> ***All training centres are not equipped with the manpower and the skills. Sometimes the theatres are closed in the afternoon. To improve the training, we must address these (Text condensate from 3 participants – ES2, L3, L9).***

5.3.4.7 Training outside Sri Lanka

Given the current limitations in infrastructure and expertise for SBST in Sri Lanka, a substantial portion of skills training has taken place overseas. In the initial phase of MIS in Sri Lanka, practising surgeons visited regional centres of excellence to learn.

> ***"I attended a laparoscopic training programme in India, and another went to Singapore. After my return, I invited some of my Indian friends to come and help me to start a laparoscopic course – T1***

Trainees also have a mandatory overseas training and enter this phase having already developed a foundational level of laparoscopic skills. In the early days of laparoscopic surgery in Sri Lanka, qualified surgeons also sought overseas training, establishing a precedent for ongoing learning and collaboration. These training initiatives are frequently complemented by experts visiting Sri Lanka to provide mentorship during a surgeon's formative years. The

> ***My early MIS exposure came "mostly during my overseas training". I had robotic training in Australia, and laparoscopic training in both Sri Lanka and Australia. The "training there is more structured and places a greater emphasis on SBST". They also had "more high-tech simulators including robotics and VR" (Text condensate from 4 participants – ES2, L2, L9, L11).***

The extent and variety of training can differ depending on the training centre, with high-volume centres also accommodating local trainees. This situation often leads to competition for hands-on opportunities in real surgical settings, both domestically and internationally.

> ***Trainees in UK have a good training atmosphere but "it's very competitive". These are speciality centres, and everyone including locals are fighting for the hands-on cases. "Local trainees get preference". It's a common problem. So, training is not standardised. "Opportunity to do a complete procedure was minimal". We should not rely entirely on overseas training (Text condensate from 6 participants – ES1, ES5, T2, L2, L6, L10).***

To enhance the training experience, there are several constructive suggestions. Inviting international experts to conduct training sessions in Sri Lanka could provide valuable insights and skills locally. Additionally, structuring overseas training programs more effectively would help ensure that all trainees receive adequate exposure to essential practices, establishing a consistent standard for skill development.

> ***We could "collaborate with international institutions to access their expertise and resources", there are "many centres in India and Pakistan, and they are willing to take trainees". "Maybe we can even bring experts to conduct regular workshops". The overseas training programme must be better structured and monitored (Text condensate from 5 participants – ES2, T1, L2, L7, L10).***

5.3.4.8 Pedagogy of surgical training

The interviews revealed several insightful pedagogical considerations related to training practices, even though specific learning theories were not directly referenced.

A key theme that emerged across all participant categories was the significance of regular practice in enhancing learning. Trainers highlighted how scheduling similar surgeries on the same day optimises learning opportunities and improves the overall learning curve. Moreover, all three groups acknowledged the diversity in individual learning capacities among trainees. They noted variations in learning speeds among individuals even when participating in the same training program. Additionally, experts mentioned the importance of self-reflection in recognising personal areas for improvement. Interestingly, some trainees may struggle to reach competency despite extended training, highlighting the need for tailored approaches.

> ***"Numbers" certainly matter; if you have a lot your learning curve can be improved". "Practicing specific skills repeatedly" is very useful. "Urethroplasty has a steep learning curve. So, we kept one list" so that I could demonstrate the first case and then supervise during the next. Everyone "exposed to the same environment won't be able to get the same skills, that's a fact of life". You must judge individually. "There will be outliers" who might not achieve the milestones even with prolonged training (Text condensate from 7 participants – ES1, ES2, ES4, T1, T4, L2, L7).***

One ES pointed out that current trainees exhibit higher skill levels compared to when they were in training at the same stage. This observation underscores the impact of evolving training methodologies and a commitment to continuous improvement. Furthermore, a trainer emphasised the value of lifelong learning as an essential aspect of professional development. A trainee also reiterated the importance of hands-on training, advocating for its advantages over purely simulation-based training.

> ***"The present generation of trainees is much more skilled" in MIS than we were as trainees, and that is mainly due to the structured training they have, and we didn't. I have a surgeon for "over 25 years but even in the last workshop I learned a lot" (Text condensate from 4 participants- ES1, ES5, T2, T4, T5).***

These discussions offer valuable perspectives on enhancing training efficacy and fostering an environment that supports learner growth.

5.3.4.9 Limitations of the current training programme

5.3.4.9.1 Clinical demands

Surgical training is fundamentally an on-the-job experience, integrating service delivery within the role of the trainee. The clinical demands present both challenges and opportunities for enhancing surgical training. While the clinical workload can limit the dedicated time available for skill development, it also ensures that trainees are actively engaged in patient care, providing them with valuable real-world experience. Trainees may find themselves without operating exposure during an entire 13-hour shift, highlighting the need for a balanced approach to training that maximises skill acquisition while fulfilling clinical responsibilities. Certain common emergency procedures (e.g., laparoscopic appendicectomy for acute appendicitis) may not be ideal training opportunities due to factors such as limited direct supervision during after-hours surgeries and varying surgical complexities.

> ***In Sri Lanka, the training is quite hands-on from an early stage. There is "significant operative experience, often out of necessity due to high patient volumes". But some operating, especially out-of-hours emergencies are not supervised, and that's not good training (Text condensate from 5 participants – ES2, T2, T3, L3, L8).***

To effectively navigate these demands, it is essential to create structured opportunities for skills training, particularly through dedicated SBST. This approach can facilitate targeted skill development while maintaining important clinical responsibilities. Additionally, the concept of opportunistic training, which has become a hallmark of modern surgical education, introduces an innovative dimension to skill acquisition. However, it does come with challenges in planning.

> ***"Demanding clinical workload often leaves limited time for structured simulation" practice. The challenge is in balancing these clinical responsibilities and surgical practice. That's the biggest barrier to the broader adoption of simulation. Simulation is essential, mainly to provide adequate exposure for uncommon surgeries and demanding skills like suturing (Text condensate from 5 participants – T5, L2, L8, L9, L10, L12).***

To enhance these training experiences, it will be important to establish systems that allow for better supervision and control over the complexity of surgical cases, aligning them more closely with the competencies of trainees. By addressing these factors, we can ensure that surgical training remains robust, effective, and adaptable to the clinical environment.

5.3.4.9.2 Training opportunities

The training of surgical skills has the potential for improvement, as current methods often lead to significant variations in opportunities for trainees. Several factors contribute to this variability, including the type of hospital, its geographical location, the specific surgical unit, and the individual consultant's approach within that unit. Recognising these confounders is crucial for all stakeholders involved. Trainers highlight the challenges posed by opportunistic training, which complicates establishing a fair and equitable training system.

> ***The "case load, exposure, and opportunities vary" by cities, hospitals, and units. This is "something that we can't equate for". We also see a variability in training quality across different institutions; Some trainees have better access to resources and mentorship, which creates disparities in skill levels. It is "impossible to establish a perfect system in clinical medicine" (Text condensate from 7 participants – ES2, ES3, T1, T2, L4, L7, L11).***

It's essential to address the differences in trainer competence to enhance training consistency, as this directly impacts the level of exposure and independence granted to trainees during procedures. Moreover, the trainers' attitudes towards SBST significantly shape trainees' opportunities to pursue SBST programs outside their primary training centres. In Sri Lanka, many hospitals lack their own simulation facilities, making it vital for trainees to seek opportunities at larger centres. Consequently, fostering a supportive environment where trainers encourage participation in these external training programs can greatly benefit trainees' skill development.

> ***Depends on the surgeon they are working, their training would vary, as some surgeons do more laparoscopy than others. "Some trainers are still learning", so trainees also get***

> ***fewer opportunities. "Some senior surgeons also not fully convinced of value of simulation and prefer traditional apprenticeship model" with learning on patients. Many are reluctant to release us to go and attend training sessions (Text condensate from 5 participants – ES4, T2, L2, L5, L8).***

Additionally, while theoretical knowledge is essential to surgical education, balancing it with practical skills training is critical. Some trainers may prioritise theoretical study, which can detract from hands-on practice. Encouraging a more integrated approach that values theoretical and practical training aspects can help trainees develop more comprehensive skills. There is also an opportunity to enhance laparoscopic training. Some trainers may hesitate to introduce laparoscopic methods early on, concerned that trainees might change their subspecialty focus. However, emphasising early exposure to laparoscopic techniques could yield long-term benefits for trainees regardless of their eventual specialisations.

> ***Some surgeons do not encourage trainees to train in MIS, because they haven't committed to laparoscopic surgery. Cultural factors. In Sri Lanka, "we often focus on theoretical knowledge rather than practical skills. We need to change our mindset to prioritise hands-on training" (Text condensate from 3 participants – T1, L1, L4).***

> ***SBST certainly helps with understanding the basics of laparoscopy, "because during surgery it's difficult to learn the basics, like coupling effect". This they should learn during the basic laparoscopy programme. That will give them the basic skills to then practice in the OR (Text condensate from 4 participants – T2, T4, T5, L10).***

Lastly, developing a clearer program structure is necessary to provide better guidance for surgical skills training. Establishing recommended minimum numbers of procedures, competency benchmarks, and a framework for graded exposure can significantly improve training outcomes and ensure a more standardised experience for all trainees. We can create a more equitable and effective surgical training environment by addressing these areas thoughtfully.

> ***"We had little formal training with the supervisors. Maybe holding a camera and a little dissecting of the gall bladder off the liver". Most of the time, the trainee will assist the surgeon for about 5 cases, then the trainer will assist for a few (Text condensate from 4 participants – ES2, T1, T4, L3).***

5.3.4.9.3 Inherent problems with MIS

Minimally Invasive Surgery (MIS) presents particular challenges that could make the use of SBST more beneficial than traditional open surgery. Interestingly, the trainees interviewed did not fully recognise these challenges.

One key aspect of MIS is that the anatomy can appear different during procedures. This is primarily due to the limited visibility provided by the camera, which reduces the recognition of anatomical landmarks. Additionally, the use of non-anatomical planes[7] during surgery, trainees must have a strong understanding of anatomy and the ability to create mental representations, as further explained in the discussion on mental representation in the next section.

> ***"Laparoscopic anatomy is different". Some surgeries, like TEP, are done in locations which are usually not seen during open surgery. Even in familiar territories, because the image from the camera only shows a small area, it's easy to lose the bearings (Text condensate from 4 participants – ES1, ES3, ES4, T8).***

Another consideration is that even minor bleeding can obstruct vision during laparoscopy, while conditions like fibrosis may complicate instrument manipulation.

> ***With laparoscopy, "even a little additional fibrosis makes dissection difficult". If you get even a "little bleeding, it significantly affects your vision" (Text condensate from 3 participants – ES1, ES2, T2).***

Hand motions during laparoscopy also introduce unique adaptations. Unlike open surgery, where depth perception is more intuitive, laparoscopy involves a fulcrum effect that can challenge a surgeon's spatial awareness. Moreover, the absence of tactile feedback means that the ability to physically touch and assess the organs is limited. A trainer noted that the challenges associated with motion in laparoscopy can be effectively addressed using SBST. This approach can help trainees develop the necessary skills to navigate these complexities more confidently.

> ***"One of the biggest challenges initially was adapting to the loss of depth perception in a 2D environment". This is quite different from open surgery. The loss of some tactile feedback also made it difficult to judge tissue consistency. So, hand-eye coordination, spatial awareness, and precision are critical. "Simulation allows refining these skills before stepping into the operating room" (Text condensate from 6 participants – ES1, ES2, T2, T5, L3, L12).***

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[7] Tissue planes that are not usually encountered during surgery or anatomy lessons– e.g. Total Extraperitoneal Plane in inguinal hernia repair

5.3.4.10 Suggestions for improvement

Participants provided valuable suggestions for enhancing the program based on the insights gathered regarding the current training program for laparoscopic surgery. These recommendations can be categorised into a few key areas.

One primary focus for improvement is the design and implementation of the curriculum. Participants expressed a need for a more structured curriculum to guide laparoscopic surgical training. A well-organised approach could enhance the consistency of content and training opportunities. Key elements for this structure include initiating basic laparoscopic training early in the program and establishing clear benchmarks for the number of procedures as well as the desired level of competence. Additionally, effective implementation of this curriculum is crucial. To achieve this, careful consideration should be given to the allocation of training centres, ensuring that all facilities and trainers align with the established recommendations. The Postgraduate Institute of Medicine (PGIM) could play a pivotal role as the regulatory body, ensuring adherence to these standards.

> ***A "structured training programme" and a "better organised curriculum" are needed. Now it's very haphazard. Every trainee must "undergo a basic laparoscopic surgical skill course early" In their training. "Defined milestones and benchmarks" are also important to keep training uniform. (Text condensate from 6 participants – ES2, ES4, T2, T4, T5, L3).***

An important extension to this curriculum design is the incorporation of competence-based learning. The PGIM could take the lead in clearly defining the competencies required for laparoscopic surgery and outlining appropriate corrective actions for those who do not meet these standards. While some trainers and surgeons advocate for the establishment of specific performance standards and milestones to evaluate progress, others believe that completing a designated number of surgeries should suffice.

> ***"PGIM can standardise the curriculum, it will ensure that all trainees across country receive consistent training". They should also monitor training centres, both volume and supervised training. If they are lacking, trainees should be reassigned to another unit (Text condensate from 6 participants – ES3, ES5, T3, L2, L9, L11).***

One key area identified for enhancing skills training is the preparation of trainers. It was emphasised that incorporating foundational knowledge, particularly an understanding of the biomechanics of laparoscopy, is essential. Trainees also expressed the value of pre-learning and acknowledged the importance of confronting challenges while building resilience throughout their training journey.

> ***There should be guidance on the types of operations and competencies they should achieve during each training rotation. That could give "both the trainee and the trainer a realistic expectation of what to achieve". A trainee "should not leave the unit until they've reached achieved that competence" (Text condensate from 7 participants- ES2. T2. T4, T5, L8, L9, L10).***

To address the limitations of certain hospitals and trainers regarding case mix and expertise, all three groups suggested a collaborative approach, allowing trainees to work with different surgeons. This strategy is anticipated to enrich the learning experience in two significant ways: first, it would provide trainees with opportunities to observe and engage in surgeries they might not have encountered otherwise; second, they would gain insights into various techniques employed by different trainers for the same surgical procedures.

> ***If "exposure to certain cases is less l during a rotation, you can allow them a week to visit another place for additional exposure". This will also allow them to see the different ways of doing the same surgery. You must allow them to get trained by many people, rather than seeing one person's way of doing things (Text condensate from 4 participants – ES2. ES3. ES5, T1).***

Moreover, the potential of SBST as a constructive solution to the existing challenges in surgical training was highlighted by trainers and ES. Trainees can better navigate the inherent limitations of minimally invasive surgery (MIS) and enhance their hand-eye coordination by focusing on developing essential skills.

> ***They should do "regular simulations, at least one session a week. They can come and work with beads or dissecting the skin of the chicken", simple things like that. That will "help them develop the hand coordination" etc and improve the learning curve (Text condensate from 3 participants).***

5.3.5 Simulation-Based Surgical Training

The previous section highlighted several challenges to training surgical skills during live operating. As one of the solutions for overcoming the limitations of the current training programmes was SBST, this was explored in detail during the interviews.

5.3.5.1 Current state of SBST

The supplementary training programs for laparoscopic surgery primarily consist of one-day workshops that integrate lectures with hands-on training. These workshops were particularly beneficial for early learners, as they aim to teach the fundamentals of laparoscopy along with basic laparoscopic skills. Participants engage in activities designed to enhance hand-eye coordination and adapt to the fulcrum effect, utilizing box-trainers as a core training tool.

> ***In my early training, we "had a basic skills course" which primed me to learn during the practice. I then had the skills and confidence to practice on my own, and to experiment (Text condensate from 3 participants – ES1, ES5, T1).***

Trainers also emphasised that attending a skills course does not ensure skill acquisition, and the need to accommodate varying learning needs.

> ***"In a course, you may be there and listen, or you may not". You may have the necessary skills to learn the techniques taught, or you may be too inexperienced. "It's also time-constrained, sometimes it's too quick to grasp" (Text condensate from 3 participants – T2, T4, L4).***

Interestingly, some trainers had not experienced structured training programs as trainees themselves, finding their initial roles as trainers within such programs. Although they have valuable surgical experience to share, enhancing their ability to guide trainees, especially during simulation training, could be achieved by providing them with more structured training in advance.

> ***During the first course I attended, I was a trainer, not a trainee. But I still got the chance to experience the training - T3***

Furthermore, some experienced surgeons have had the opportunity to participate in longer training programs overseas that focus on advanced laparoscopic skills. These programs often include extensive dry-lab or wet-lab sessions, offering greater emphasis and more opportunities for developing skills. This highlights the importance of considering expanded training formats that could better meet the needs of both trainers and trainees in the future.

> ***I attended a programme in India for about 10 days, where we practised skills as well as discussed complex procedures - ES1***

All three participant groups recognised the need for improved availability and integration of SBST within the surgical training program. This is an area that could benefit from advancements in both curriculum and infrastructure. Trainees who have experienced training in Sri Lanka and overseas noted that in the UK, SBST is more effectively integrated into the curriculum, providing a variety of simulation training levels that cater to trainee needs.

> ***"In Sri Lanka, we're making progress, but simulation isn't as ubiquitous", and its implementation is still in its early stages. "In the UK, simulation is deeply integrated into surgical training programs. They have dedicated simulation centres with a wide range of tools" (Text condensate from 4 participants – ES5, L2, L3, L9, L10).***

Both educators and trainers acknowledged the significance of SBST as a crucial component of laparoscopic training. They emphasised the importance of beginning training with a strong foundation in simulation-based methods. There is shared optimism that with continued efforts in both infrastructure and curriculum development, SBST will become increasingly accessible to all trainees in the future.

> ***"When I first started, training heavily depended on observing senior surgeons and gradually assisting in procedures". Over the years, a significant "shift towards incorporating simulation-based training" has occurred. "I believe future of surgical training, even in resource-limited settings, will involve more simulation and deliberate practice". "I consider it essential" (Text condensate from 6 participants – ES3. ES4, T3, T4, L1, L10).***

5.3.5.2 Role of simulation in surgical training

Participants highlighted several constructive advantages of SBST.

Firstly, SBST plays a crucial role in developing fundamental skills, which is especially important in laparoscopic surgery. The challenges of navigating the loss of 3D vision and the fulcrum effect require trainees to enhance their hand-eye coordination. Traditionally, this skill development occurred during live surgeries, which can create undue stress for the trainee and introduce unnecessary risks for the patient. By utilizing SBST, trainees can hone their dexterity in a controlled environment, ultimately boosting their confidence and enhancing their performance during laparoscopic procedures.

> ***"I think ideally if they can do a little bit of dry lab work initially", "It will give a feel of the instruments. It gives you some degree of hand-eye coordination". By the time you step into the OT, you're not only familiar with the instruments and procedures but also confident in your ability to handle unexpected situations. Many centres use simulation***

> ***for new trainees to learn basic skills before working on patients (Text condensate from 6 participants – ES4, ES5, T1, T5, L7, L12).***

Secondly, SBST is beneficial for advancing surgical skills. Advanced simulators can create immersive environments that closely mimic real surgical settings, without the inherent pressures of actual surgery. These modern simulators effectively replicate both the visual and tactile aspects of surgery, which is invaluable for trainees who have already mastered basic skills but need to develop a deeper mental understanding of anatomy for specific procedures.

> ***New technologies have the potential to provide immersive experiences that more closely replicate the challenges of actual surgery (Text condensate from 3 participants – T3, L11, L12).***

Additionally, simulation offers a stress-free learning environment for individuals at all competence levels. The operating theatre can be a high-pressure setting that is not always conducive to mastering fine motor skills. By allowing trainees to practice independently, without the constraints of patient volume and at their convenience, SBST fosters an atmosphere of confidence and improves the overall learning experience. This, in turn, can lead to heightened performance during actual operating theatre sessions.

> ***"Laparoscopy has a longer the learning curve", and "during the surgery itself, it's difficult to learn the basics". Especially for junior trainees, we must increase simulation training opportunities. That will make it less stressful to be in theatre. Confidence is very important for a trainee (Text condensate from 5 participants – ES1, ES2, T3, T4, L2, L5).***

5.3.5.3 Intended outcomes

The SBST plays a vital role in enhancing both learning and patient outcomes in the field of medical training. One of the significant benefits of SBST is its ability to accelerate the learning process for laparoscopic trainees. By integrating simulated training into their education, trainees can develop essential skills more efficiently than they would through traditional surgical experiences alone. This is especially beneficial for complex tasks like laparoscopic suturing, which demands precise hand-eye coordination in a 2D environment.

> ***Ability to practice on a virtual platform before operating on a real patient has "significantly reduced the learning curve"" and improves confidence. The learning curve can be improved, especially with suturing. Trying first time in a theatre means it's a totally different ball game (Text condensate from 5 participants – T1, L2, L7, L8, L10, L11).***

Furthermore, SBST contributes positively to patient care by reducing the likelihood of trainees acquiring foundational skills during actual surgeries. This proactive approach minimizes risks to patients and ensures that trainees develop a higher level of competence. As a result, the quality of their surgical performance improves, leading to enhanced patient outcomes. Additionally, SBST provides opportunities to practice rare surgical procedures and to prepare for unusual but critical intra-operative complications, ultimately fostering safer and more effective healthcare delivery.

> ***Simulation is valuable in skill development and patient safety. It ensures that trainees have a "strong foundation before they perform procedures on actual patients". It allows you to make mistakes in a safe environment and learn from them without endangering a patient. Surgeons are more skilled, confident, and capable of handling the complexities of laparoscopic surgery. It "reduces the risk to patients, and patient outcomes, morbidity, mortality can be improved" (Text condensate from 7 participants – ES1, ES2, ES5, T4, L3, L8, L10).***

5.3.5.4 Infrastructure

5.3.5.4.1 Type of simulators

Participants from all categories acknowledged that the primary simulation tools available in Sri Lanka are predominantly box trainers. These box trainers, which are simple rigid structures with instruments inserted through their walls to simulate the abdomen, offer several advantages. They are cost-effective and can be constructed from readily available materials. Despite their limited fidelity, box trainers serve as an excellent resource for developing basic laparoscopic skills among beginners, and they can be effectively combined with dry-lab training for intermediate trainees. As a result, they are well-suited for foundational skills training and have become a key component of laparoscopic SBST in Sri Lanka.

> ***The main barrier is lack of resources. "We don't have enough simulators, and the simulators we have are outdated". "Opportunities for advanced surgical training, especially minimally invasive surgery, are limited". "Some larger teaching hospitals have started to incorporate basic simulation tools, like laparoscopic box trainers. However, access is limited and it's not a formal part of the training curriculum". Trainees and trainers could advocate for better simulation resources (Text condensate from 7 participants – ES1, ES2, ES5, T3, T5, L7, L10).***

On the other hand, advanced high-fidelity simulators, while more effective, are currently expensive and unavailable in the country. Some surgeons have expressed that simulation cannot fully replicate the actual surgery experience. Several trainees who have trained on advanced simulators during their experiences in the UK and Singapore, however, recognise their significant benefits and are actively advocating for their introduction into the Sri Lankan training landscape. This push for high-fidelity simulators highlights an important opportunity for enhancing surgical training in Sri Lanka.

> ***“Another limitation is the gap between simulation and actual surgery. Box trainers cannot fully replicate the nuances and pressures of a real surgical procedure”. “We can expect more sophisticated, immersive, and realistic simulation models with Virtual reality and augmented reality”, but these are expensive, and we can’t afford them. The biggest contrast between Sri Lanka and developed countries is probably the availability of resources and advanced technologies. “Even the simulators we have, we don’t optimally use” (Text condensate from 8 participants – ES2, ES5, T2, T4, L3, L4, L10, L12).***

5.3.5.4.2 Access to simulators

Access to simulators is crucial for effective training, yet their availability is often limited. One challenge is that simulators, including box trainers, are typically found only in main training centres, making them inaccessible for trainees in other locations. Even in these centres, the simulation facilities are open primarily during regular working hours, which may conflict with trainees' schedules and prevent them from practicing during their free time. Recognizing the importance of flexible access to simulators, some trainers and educational supervisors have acknowledged the need for improvements, although specific implementation strategies have yet to be discussed. It's encouraging to see that some trainees have taken the initiative to set up box trainers at home to further develop their skills.

> ***Availability of well-equipped simulation centres is limited, restricting opportunities for regular practice. Even maintaining basic simulation tools can be challenging given budget constraints. But we need to make simulation more accessible and affordable. “We could establish partnerships between institutions to share resources and expertise. Perhaps create regional simulation centres” (Text condensate from 3 participants – ES3, T2, L2).***

Additionally, the demanding nature of clinical workloads often prioritizes hands-on surgery as part of service delivery, limiting opportunities for simulator training. Addressing these challenges could enhance training experiences and improve skill acquisition for all trainees.

> ***There's no dedicated time for simulation. The schedules are very busy with clinical duties. I've had to be more creative and set up a basic laparoscopic trainer at home, to practice in the little time I get. Some trainers don’t encourage home training but suggest going to the simulation centre when there is free time (Text condensate from 5 participants – ES2, T3, L3, L11, L12).***

5.3.5.5 Content and delivery

The content and delivery of SBST can be categorized into three main areas: basic and advanced training and remedial training. Basic and advanced training can be provided in an elective format, often scheduled for larger groups, while remedial training is tailored to individual needs and is conducted on an ad-hoc basis.

In Sri Lanka, the basic training component of SBST is the most established and involves dry-box or beetle training. This foundational training is mandatory for all junior trainees to enhance their laparoscopic skills. The focus here is on developing essential hand-eye coordination to effectively navigate the limitations of minimally invasive surgery (MIS). Key activities in this training include tissue handling, cutting, grasping, retraction, and suturing—skills that are fundamental to any surgical procedure. It's worth noting that many experienced surgeons have expressed the importance of revisiting basic training when faced with complex tasks, such as laparoscopic suturing. Both experienced surgeons and trainers encourage trainees to practice suturing in a controlled environment before embarking on procedures with actual patients. The consensus is that dry lab or beetle training suffices for SBST in the basic training phase, while wet lab training is less favoured at this level.

> ***We "practiced suturing and knotting on the lap trainer available in our department". I ask trainees to work at least 10 hours before they start practicing on a patient. "I am not a big fan of wet lab training on, for instance, live animals. I'm not very sure whether it is actually necessary in our context" when we have the opportunity to operate on patients (Text condensate from 6 participants – ES2, ES3, T1, T2, L2, L3).***

When it comes to advanced training within SBST, which encompasses the execution of certain steps or entire surgical procedures, opportunities are currently limited in Sri Lanka. Two of the most effective options for advanced training involve either VR simulation or wet lab/animal models. VR simulators offer the advantage of providing objective performance assessment metrics and accurate haptic feedback. Their availability, however, is restricted due to high costs and they are not yet accessible in Sri Lanka. The alternative of using animal models is also present, though live animal laparoscopic training is not practised in the country; currently, only cadaveric training is offered. While cadaveric training provides valuable tissue fidelity, the absence of bleeding during these sessions can be seen as a notable limitation.

> ***"VR simulators often come with feedback systems that can assess performance in real-time, providing metrics on precision, speed, and even the economy of movement". There is also "traction and counter-traction with haptic feedback", but these are not available in Sri Lanka. We can overcome some of these by using animal tissue inside box***

> ***trainers, but there is no bleeding (Text condensate from 6 participants – ES2, ES3, ES5, T2, L3, L12).***

Lastly, remedial training plays a crucial role when specific weaknesses are identified. This form of training is typically confined to reinforcing the basic skills that need improvement, ensuring that individuals can enhance their competencies through focused practice.

> ***If I feel that the dexterity and his hand eye coordination is not good, probably I would take over and "ask to go back to Beatle and practise some more and come back" (Text condensate from 2 participants- ES3, T3).***

5.3.5.6 Attitudes

The interviews revealed several insightful perspectives regarding the attitudes towards SBST. Trainers emphasised the value of fostering a non-threatening learning environment for trainees, which can facilitate better learning experiences. Experts in the field noted that while advanced training, such as robotic training, may not be essential as a core component, focusing on core competencies is crucial. This approach allows trainees to build a solid foundation from which they can later develop advanced skills as needed, ultimately optimising resource allocation to benefit a wider group.

> ***"The guidance and feedback from experienced surgeons are irreplaceable". "Establishing more structured mentorship programs could help bridge the gap between simulation and real-life surgery". Trainers should avoid punishing for making mistakes and ensure that the trainees know that they are there for them. "I don't think it will take anybody more than six months to get trained in robotics when required, our training should be robotic training compatible" (Text condensate from 6 participants – ES2, ES3, T1, T5, L3, L8).***

All groups recognised the critical need for ongoing training for educators, both in surgical skills and in pedagogical methods. ES particularly emphasised the importance of a trainers' surgical skills and advocated for the formal accreditation of their expertise and surgical volume. Conversely, trainers and trainees highlighted the necessity of training educators in effective teaching practices. An emphasis on pedagogy was viewed as essential for effective mentorship, bridging the gap between simulation experiences and real surgical environments.

> ***"Education is crucial - not just for trainees, but for senior surgeons and hospital administrators". "To be a laparoscopic trainer, there should be some accreditation". Many trainers don't how to train, and there is a shortage of people trained in simulation-based education. Some senior surgeons do not fully appreciate the value of***

> ***simulation and see it as a distraction from clinical duties (Text condensate from 6 participants – ES1, ES3, T4, L2, L3, L8).***

Additionally, the three groups brought different perspectives to light regarding SBST. Both experts and trainers shared concerns about the lack of standardisation and the resulting variability in training among different trainees. In contrast, trainees noted that some trainers may not fully grasp the significance of SBST, which can impact their ability to effectively guide trainees in skill development. This feedback provides a valuable opportunity for improving training practices and enhancing the overall training experience.

> ***"Lack of standardisation and formal integration of simulation into the training curriculum" is a problem. Another issue is the "variability in training quality across different institutions". Some trainees have better access to resources and mentorship than others, which can create disparities in skill levels (Text condensate from 5 participants – ES5, T3, L2, L3, L5).***

5.3.5.7 Limitations affecting broader SBST use

The participants highlighted several limitations affecting SBST. The lack of a standardised curriculum for SBST affects exposure. Especially given the opportunistic exposure to surgical procedures, and the unequal distribution of simulation resources, a curriculum would provide guidance for the training. The lack of an overall structure also limits the advice and enforcement by trainers. A trainer stated that they can't suggest an activity as compulsory because there is no overall structure or defined milestones. Cultural factors affecting SBST were also highlighted by both ES and trainers, including the undue emphasis on theoretical knowledge, and a focus on hands-on surgery over SBST.

> ***"Lack a standardized curriculum for simulation and deliberate practice" is a problem. "Case load exposure will be variable between hospitals, cities, units, but if you have that basic structure then I think it will help". Making simulation training compulsory will help, "now we tell them when they get an opportunity, but I think we're not enforcing it". There's also a cultural aspect to consider. "There's sometimes a perception that "real" learning happens only in the operating room" (Text condensate from 7 participants – ES2, ES5, T1, T3, L4, L6, L11).***

Both trainers and trainees highlighted the impact on time constraints on their training. Busy clinical workloads, often with minimal hands-on surgical training, reduce the potential time that could be spent on SBST. If more time cannot be spent on training, the learning outcomes from the time spent need to be optimised.

> ***"There's also a lack of dedicated time for simulation. Schedules are very busy with clinical duties". "Surgeons and trainees are often stretched thin", making it "difficult to allocate dedicated time for simulation and deliberate practice" (Text condensate from 3 participants – T4, L11, L12).***

5.3.5.8 Improving SBST

5.3.5.8.1 Structure and integration

Several constructive suggestions were made for enhancing the existing SBST program in Sri Lanka. Both ES and trainers advocated for the implementation of an online platform for initial training, with specific modules tailored to each training component. Additionally, there was a strong consensus on the need to reinforce the current basic skills training program. All stakeholders agreed on the importance of a structured training program, with ES and trainers highlighting the value of a stepwise exposure approach. This method would facilitate gradual skill development, allowing trainees to progress at their own pace. One trainer pointed out that even within the same workshop, it is essential to address different learning aspects, as the competencies of trainees can vary significantly. To optimize learning for each level, suggestions included engaging in discussions with surgeons who can demonstrate critical skills.

> ***"Online modules which deal with different aspects of laparoscopic surgery", and virtual coaching will be useful. "Adding structure is important". Simple skills, like suturing and knot-tying, could be taught on a box trainer first, and helps with understanding the basics of laparoscopy, "because during the surgery itself, sometimes difficult to learn the basics". They can then be allowed some real operating gradually under supervision (Text condensate from 5 participants – ES2, T2, T3, L3, L10).***

Trainees and surgeons with experience in international training programs noted the successful integration of SBST in those contexts and expressed optimism for improvements in Sri Lanka. While many recognised the need for better integration into the curriculum, there were challenges in proposing specific strategies. A primary recommendation was to establish a structured curriculum to guide trainers, encouraging them to motivate trainees to use simulation facilities during their available time.

> ***Programme should "include stepwise progression" and should "Integrate simulation more" formally into training curriculum. This will standardise the quality and content of training (Text condensate from 4 participants - ES4, T5, L1, L3, L9).***

Moreover, one trainee suggested that speciality-specific SBST should align with clinical rotations, particularly emphasising advanced laparoscopic training, which is currently less common in Sri

Lanka. An educator also proposed adopting the DP framework to develop a more effective training structure, further enhancing the program's overall efficacy.

> ***"Incorporating simulation training into the clinical curriculum", such as during off-duty hours or elective periods is essential. Also, the simulation activities must align with their surgical rotation (Text condensate from 3 participants – ES2, T1, L12).***

5.3.5.8.2 Competence-based learning

To enhance learning through SBST, it would be beneficial to establish clearly defined competencies to be achieved by the end of the training. ES proposed implementing certification of achievement at various milestones, with each assessment of competence serving as a gatekeeper for progression to the next level. This reflects the principles of mastery learning. Some trainers recommended recognising and rewarding participation, which, although valuable, might be viewed as a basic level of learning outcomes. Another trainer highlighted the importance of including operative volume and patient outcomes, representing higher levels of competence to evaluate.

> ***"There should be some certification", then only should you permit progression to the next level. This could include the number of procedures, the types of procedures, and morbidity and mortality. "Recognizing and rewarding participation in simulation-based training" could be considered (Text condensate from 4 participants – ES5, T2, T4, L8).***

A trainee also introduced the idea of tracking training volume, focusing primarily on the number of procedures completed. Additionally, they suggested incorporating periodic simulation-based assessments, a concept that neither trainers nor ES had previously suggested. These ideas collectively hold potential for enriching the training experience and ensuring comprehensive skill development.

> ***It should "be a formal requirement". "Trainees should have a logbook of simulation hours. Just like we do for real surgeries". "We could also have regular assessments on simulators to track our progress" (Text condensate from 3 participants – ES2, L4, L9).***

5.3.5.8.3 Orchestration

To enhance the orchestration of SBST, several constructive recommendations emerged from the discussions. A key theme was the need to increase simulation opportunities. Interview participants, including both ES and trainees, advocated for exploring cost-effective alternatives to expand access rather than concentrating solely on high-end simulators. One trainer also noted the importance of ensuring that at least one centre is equipped with advanced simulators.

> ***We should explore more affordable simulation options. "A surgeon had made a low-cost box trainer with a plastic box and a webcam". "We should have at least one central place for simulation with high-end facilities", rather than every university or every hospital trying to have their own training centres. There must be regular simulation sessions, at least weekly. That will improve the learning curve. And easy access to those who are interested (Text condensate from 6 participants – ES1, ES4, T2, T3, L2, L11).***

There was a consensus among trainers about the benefit of increasing the frequency of training sessions, and ES emphasised the need for a standardised curriculum across the country. While opinions varied on training content, many trainers expressed that expanding the use of cadaveric or animal training could be beneficial, particularly in teaching tissue handling. ES concurred that these methods could serve as valuable alternatives to high-fidelity simulators.

> ***"Dedicating a mandatory amount of time each week for deliberate practice session" is needed. "While high-fidelity simulators are great, a lot can be achieved with more basic tools". "Maybe dissecting a cadaver or a pig's gall bladder will develop basic skills" like instrument handling (Text condensate from 4 participants – ES5, T2, T4, L7).***

Additionally, training the trainers emerged as a vital suggestion to bolster SBST effectiveness. Trainees underlined the necessity of supervision in enhancing the learning process, which directly ties into the development of clinical practice. To address challenges related to the availability of proficient trainers, tele-mentoring and remote learning were proposed as viable solutions. ES reaffirmed the critical importance of hands-on training, particularly in the areas of clinical judgment and decision-making, recognising that while this may not directly impact skill development, it plays a significant role in overall competency

> ***"We should train more faculty in simulation-based education". Remote mentoring will allow trainees from different parts of the country—or even the world—to access high-quality education without the need to relocate". "While simulation is valuable, the guidance and feedback from experienced surgeons are irreplaceable. Establishing more structured mentorship programs could help bridge the gap" (Text condensate from 5 participants – ES3, T2, L2, L4, L5).***

5.3.6 Deliberate practice

The systematic reviews and the mixed methods study revealed that the SBST fell short of delivering the desired learning outcomes. In light of this, Deliberate Practice (DP), renowned for its transformative impact in music and sports, emerges as an innovative instructional design aimed at maximising the potential benefits of SBST.

DP, however, was brought up by during the interviews only by a minority. In most situations, except when specifically mentioned, the discussion on DP focussed on its use in traditional hands-on training, and not simulation.

5.3.6.1 Understanding of DP

The participants exhibited a diverse range of knowledge regarding DP. It was notable that several ES trainers and trainees did not initially recognise the significance of DP, and some expressed that they were unfamiliar with its principles. A few participants even confused DP with structured and formal training, highlighting an area for improvement in understanding.

> ***Deliberate practice is formal, structured training (Text condensate from 3 participants – ES4, T3, L4).***

Many participants demonstrated a basic comprehension of DP, with a recurring theme being the emphasis on an explicit structure within training programs. One educator pointed out the focused nature of practice that is essential for skill development, while a trainee noted that DP encourages learners to take a proactive approach to their training. Interestingly, a deeper understanding of DP was primarily observed among the trainees, with only one ES and no trainers exhibiting this level of insight. The key components they identified included breaking down complex tasks into smaller, specific learning goals, developing a clear plan to achieve those goals, and engaging in deliberate practice to enhance skills.

> ***DP is a focused method of practice for skill development, which requires you to be proactive about your training. Both experts and trainees recognise its importance for continuous improvement and lifelong learning (Text condensate from 4 participants-ES2, T1, L1, L4).***

One trainee underscored the significance of mental preparation, which encompasses both visualising the task and maintaining motivation—especially since it requires effort to actively prepare for learning activities. Another trainee echoed this sentiment, emphasising the roles of motivation and perseverance in the learning process. Additionally, the importance of feedback during DP training sessions was recognised, with one participant noting its positive impact on learning outcomes. Furthermore, trainees acknowledged the benefits of DP for skill-based training, particularly the value of repetition in enhancing performance levels.

> ***DP is being focused on specific skills you want to improve, having a clear plan, practising deliberately, and getting feedback to achieve this. The "idea is to push the boundaries of your current abilities, work on your weaknesses, and gradually expand your skill set". You also shouldn't neglect mental practice, visualise procedures in detail when you can't access physical simulators. But you "must be patient and persistent". "DP is a long-term investment, but it pays off in the end" (Text condensate from 5 participants – ES1, ES2, T1, L4, L12).***

Overall, this feedback indicates promising opportunities for deepening the understanding of DP across all participants and enhancing training approaches moving forward.

5.3.6.2 Mental representation

A key element of the DP framework is mental representation, which refers to the ability to visualise the task and its desired outcome in one's mind. This capability is particularly crucial for identifying and correcting mistakes, especially in self-directed learning contexts.

In the realm of laparoscopic surgery, mental representation can manifest in two primary ways. First, it involves comprehending the sequential steps of the procedure and the expected end results—this defines the traditional view of mental representation. Additionally, gaining a thorough understanding of laparoscopic anatomy is vital, given that the typical anatomical landmarks may not always be visible on the screen. Observing various surgeons and their techniques can significantly aid in developing this understanding. Many trainees have referred to their practice as mental rehearsal, which may also reflect their motivation and commitment to learning.

> ***"Trainees often need to work on bigger, more obvious skills". "Deeper understanding of surgical anatomy and can make practice" more effective. "Experts also seem to be better at identifying their own problems to correct, and to find small details to improve". Watching how different experts performs surgeries help to get a broader understanding (Text condensate from 5 participants – ES4, T3, T4, L4, L9).***

Interestingly, none of the ES interviewed explicitly mentioned mental representation in this context. Since it is a fundamental aspect of achieving expert-level performance in surgery, however, it is unlikely that they lacked this skill. It could be that they simply did not identify it as part of the DP framework or were unaware of possessing this capability. This observation aligns with the ideas of unconscious competence and expert reversal, which will be explored further below.

5.3.6.3 Motivation

A fundamental aspect of DP is the motivation of the participants, which can be categorised into two key areas: motivation to participate and motivation to enhance performance. Insights from interviews highlighted the significance of both dimensions. An ES emphasised that motivation is crucial when striving for expert performance, as achieving mastery in a single movement may require hours of dedicated practice. Simulation is essential in this process, allowing for focused repetition that wouldn't be feasible in real surgical settings.

> ***You must "focus on the weakest skills and try to improve them gradually". You can't rush the learning process. It will be slow, but you must remain motivated. A strong foundation in your basic skills is essential (Text condensate from 3 participants – ES3, L3, L8).***

Conversely, trainers predominantly focused on motivation to participate, discussing both intrinsic and extrinsic factors. They shared how they inspire trainees through explicit guidance and implicit encouragement. Additionally, they noted the cultural challenges that can affect DP, such as the perception of spending prolonged periods on simulations to perfect specific skills.

> ***To improve, we must "focus more on refining very specific techniques and might need to spend hours perfecting a single movement". "Determination and patience are essential". Trainees are encouraged to practice when they get an opportunity, but often "it's not enforced enough". We must also "dispel misconceptions like not spending too much time on simulation training" (Text condensate from 4 participants – ES3, T2, T5, L2).***

Trainees echoed these sentiments, recognising both aspects of motivation in their training. One trainee outlined her approach by creating a structured practice schedule, while another described his efforts to improve weaker skills through deliberate practice. They also exchanged valuable motivational strategies, encouraging one another to leverage available resources, maintain a positive mindset despite any limitations, and apply DP principles across all training tasks. One trainee notably emphasised the importance of focusing on skill improvement without hastening the learning process, reinforcing the value of perseverance in mastering new techniques.

> ***"You must be interested in your learning, can't wait for perfect conditions or resources". Making a schedule and practising regularly, even for short periods, is essential. You must be self-motivated to improve; "set specific goals, practice regularly, and seek feedback" (Text condensate from 4 participants – ES5, L2, L3, L11).***

5.3.6.4 Task design

5.3.6.4.1 Overall task design

The DP framework encompasses four subcomponents for effective task design, with one notable highlight being the significance of incorporating multiple difficulty levels within tasks.

Separate emphasis on the various aspects of training is important, and should cover both basic skills training for primary tasks, such as tissue handling and suturing, and advanced simulation scenarios that include partial or complete surgeries. Trainee highlighted good practices they witnessed elsewhere, like the inclusion of specific learning objectives and clear instructions at the outset of their SBST, which contributed positively to the learning experience, and recognising the current skill level of trainees when designing and selecting training tasks.

> ***"Specific goals must be set for each practice session", to avoid practising aimlessly. "Know what you want to improve and how you can know if you're progressing". Different skills should also be separated, for example, suturing, knot tying, and instrument manipulation should be initially practised separately". "The programme should have a stepwise progression of difficulties" (Text condensate from 5 participants – ES3, T1, T5, L4, L7).***

By placing a greater emphasis on understanding trainees' present skill levels and aligning training activities accordingly, alongside providing explicit instructions and ensuring comprehension, we can enhance the overall training process. This thoughtful approach could improve outcomes, fostering an environment where unconscious competence is more readily developed. This, however, was not mentioned by ES or trainers. Like mental representation, this may indicate unconscious competence.

> ***"Trainees had regular, scheduled simulation sessions, targeted to their skill level", maybe suturing at a second stage and then advance the work at a third stage. "The objectives of the training were clearly informed at the beginning", and "there was immediate feedback" (Text condensate from 4 participants – ES2, ES4, T1, L1, L4).***

5.3.6.4.2 Stepwise approach

The discussion surrounding the stepwise approach[8] to task training has primarily centred on enhancing hands-on surgical training. However, it might be beneficial to explore how DP can further enrich SBST. In real surgical environments, a stepwise approach can be effectively implemented through various methods, including task allocation, case selection, and the progressive increase in difficulty during surgery.

One of the most straightforward implementations of the stepwise approach is through task allocation. For instance, the initial stage of laparoscopic surgical training often begins with trainees learning to insert ports, followed by progressing to roles such as the assistant, camera assistant, and eventually the primary surgeon. Some trainers have reported a positive experience by allowing trainees to work independently after an initial phase of supervision, promoting their confidence and skills.

> ***"Supervised stepwise exposure", initially they might place ports and hold the camera, then they would do some easy dissections. I judge their abilities, including whether they recognize when they can't proceed by themselves. "After this, I am completely hands off, so they get their training in a very graded way" (Text condensate from 5 participants – ES4, T1, T2, L3, L11).***

Another aspect of the stepwise approach is case selection. An expert in genito-urinary surgery noted that he opted for less complex surgeries during the early stages of his laparoscopic practice. The selection process was guided by the complexity of the disease and the required dexterity, with specific emphasis on laparoscopic suturing skills. This progression typically followed a pathway from simple diseases without suturing to more complex cases, including suturing in challenging spaces.

> ***"We started with simple cases like large renal cyst decortication, then moved to simple Nephrectomy. Pathological kidneys were done thereafter, followed by radical nephrectomy, pyeloplasty, and then ureteric work. Final step was to get into the pelvic surgeries and radical prostatectomies". This was because it was self-training. Same with general surgery, "when I'm confident in them doing cholecystectomy and appendectomy, I introduce them to do colorectal work" (Text condensate from 3 participants – ES5, T2, T5).***

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[88] Training in the skills lab to develop basic skills, followed by easy tasks during surgery

Additionally, selecting simpler tasks within surgeries for training can take on various forms. For example, a trainer could handle the more intricate tasks of a procedure while allowing the trainee to focus on simpler tasks, such as dissecting the gallbladder from the liver. Another effective method is using straightforward surgical procedures to impart complex skills by focusing on non-critical tasks that don't require perfect execution. For example, performing an appendicectomy could serve as a platform to practice knot-tying, while laparoscopic hernia repairs can help trainees refine their suturing techniques. Mastery in these fundamental skills can then facilitate progress to more intricate procedures, such as intracorporeal bowel anastomosis. An opportunity for enhancement also exists in establishing multiple difficulty levels for the same task, such as differentiating between laparoscopic suturing in easily accessible sites versus more challenging, confined spaces, like deep in the pelvis.

> ***'The easy ones I get them to dissect the gall bladder, and gradually allow them crucial parts like dissecting in the Calots triangle". Then I teach them clipping the structures, and how things can go wrong. "I'd focus on specific skills, gradually increasing difficulty and complexity". In nephrectomy, "the most difficult part was the pedicle control. So that was the last step". "Stopping at that right point doesn't discourage you from doing laparoscopic training" (Text condensate from 6 participants – ES2, ES3, T2, T5, L5, L11).***

5.3.6.5 Feedback

Four components of feedback in the DP framework are discussed separately: supervision during training, timing of feedback, content of feedback, and allowing remedial training.

Here again, emphasis was predominant on feedback during real surgery. The little mention of SBST was a conceptual discussion rather than an actual application.

5.3.6.5.1 Source of feedback

5.3.6.5.1.1 Trainer

There is a valuable opportunity for supervision at all stages of training. One ES emphasised that even at their experience levels, they benefit from ongoing supervision and mentorship to enhance their skills continuously. One trainee pointed out a common challenge: the reluctance to embrace supervision and feedback, as it can sometimes be misconstrued as a sign of weakness. However, an ES strongly underlined the importance of being receptive to feedback, which is vital for growth.

> ***We must "promote a culture of continuous improvement and normalise seeking feedback". Feedback is crucial in self-improvement, whether it's from a mentor, a peer,***

> ***or the simulation software itself. "In our culture, there is sometimes resistance to admitting areas for improvement or seeking feedback, because people think that indicates you are not good" (Text condensate from 5 participants – ES2, ES3, T2, L2, L8).***

A trainer noted that fostering a culture of open discussion and constructive feedback can significantly change trainees' perspectives. Initially hesitant individuals often become more amenable to the process as they see its benefits. One trainer shared his approach of granting independence to trainees early; while this encourages self-reliance, it can also reduce the frequency of supervision and feedback.

> ***"We very openly discuss, and registrars who are little backward and reluctant to talk or apprehensive for feedback naturally start talking". I am completely hands off following their initial training (Text condensate from 4 participants – ES2, T2, T4, L3).***

All three groups of participants consistently expressed the essential role feedback plays in development. The ES reiterated that proactively seeking feedback is crucial. They also highlighted various sources of feedback, such as mentors, peers, or even automated systems from simulation software, which can all contribute to a comprehensive learning experience.

> ***"Seek feedback constantly and be open to constructive criticism". It's through feedback and deliberate practice that you'll truly grow as a surgeon (Text condensate from 3 participants – ES2, L3, L12).***

5.3.6.5.1.2 Self-evaluation

A crucial aspect of developing surgical skills is the ability to self-evaluate one's performance. All three groups emphasised the value of self-reflection in this process. Interestingly, it was noted that ES typically excel in this area; trainees observed that experienced surgeons possess strong self-reflective skills, while trainers and ES pointed out that many successful surgeons have honed their abilities through ongoing self-evaluation.

> ***"After each real surgery, I reflect on what went well and what I need to work on". "Evaluating your progress can be challenging, especially at the beginning when improvements are incremental, and you are not competent, but over time, you start to notice significant advancements". Skilled surgeons are very good at identifying their own weaknesses. "If you take Doctor Palanivelu, he's pretty much a self-made laparoscopic surgeon, and he's a pioneer" (Text condensate from 5 participants – ES2, ES3, T3, T5, L8).***

Given the high demands and significant cognitive load present in surgical environments, self-reflection during surgery may not always be feasible. A practical alternative is to record the surgical procedures for post-analysis. Most laparoscopic systems now offer recording capabilities, allowing for comprehensive performance review after surgery. This approach benefits the trainee and enables trainers to assess the trainee's skills even when they are not physically in the operating room.

> ***Video recordings are very useful for self-assessment. " I record my practice sometimes on my phone to review later and get feedback from my trainer, to see where I can improve" (Text condensate from 3 participants – ES2, L2, L9).***

Recognising the importance of this element, we will further explore self-evaluation and reflective practices in the relevant section.

5.3.6.5.1.3 Video analysis

A recurring theme emphasised by all three participant groups was the valuable role of videos in the learning process. Videos served two primary purposes. Firstly, they provided opportunities to observe the techniques of experienced surgeons, helping learners become acquainted with laparoscopic anatomy and learn from mistakes and complications, which is crucial for developing a mental representation of surgical procedures.

> ***You should watch several videos of the procedure, "there are many available online". These will "show the anatomy, the different views, different ways people dissect", and problems people may encounter during surgery. Especially for senior trainees, they can learn by watching videos (Text condensate from 5 participants- ES2, T2, T3, T4, L3).***

Secondly, video recordings of one's own surgeries offer significant feedback and self-improvement advantages. This approach allows individuals to review their performance multiple times, away from the high-pressure environment of the operating theatre. Observers can focus on different elements during each viewing, such as tissue handling in one session and movement efficiency in another. Given that surgery inherently increases cognitive load, being able to analyse each step at one's own pace helps trainees manage this load more effectively.

> ***"Video analysis can identify areas of improvement in dexterity and efficiency". Surgeons overseas "routinely record their surgeries and watch them later" (Text condensate from 3 participants – ES4, L4, L9).***

Additionally, recording surgeries facilitates post-procedure discussions with trainers, enabling constructive feedback even in the trainer's absence. Thankfully, most modern laparoscopic tools come equipped with video recording capabilities, making it easy to capture these invaluable learning moments. Overall, utilising videos in surgical training can significantly enhance the educational experience and support the development of essential skills.

> ***You can "receive feedback from the supervisors through video review, to help identify areas for improvement". "I record my practice on my phone to review later and correct myself or get feedback from my trainer" (Text condensate from 5 participants – ES2, ES5, L7, L10, L12).***

5.3.6.5.2 Timing of feedback

The DP framework emphasises that immediate feedback is crucial for effective training. In the context of surgical training, this feedback can occur at two key moments: during the surgery and after its completion. An ES pointed out the significance of receiving real-time feedback during procedures, noting that insights can be valuable even from colleagues with less experience. Reflecting on their own training experiences, they acknowledged the benefits of real-time feedback, which allowed for timely corrections.

> ***Feedback is mostly completed in theatre verbally, sometimes a "little chat on the side, or at the end of the procedure". When they are operating, I might correct them or demonstrate a better technique "if they're dissection is crude, or they are getting lost". It's also useful when the Assistant is experienced and express their opinion freely during the process (Text condensate from 4 participants – ES1, ES3, T2, T5).***

Trainers also focused on providing both immediate and post-procedure feedback. Many emphasised the importance of delivering feedback right after the surgery, rather than delaying it to a later date. While feedback often took the form of commentary on surgical skills and suggestions for improvement, there was a lack of standardised approaches, such as Directly Observed Procedural Skill (DOPS), mentioned in the interviews.

> ***We have post scenario discussion all the time, "I don't have a structured way of giving feedback" (Text condensate from 3 participants – ES4, T4, T5).***

In surgical practice, instances of non-progression in a procedure can serve as a form of immediate feedback. Although this doesn't directly specify the corrective actions needed, it does present an opportunity for trainers to step in and offer guidance, turning challenges into teaching moments.

> ***Later we "discuss why we had to convert, or why there was non-progression, or why it took long time, why was it difficult" (Text condensate from 3 participants – ES2, T3, T4).***

5.3.6.5.3 Content

In surgical training, performance metrics are essential for developing skills. At one end of the spectrum, motion analysis serves as a valuable tool that quantifies the efficiency of movements and accuracy. Although this requires specialised software and is typically utilised during real surgeries or in simulated environments, it remains a less common form of feedback. The most prevalent form of feedback comes from intraoperative observations, which are vital for trainee development. This feedback can focus on two aspects: the process and the outcome. Process-related feedback includes gentle tissue handling and the fluency of movement, while outcome-related feedback addresses concerns such as tissue trauma, blood loss, and precision. Trainees usually receive a mix of both types, which are beneficial as they provide near-immediate insights into their performance.

> ***"Virtual reality simulators they give you right down movement, left arm movement, unnecessary movement" and that reduces the trainer time commitment. The key is to get "feedback, either from a mentor, peer, or even through video" and then use that feedback to guide the practice. The method of feedback must be acceptable to the learner. They should feel happy to take the opportunity to "come back to us or ask for any advice" (Text condensate from 6 participants – ES2, ES3, T4, L1, L10).***

Surgical outcomes, including metrics like surgical site infections and hematomas, are at the other end of the performance spectrum. These objective measures can indirectly indicate a trainee's intraoperative tissue handling and skill. However, broader outcomes such as length of ICU stay or mortality can be influenced by multiple factors, making them less reliable as direct measures of surgical competence.

> ***Analysing the results post operative complications provide automatic feedback (Text condensate from 3 participants – ES4, L2, L11).***

Interestingly, most feedback provided to trainees focuses on intraoperative process and outcome observations. While one trainer mentioned using Direct Observation of Procedural Skills (DOPS) to deliver structured and objective feedback, many opt for informal, unstructured methods. This variance emphasises the importance of delivering feedback in a way that resonates with trainees. If the feedback's timing or nature makes a trainee feel uncomfortable, it could hinder their willingness to seek guidance in future situations, potentially compromising patient safety.

> ***Some trainees do DOPS for them. Most have no scientifically proven or objective feedback method (Text condensate from 4 participants – T4. L4, L5, L9).***

Overall, enhancing the feedback framework in surgical training to include more structured methods, like DOPS, while ensuring it is delivered in a supportive manner, can significantly benefit both trainees and patient outcomes.

5.3.6.5.4 Repetition

Only one trainer explained that they direct trainees for remedial training. If they find a trainee lagging in a particular are (laparoscopic suturing is often the most difficult task to master), they advise them to go back to the beetle and practice the skill. This, however, is almost always unsupervised.

> ***"I asked them to go back to the beetle and practice at least 2 hours before they start suturing during surgery" – T3***

5.3.6.6 Adoption of DP in surgical training

Several constructive suggestions emerged regarding the utilisation of SBST and DP in training. One educator emphasised the value of various components of DP, even when considered individually, in enhancing surgical education. They identified reflective practice and feedback as particularly crucial for growth. Additionally, they encouraged persistence in the face of challenges that come with the steep initial learning curve.

While most trainers expressed that DP may not have a direct application in surgical training at this time, there is a recognised potential for SBST to make a positive impact. A few trainers also acknowledged the possible benefits of DP, though specific, actionable recommendations were not yet established.

> ***A "standardised curriculum that incorporates DP" is essential to ensure the consistency and effectiveness of training. I believe future of surgical training, even in resource-limited settings, will involve more simulation and DP. Technology is making simulation more accessible and affordable (Text condensate from 5 participants – ES4, ES5, T2, T4, L8).***
>
> ***I don't know how we can adapt that (DP) to surgical training – T1***

The ability to engage in learning without compromising patient safety was a key point highlighted by one trainee, who noted that the integration of Artificial Intelligence could significantly enhance VR simulators by delivering personalised feedback.

> ***With more DP and simulation, trainees could have better skills before operating on real patients. This would improve patient safety and their performance in emergencies (Text condensate from 3 participants – ES4, T1, T4).***

Both trainees and trainers also recognised the need to foster a culture of feedback and address existing hesitance towards it, creating an environment where constructive criticism can lead to continuous improvement and learning.

> ***We need to foster a culture of DP beyond just simulation by encouraging reflective practice, structured feedback, and continuous improvement in all aspects of surgical training. This is the groundwork for more formal simulation-based training. We must also address cultural barrier and dispel misconceptions and create protected time for simulation (Text condensate from 6 participants – ES4, ES5, T4, T5, L1, L12).***

Despite the differences in experience levels, all participants agreed on the direction needed to better integrate DP into SBST.

6 Discussion

The discussion broadly focuses on the surgical training programme in Sri Lanka, the use of simulation for surgical training, and Deliberate Practice as an instructional design.

As there is significant overlap between these areas, and the focus was predominantly on DP, several themes identified during exploration of training and simulation have been discussed under elements of the DP framework.

6.1 Mixed-methods design

Each phase of the study built on the previous one: the systematic review identified *what* issues to examine, the survey measured *how much*, and the interviews explored *why* and *how*. Integration points were planned at each transition. For example, preliminary survey analyses guided the selection of interview participants (Creswell et al., 2011), and emerging themes from interviews were compared back to survey and literature findings. In this way the qualitative and quantitative strands remained linked and ensured that the qualitative phase elaborated and explained the quantitative findings (e.g. similar areas explored in quantitative and qualitative methods are organised under the same headings in each section (e.g. "lack of deliberate practice opportunities")).

This sequential and themed presentation of findings concretized the merging of text and numbers subsequently in the discussion, as described by Creswell and Plano Clark (2017). This was crucial given the volume of material. Furthermore, data across methods were triangulated. Qualitative themes were compared to quantitative trends: where both strands converged on the same barrier (e.g. time constraints), I gained confidence in that finding. Where they diverged, I probed the discrepancy through re-analysis of the interviews and surveys. This approach mirrors Greene's concept of convergence and complementarity (Greene et al., 1989). For instance, if a survey scale indicated low confidence in DP but interviews revealed personal strategies for feedback, I interpreted the quantitative finding considering those nuanced accounts. When the survey showed that many trainees cited "lack of faculty time" as a major barrier, qualitative interviews revealed how this lack played out (e.g. ad hoc training schedules, perfunctory feedback) and why it persisted (organizational culture, competing priorities). In this way, the qualitative data gave meaning and context to the quantitative trends. Conversely, numeric survey results grounded the qualitative findings in a larger population, illustrating which concerns were widespread versus idiosyncratic.

Finally, the datasets were woven together in interpretation (Fetters et al., 2013). Integration primarily occurred in the Discussion chapter through narrative weaving and joint presentation of findings from the two data collection approaches. Here, I explicitly drew meta-inferences by synthesizing evidence across datasets (e.g. concluding that "Barrier of clinical workload is widespread (survey) and rooted in culture/policy (interviews)"). This staged narrative approach – presenting data "side by side" rather than separately – is recommended for mixed-methods reporting (Fetters et al., 2013). These strategies ensured that my analysis did not treat the qualitative and quantitative findings in isolation but as parts of a coherent whole.

6.2 Participants

Although it was not a randomized selection of participants, the distribution reflects the general sex distribution see in the surgical work force in Sri Lanka. Worldwide, males outnumber females in surgery severalfold (Lyons et al., 2019; Van Heest & Agel, 2012), but the gap is progressively narrowing (Lyons et al., 2019).

Several reasons have been identified, including family commitments and a perception of being treated inferiorly (Saalwachter et al., 2005). Female trainees were given less autonomy in operating, despite not showing significant differences in performance ratings (Chen et al., 2021). Female trainees were also less likely compared to males in choosing surgery if they were given another opportunity (Saalwachter et al., 2005). Although initial levels of surgical abilities appear lower among females, structured training with feedback provides greater benefits for females (Ali et al., 2015). This is particularly suited for SBST and DP, as focussed on this study. The age distribution of the three groups also shows a characteristic distribution. Laparoscopic surgery was introduced to Sri Lanka at the turn of the millennium, and most trainers and the senior expert surgeons belong to the "pioneers" (Gumbs et al., 2021). The majority of ES were "early adopters".

6.3 Surgical training

Learning in the clinical setting largely depends on patient encounters and resultant clinical actions undertaken, implying that clinical learning is implicit. This unconscious change in knowledge is reactive and triggered by being confronted with a problem without a ready solution (Hoffman & Donaldson, 2004). Several studies have shown that gaps in skills trigger goal setting and planning for learning (Sargeant et al., 2006; Slotnick, 1999). These behaviours were reported by both trainers and trainees we interviewed. Trainers, however, rarely emphasised how they encourage productive goal setting and learning planning. Even present-day surgical education relies on implicit learning from patient encounters, which leads to automatic activation of the right knowledge at the right time through pattern recognition (van de Wiel & Van den Bossche, 2013). Development of expertise, therefore, requires trainees to be self-regulated learners who plan, monitor, and reflect on their actions to learn and improve (Van De Wiel et al., 2000). Deliberate engagement with work experience is thus essential for lifelong learning in surgeons (Guest et al., 2001).

Laparoscopic surgical training has a significant and poorly defined learning curve (Dagash et al., 2003). The majority of training programs rely on training on patients in the operating theatre (Brian et al., 2022). Accordingly, the Accreditation Council for Graduate Medical Education (ACGME) has defined minimums for general surgery residents' graduate case logs, for both open and laparoscopic procedures. Most trainees start their laparoscopic exposure as the camera assistant (Abbas et al., 2015). With the introduction of work hour directives, the operative exposure has reduced, and the spectrum has narrowed (Drake et al., 2013). Published data also indicate an inadequate exposure to essential everyday operations (Malangoni et al., 2013). Resultantly, graduating residents have achieved autonomy in only a small subset of laparoscopic surgeries (Bohnen et al., 2020). Trainees complete their surgical training unready for independent practice in many procedures (George et al., 2017) and increasingly rely on fellowships after graduation (Shockcor et al., 2021). These findings mirror the sentiments echoed by our participants.

In summary, the results indicate that although MIS training in Sri Lanka improved compared to the early laparoscopic period, it remains heavily focussed on hands-on training, unstructured feedback, poorly defined milestones, and opportunistic training. The main reasons for this are the heavy clinical workload and poor resource allocation. This underpins the importance of SBST to improve the training, and DP to enhance learning from SBST. The suggestions made by the participants on improving surgical training also focused on these aspects.

6.3.1 Trainee attributes

The ability to understand the training objectives is a crucial element in optimising training. Trainees who developed their own learning objectives were able to better focus on improving skills, reported increased case preparedness, ability to track improvement, and satisfaction with improvement in skill. The supervising faculty corroborated these (Khalid et al., 2023). Preparedness was an important attribute highlighted by the trainers (see below 6.5.2). As trainees, ES had used each training session as a part of their long-term plan, which is consistent with the available evidence. Those who use self-directed practice outperform the gains from prescribed practice sessions (Nayar et al., 2020).

Performing a surgery is a dynamic, high-intensity task with many variables. Maintaining and increasing cognitive performance through practice has been shown to reduce the mental workload, leading to better performance during surgery (Marquardt et al., 2015). Self-knowledge, the appreciation of one’s own skill, is also a key component of Emotional Intelligence (Cutmore et al., 2023), and an essential quality of an ES.

Another characteristic observed among ES was the ability to break down learning tasks into smaller tasks. Breaking down tasks into simpler components can improve performance and reduce fatigue (Hu et al., 2016). There is also evidence that practising fine motor skills using suitable virtual reality games translates into better MIS performance, further supporting the benefits of task deconstruction (Boyle et al., 2011). As demonstrated by the results, ES were more likely to analyse their technical skills. Reflection is the purposeful thinking with a goal of improving (Boud et al., 2013a). Self-reflection is deep introspection performed by oneself to explore personal behaviours (Boud et al., 2013b). This introspection has been identified as a fundamental quality of proficient surgeons (Huang, 2018; Sachdeva, 2020; Soliman & Soliman, 2023). The ability to detect surgical errors predicts technical skill and performance (Bann et al., 2005). Similar to our findings, Bann et al (2003) identified that the ability to identify errors can discriminate between experienced and inexperienced surgeons, and this association is stronger for more technical tasks. This can be used to optimise SBST, as discussion of technical errors (Steinberg et al., 2014) and visual examples of expert performance (Cauraugh et al., 1999) have been found to result in more performance improvements than passive learning of the task.

ES were also more likely to use published material to improve their techniques. Surgical training has transitioned from the mentorship-oriented direct teaching to more structured, self-learning. To facilitate this knowledge transfer, experts have advocated for a uniform style of reporting surgical techniques (Ruff & Pawlik, 2023). Ergonomics is an important aspect of surgery, especially in MIS. Good ergonomics improves efficiency and prevents chronic musculoskeletal injuries (Yeola & Nayak, 2023). Our results, which indicate ES have a better understanding of ergonomics, mirror the findings of Athanasiadis et al that identified trainees report more discomfort after surgery than ES (Athanasiadis et al., 2021).

In the study, trainees consistently self-reported a higher degree of desirable characteristics than the trainers. Overestimation during self-assessment was identified in surgical performance in a systematic review of 40 articles, with greater accuracy in more experienced trainees (Nayar et al., 2020).

Cumulatively, the results demonstrate that ES poses a set of characteristics that set them apart from other surgeons and trainees. Deep Neural Network analysis of cognitive and motor skills and neural activation has identified distinct performance states between ES and trainees (Yanik et al., 2024). Expertise-related disparities in brain activity, including increased crosstalk between segments, have been reported by multiple authors (Deligianni et al.; Hannah et al., 2022). High-level cognitive skills enable ES to recognise potential errors and adapt their strategies accordingly (Yang et al., 2023). The hand dexterity of ES distinguishes ES from others, even in non-surgical tasks (Ahmmad et al., 2014).

6.4 Simulation-based surgical training

In Sri Lanka, more ES than trainees recognised the importance of easy access to the simulation centre. Similar to our findings, Saiydoun et al (2024) also, nearly half of their participants had not received SBST for technical skills. The majority, however, agreed that SBST was essential before performing surgery on a patient. 88% of the participants studied by Korndorffer Jr et al (2006) also considered skills labs to be effective in skill acquisition that transferred to the operating theatre.

Time allocation for SBST is a significant factor affecting SBST use. Eighty-four per cent of participants interviewed by Stairs et al (2020) indicated this was a concern for them, while 43% stated it was a direct barrier for use, with 65% having used SBST outside work hours or during their holidays. Availability of SBST facilities according to the learner schedule was also felt to be very important by our participants. Incorporating simulators into training, however, may require reducing the time spent on standard training (Gurusamy et al., 2009).

Stairs et al (2020) identified that a majority of the participants had used less than 10 hours of SBST in the preceding 12 months. Similar to our findings, Saiydoun et al (2024) reported that 30% of French trainees have never taken part in SBST. This study also reported that 47% of surgical trainees had no local access to simulation, and 30% had had no SBST. This is comparable to our sample, where half of the trainees did not consider a simulation centre to be important. Furthermore, simulation was available at one’s own hospital for only 52% of the participants in the French study. Providing easy access to simulation, like a small skills lab in the operating room, encourages practice, both within and outside the formal curriculum (Haluck et al., 2007). The location, however, was problematic only for 11% of the participants of the study by Stairs et al (2020). Most of the trainee-participants did not feel the location of the simulation centre was important. Sri Lanka is a small country, and travelling between training centres or to a central simulation centre is unlikely to be a concern. Providing round-the-clock access to trainees to simulation centres (Meier, 2010) and simulators for home training has proven effective in increasing simulation use and skill acquisition (Bamford et al., 2016).

The availability of high-fidelity simulators depends on the financial capacity of training centres. While Sri Lanka only has low-fidelity simulators and animal models, over 25% of French trainees had access to high-fidelity simulators (Saiydoun et al., 2024). Most core SBST curricula, like the Fundamentals of Laparoscopic Surgery (FLS), however, use box trainers (Meier, 2010). Furthermore, the superiority of VR over box trainers for learning has not been established (Botden et al., 2008). SBST should therefore be considered an extension to the educational mission of the department, and equipped based on the curricular needs (Meier, 2010). Integrating SBST into the existing training programme is crucial for its success. While trainers among the participants recognised this, ES and trainees were less appreciative. Among published studies, only a fifth integrated simulation into the curriculum (Shaharan & Neary, 2014).

Given the limitations in the Sri Lankan simulation programme, widespread adoption of a low-cost training programme is likely to yield the best results. Using a box-trainer, Fried and colleagues developed the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS) in 1998 (A. M. Derossis et al., 1998; Fraser et al., 2003; Fried et al., 2004). They initially selected several key laparoscopic procedures and identified the seven most appropriate skill domains for training (e.g. use of both hands in a complementary manner). The domains were then refined into five tasks (e.g. peg transfer). Multiple studies have confirmed construct, face, predictive, and transfer validity of MISTELS as both a training and an assessment tool (Adrales et al., 2003; Black & Gould, 2006; A. Derossis et al., 1998; Derossis et al., 1999; Fried et al., 1999; Fried et al., 2004; Vassiliou et al., 2006). The MISTELS programme may be a good option for Sri Lanka. Learning could be structured according to a curriculum or opportunistic (e.g. Just-in-time learning). They could also be time-based (e.g. everyone proceeds at the same pace through the curriculum) or flexible (e.g. students proceed at their own pace) (Winget & Persky, 2022).

Training a surgical trainee in the operating theatre costs approximately USD 50,000 per trainee per year in the USA (Bridges & Diamond, 1999), and estimated an annual cost to nearly USD 500,000 per hospital (Allen et al., 2016). This includes direct costs like trainer time, and indirect costs like increased operating time and morbidity, and more extended hospital stay due to the learning curve (Bashankaev et al., 2011). SBST can move the learning curve out of the OR, and improve learning higher skills in the OR (Meier, 2010). Although these costs have not been directly estimated in Sri Lanka, there are comparable costs. Simulation can also provide reproducible assessments for trainees, with a wide range of conditions and an objective skill assessment. Although this is advocated (Milburn et al., 2012), it's not currently being used for assessment or accreditation in Sri Lanka.

SBST has proven effectiveness in reducing the learning curve in MIS and thereby improving patient outcomes. This also reduces the healthcare cost due to reduced complications (Köckerling, 2018). There is no evidence on when to start SBST (Feins et al., 2017). The best use of simulation for Sri Lanka, especially with a limited budget, is perhaps to improve the early learning curve (De Win et al., 2013). Moving basic skills training out of the operating theatre and into the simulation centre increases patient care efficiency and reduces surgery errors. Simulation-based training has been shown to produce significant surgical skill competency at a very early stage (Nesbitt et al., 2013). The benefit of participating in a skills workshop is more profound for junior trainees (Fann et al., 2008; Wanzel et al., 2002). Junior residents are also more likely to prefer learning new skills through simulation, which could be due to their higher perception of its utility (Boyd et al., 2006).

The Sri Lankan training programme should focus on increasing the frequency and availability of SBST in MIS for junior trainees to shorten the learning curve and allow them to develop advanced skills during live surgery. Daily or weekly SBST sessions are recommended for the most effective skill gains, while once or twice a year training makes no difference (De Win et al., 2013). Currently, most workshops in Sri Lanka are conducted biannually. The availability of VR simulation, with its inherent ability to provide feedback, better supports distributed practice. This can augment learning and skills consolidation (Andersen et al., 2018; Andersen et al., 2015). VR, however, is not available in Sri Lanka. Compared to Europe, Sri Lanka does not have work-hour restrictions, and trainees have ample opportunity for hands-on training. The lack of advanced MIS simulators, therefore, could be overcome with DP-guided training during live surgery.

Objectively assessing the technical skills of trainees based on intermittent observation of their performance on multiple surgical procedures in the operating room is difficult. Objective and criterion-based assessment of performance and provision of feedback is a distinct advantage of SBST (Dunkin et al., 2007). This importance is recognised by all groups of participants, but more by ES and trainers. SBST with proficiency targets improves learning and performance (Gauger et al., 2010). Objective assessment is essential to the principles of DP and will also be discussed below.

Multiple factors affect the learning environment, and these can be objectively quantified (Cassar, 2004). Most of the individual elements of this scale relate to the presence of a positive learning environment. Several participants in this study echoed the importance of a positive learning environment. Training program directors have a crucial role in enthusing the faculty and trainees.

Aligning and integrating SBST to existing clinical curricula would strengthen their educational impact (Meier, 2010). It should ideally be synchronised with their clinical exposure (Spruit et al., 2015). Several participants highlighted this and suggested that SBST is appropriate for their training rotation. This, however, is logistically difficult. Worldwide, SBST is often inconsistent with the trainees' clinical training phase (Bjerrum et al., 2018).

Only the number of cases handled, and not the number of years of experience, predicted professional performance (van de Wiel & Van den Bossche, 2013). Many trainees expressed their concern about clinical commitment reducing their skills training. Trainees with more clinical duties are less likely to ask for feedback and have lower levels of DP (van de Wiel & Van den Bossche, 2013). Trainers should therefore ensure clinical commitments do not erode operative exposure. Protected training time has nevertheless been advocated and adopted in many countries, with participation in SBST being mandatory and monitored (Meier, 2010). The Sri Lankan training programme needs to adopt a similar approach.

When designing learning activities, Meyer et al (2010) advise to reduce extraneous material and redundancy. Structured briefing and advanced organisers for trainees before the training activity are crucial for maximising learning (Cannon-Bowers et al., 2010). To produce the best performance, the goals need to be challenging but achievable (Locke & Latham, 2002).

All three participant groups highlighted the poor integration of simulation in the Sri Lankan training programme. The integration of simulation technologies in surgical training presents an opportunity to enhance medical education. By adopting innovative methods for curriculum development, more effective training programs and robust certification processes that better prepare future surgeons can be created (Sakakushev et al., 2017). Simulation-based curricula require a blend of cognitive input, skills training, and skill assessment (Chauvin, 2015). To enhance the training experience, it is advisable for curricula to thoughtfully incorporate a variety of simulation methods, each aimed at addressing different aspects of surgical competence (Ounounou et al., 2019). This comprehensive approach ensures that trainees acquire diverse cognitive and technical skills (Knol & Keller, 2019). Policymakers can formulate their decisions based on the successful integration of the Fundamentals of Laparoscopic Surgery (FLS) program, and the American College of Surgeons (ACS) Accredited Education Institutes (AEI) network (Shahrezaei et al., 2024).

The lack of funding has prevented using high-fidelity simulators as a regular part of Sri Lankan SBST. Existing evidence, however, suggests that fidelity does not impact skill acquisition (Grober et al., 2004). Low-fidelity simulators are as effective in acquiring basic skills (Korte et al., 2020) and skill gains translate into improved performance in live surgery (Price et al., 2011). Low- and high-fidelity training should therefore be considered as complementary components of SBST (Feins et al., 2017). Although the fidelity does not affect the learning of junior trainees, it may affect the learning ceiling of advance trainees (Price et al., 2011). Novice trainees are unprepared to use the additional contextual information provided by high-fidelity models (Sidhu et al., 2007). When both resources are available, the most cost-effective strategy is to allow gradual progression to high-fidelity simulators based on milestones (Grober et al., 2004).

6.5 Deliberate Practice

Despite a strong pedagogical support and evidence on its effectiveness, and this study was anchored in the theoretical framework of DP, it is important to acknowledge that the term itself was not familiar to many participants. Consequently, participants often engaged with DP indirectly—through its core elements such as structured repetition, feedback, and targeted task design—without explicitly labelling it as DP. This introduces both a theoretical and methodological challenge: the research investigates DP's role using conceptual proxies rather than respondent-recognised terminology. This approach, however, offers practical validity, as it captures authentic training behaviours. It also requires caution in interpretation, as participants' descriptions may map partially, rather than wholly, to the DP construct.

Although most participants in the study were unaware of DP and did not use it in their training, this has been the case in other studies as well (Higgins et al., 2021). There have been disagreements between the original author and others who attempted to quantify the benefit of DP (Ericsson, 2015; Macnamara et al., 2014).

ES highlighted the importance of DP for skill acquisition. Participants studied by Saiydoun et al (2024) stated simulation and practice helps build confidence, accelerate learning, and reduce complications.

6.5.1 Mental representation

For effective SBST use through DP, an accurate mental representation of the task is essential. There is clear evidence of differences between novices and experts in preparing to perform a surgery; while novices seek external sources, experts rely on sensory memories. Novices progressively internalise these experiences and become increasingly self-reliant (Crebbin et al., 2021). This is an important consideration in designing SBST, as resources (e.g. supervision) spent on expediting this transition will likely provide the greatest return.

An in-depth understanding of the task's assessment metrics can help develop the mental representation. Providing a video performance of the task and the assessment tool used for grading has proven effectiveness in developing this mental representation (Haluck et al., 2007).

The difference in appearance during MIS, combined with the loss of landmarks due to the narrow field of view of the camera, impacts the safe performance of a surgery. During the interviews, many participants highlighted the utility of good mental imagery in becoming a successful surgeon. Mental imagery has been strongly correlated with skill gain during SBST (Schmidt et al., 2025), and this closely aligns with the DP. Although not discussed during the interviews, the spatial cognitive style of learning was associated with greater performance at SBST tasks, with quicker task completion and fewer errors (Mathias et al., 2020).

The qualitative exploration revealed that trainers often thought of understanding pathophysiology and imaging as pre-learning, whereas trainees identified surgical skills as their primary focus in pre-learning. This discrepancy leads to a significant mismatch in operating room teaching and has been reported by other authors as well (Chung, 2005). Addressing this is crucial in optimising skills training. This could also represent an unconscious competence on the part of the ES, as they may not recognise they have already developed these schemas.

6.5.2 Learner motivation

Work motivation is defined as a force that originates both within and beyond an individual, to initiate work-related behaviour and to determine its form, direction, intensity, and duration" (Latham & Pinder, 2005). Achievement-related motivation is governed by both the learners' expectation for success and the value they place on the task. These depend on four factors: attainment value (importance of doing well), intrinsic value (enjoyment), utility value (perceived usefulness), and cost. (Adler et al.). Expected success has the strongest link to performance (Leaper, 2011).

Motivation is essential as the driver of DP, as DP relies on repeated practice of the task with the goal of improvement (Ericsson, 2015). DP inherently expects the learner to ignore enjoyment and believe in the value of the DP approach. ES being more motivated is therefore an expected outcome. Motivation is essential for self-regulation that guides strategically planning and adapting actions towards the attainment of personal learning goals (Van De Wiel et al., 2000). This has three intercalated phases occurring before, during, and after the task performance. Components of DP discussed below can also be categorised similarly (Forethought– task design, Performance and reflection – feedback, repetition). When the explicit goal is learning through task performance, learning is proactively planned, and not reactively generated or implicitly gained (Pintrich, 2000). Motivation is a key component in this.

The surgical personality is often described as pragmatic, hardworking, and assertive (Symer et al., 2018). The high-performing trainees have been identified to mirror the psychological profiles of the surgeons and have score different to the low-performing trainees (Foster et al., 2010). Our finding of ES being more motivated than trainees may indicate that the present generation may be less motivated, or a selection bias in participation recruitment. The latter is unlikely, as this cohort represents a significant proportion of current trainees. Although trainee motivation has been reported to reduce with increasing experience (Lund et al., 2022), this was not seen among our participants. Nevertheless, continuous exposure to extrinsic reward is one hypothesis for this, and trainers should be cognizant of this. We witnessed a reduction in ES motivation, which mirrors the findings of increasing surgeon neuroticism with age (Whitaker, 2017).

The trainees and ES were most motivated to develop their skills, and this sentiment was observed to the same magnitude by Stahl et al (2020). They also observed that trainees who understood the transferability of skills were more motivated. This was the second-highest rated factor of motivation among our population as well. Several authors (Dath et al., 2013; Stairs et al., 2020) have identified that trainees who spent more time in theatre performing laparoscopy had a greater interest in MIS, reported greater self-efficacy, and were more motivated to learn. This virtuous cycle could be used to enhance the motivation for SBST. Findings of Van De Wiel (2000) identified that patient care commitments also drive competence improvement goals. This is particularly useful in the Sri Lankan setup due to the clinical commitments and the emphasis on learning during actual surgery and should be further explored and adopted.

There are four main goal orientations in learning. With the close resemblance of several questions used in the questionnaire, and the GO-ST scale (Fatunmbi et al., 2022), our results indicate that the motivation seen among the participants is primarily a Mastery goal orientation (MGO). MGO is the motivation to master a topic and improve one's skill and is positively related to self-regulated learning. Performance approach orientation is the tendency to prove one's competence to others. Performance avoidance is the desire to avoid failure and unfavourable judgements, and Mastery avoidance minimises the effort to learn. Both are negatively related to self-regulated learning (Pintrich, 2000; Vandewalle et al., 2019). Mastery motivation is associated with increased use of metacognitive strategies, increased interest, and greater retention (King & McInerney, 2016). Unsurprisingly, MGO predicts performance better than cognitive ability (Huang, 2012), and skill retention.

MGO depends on both the situation and the individual (Button et al., 1996), and is inducible (Martocchio, 1994). Competitive rewards enhance performance motivations (Ames et al., 1977) while formative feedback increases mastery motivation (Ilgen et al., 1979; Lund et al., 2022). Mastery motivation is also greater among junior trainees compared to senior trainees (Lund et al., 2022). Individuals with an MGO believe that greater effort, challenging goal setting, regular practice and feedback, optimising their technique, continuous monitoring and evaluation, persistence, and a positive outlook will facilitate skill development (Pintrich, 2000). This closely aligns with the individual components of DP, and the development of an MGO will therefore seamlessly align with DP-based SBST. Van de Wiel & Van den Bossche (2013) however identified that engagement in DP was not related to goal orientations, so this area requires further investigation.

Trainers can promote motivation (Dath et al., 2013). Our interviews indicate that most trainers focus on basic knowledge as a prelude to skills training and do not emphasise skill acquisition directly. Only skill improvement goals of trainees correlate positively with their performance (Brett & VandeWalle, 1999). Surgical trainees are, nevertheless, an inherently motivated group (Symer et al., 2018) and junior trainees usually report higher intrinsic motivation for MIS, compared to senior trainees (Stairs et al., 2020). There are many factors affecting learner motivation. Positive factors include opportunities to practice and experience rare situations, providing triggers for feedback and reflection, while eliminating risks to patients. Negative factors included anxiety about performance, peer scrutiny, and making mistakes whilst observed, and issues about the degree of realism (Owen, 2017). Identifying the learners' orientation is important to guide them, and validated tools capable of doing this are available (Fatunmbi et al., 2022).

6.5.3 Task design

6.5.3.1 Tailoring the training to current competence

All three groups agreed that there was no tailoring of the difficulty in surgical exposure, due to clinical commitments and low use of simulation.

Experts agree that stepwise progression in training is essential for safe surgical training, and should have both an incremental increase in technical difficulty and complexity of cases (Abu Hilal et al., 2018; Wakabayashi et al., 2015). There is consensus on the factors affecting the difficulty (Halls et al., 2018). Available evidence suggests that a stepwise and structured training programme will reduce the impact of the learning curve (van der Poel et al., 2017).

For expert surgeons with good skills, learning may include seeing different approaches to complete the same surgical steps. For trainees who are in the skill development phase, this learning would not provide an advantage as pre-learning.

A stepwise increase in difficulty is essential for effective training. Historically, this has been through either careful selection of surgeries for novices (e.g. easy surgery like appendicectomy, easy patients like early cancer), or allowing them only to perform the easier aspects of the surgery. Most training programs begin with task training to develop basic skills and progress to the entire procedure. As expected, this transition causes a performance drop (Feins et al., 2017). Furthermore, due to greater opportunities to integrate, whole task training is often felt to be better (Lim & Reiser, 2006), especially for complex tasks (Mattoon, 1992; Naylor & Briggs, 1963). Providing instructions during complex whole-task training, however, leads to high cognitive loads (Cannon-Bowers et al., 2010). This should be carefully considered in designing SBST, especially for novices.

6.5.3.2 Demonstration of the tasks

Clear demonstration of the expected skill is mandatory for skill acquisition. Wang et al (2020) repots a confidence level comparable to 1-year of training just by following a boot-camp initiation. The current competence of a trainee is perhaps the most important single factor influencing their learning (Ausubel et al., 1978).

Learners are more likely to master a skill when the learning outcome is defined, and the delivery is appropriate for their stage of competence (Issenberg et al., 2005). Challenging scenarios that evoke feelings of inadequacy and failure serve as powerful catalysts for reflection and growth among trainees and are essential components of effective task design (van Tetering et al., 2020).

To promote self-guided learning, trainees need clear and specific goals and deliberately designed instructions (Brydges et al., 2009; Brydges et al., 2015). Instructing the learners on the task to complete is often not straightforward. The underlying mechanism of performing a task is often a mystery to experienced performers; it is “easier done than said” (Patkin & Isabel, 1995). This is most likely due to expertise reversal (Kalyuga, 2007). Instructional design, therefore, requires careful planning, and should not be impromptu.

When designed appropriately and incorporating clear self-assessment criteria, a self-guided curriculum can significantly enhance the acquisition of technical surgical skills. Implementing this approach prior to more advanced training with faculty produces the most efficient use of available resources, and produces better learning outcomes (Wright et al., 2012).

6.5.4 Feedback

Trainees reported receiving vague feedback, despite trainers stating the opposite. A mixed-methods study by Mazer et al (2018) identified that although participants’ perspectives are reliable, they rarely align with independent observers. The teachers’ communication styles affect motivation (Rawsthorne & Elliot, 1999), and may contribute to this disparity. Nevertheless, Individuals act upon their perception of reality rather than objective reality (Lewin, 1936). Trainers must therefore improve their feedback technique to match the comprehension of trainees, and strive to deliver respectful, non-judgmental, specific feedback with corrective suggestions (Hewson & Little, 1998).

Lack of feedback was a concern for 61% of the trainees in the study by (Stairs et al., 2020), where they were concerned about developing bad habits due to unsupervised SBST. Repetition with feedback is far more effective than repetition alone. Zhou et al (2023) estimated that six sessions could provide an increase of 1 standard deviation.

The supervision provided during SBST can also impact the motivation of trainees. Summative assessments may encourage performance motivation while formative assessment may influence mastery motivation (Boud, 2012). Our results indicate that most ES had a mastery orientation, while trainees had a mix of orientations. Hoffman et al (2014) identified a higher mastery than performance motivation among surgical trainees. Encouraging a mastery motivation is beneficial, as it leads to better performance on procedural tasks (Aimee K Gardner et al., 2016) and predicts greater improvements (A. K. Gardner et al., 2016) during surgical skill training. Mastery goal orientation was directly linked to learners perceiving feedback as beneficial, increasing the seeking of feedback (Janssen & Prins, 2007). Trainees' belief in an assessment being formative increased their mastery motivation. A formative approach encourages identifying strengths and weaknesses and developing a learning plan (Shepard et al., 2018). Medical students randomised to mastery motivation were more engaged and had higher meta-cognition in skills training (A. K. Gardner et al., 2016). Using regular clinical activities as formative assessments could therefore lead to greater learning. SBST design should therefore focus on encouraging the MGO approach.

6.5.4.1 Source of feedback

Advanced metrics are not freely available for SBST in Sri Lanka, so training relies on self, peer, and expert assessment. Many participants highlighted the absence of trained supervision, which largely reflects the trainers' busy schedules. Non-surgeon skills coaches are as effective as faculty educators for basic skills (Kim et al., 2010), and will be helpful, especially during the repeated practice phase of DP. Unguided self-assessment lacks reliability (Riquin et al., 2024) and is consistent with the Dunning-Kruger model of competence (Kruger & Dunning, 1999), which states learners in their initial stages are unaware of their incompetence. Guided self-assessment, however, is as accurate as expert assessment (Balvardi et al., 2024). The source of feedback is less important than its presence (Issenberg et al., 2005).

6.5.4.1.1 Trainer

There is a wide variation in the use of coaching and feedback in surgical training (Louridas et al., 2022). Training the trainer is therefore important. The trainees repeatedly highlighted this, emphasising that the guidance and feedback they receive is suboptimal. Trainer-delivered feedback encourages focus and attention, outlines goals, recalls existing knowledge, provides guidance, structures the practice, and provides objective feedback (Gagne et al., 2005; Reiser & Gagne, 1982).

More knowledge is gained in the early years of a career than in the later years (Schmidt et al., 1986). Because educator time is limited, allocating more time to junior trainees may be more effective. The higher mastery motivation among junior trainees (Lund et al., 2022), partially attributed to the novelty of training (Stoa & Chu, 2023) might also contribute to greater learning.

From a coaching standpoint, the GROW model (Goals, Reality, Options, Wrap-up) might be useful, and coaching in the OR objectively improves trainee performance. An additional benefit of a coaching approach is the development of self-assessment and self-directed learning (Bonrath et al., 2015). This will enable further independent practice with self-reflection, an essential component of DP.

Appearing competent and knowledgeable is essential in establishing patient rapport. The presence of a coach may jeopardise this. This may be one reason for the surgeons' of fear coaching and feedback (Devin & Aggarwal, 2019). Video-based feedback may help lessen this barrier as well. Using a video for expert feedback is also superior to expert feedback alone or self-assessment of the video (Halim et al., 2021). Given the logistical limitations of service delivery and clinical commitments of trainers, asynchronous and remote feedback are useful options. App-based remote feedback tools (e.g. "LAPP") reduce faculty demands (Quezada et al., 2020).

6.5.4.1.2 Self-evaluation

Self-assessment is a vital cognitive skill that encompasses reflection, self-monitoring, and the proactive pursuit of evaluation (Eva & Regehr, 2008). Self-assessment during simulation reduces the demands on trainers.

The most significant limitation of self-assessment, however, is the reliability. Kruger et al (1999) identified that the top-quartile is more accurate in their assessment, and the bottom quartile often overestimates their performance, while the top quartile underestimates their performance. The latter is due to the false consensus effect, where high scorers believe peers will also be high scorers (Colthart et al., 2008). This can be mitigated in several ways. Competence measures grounded in trainee responses are nevertheless reliable and valid (Issenberg et al., 2000; Pugh & Youngblood, 2002; Schaefer et al., 1998). Self-assessment abilities improve with repeated practice of the surgical task (MacDonald et al., 2003).

The use of objective measures like OSATS produces good reliability in self-assessment for open and laparoscopic skills (Mandel et al., 2005). When structured and guided through didactic material, self-directed training, even in the absence of expert teaching, is effective (Wright et al., 2012).

Recording one's performance and reviewing it later is another option. Halim et al (2021) identified that guided self-assessment of one's own video is as beneficial as expert feedback on an individual's performance. The visual and verbal cues during review of a video make the feedback more interactive, and improve skill acquisition, trainee satisfaction, and training time (Ahmet et al., 2018). Video recordings, however, may cause inaccurate self-assessment due to anxiety and self-consciousness (Colthart et al., 2008). Stefanidis et al (2009) identified that task completion time correlated better with participant performance, even compared to motion tracking. This can be a simple metric used during self-assessment of performance.

Educating the learners, especially for the lowest quartile, can be improved through self-assessment (Colthart et al., 2008). When properly instructed, self-assessment has been shown to have a high correlation with faculty ratings on specific tasks and global skills (Mandel et al., 2005). Accuracy of self-assessment increases with experience (Quick et al., 2017; Rizan et al., 2015) and this likely represents superior mental representation. The development of mental representation is an essential part of the ability to self-monitor performance. Provision of precise instructions, including video, aids in this and improves skill acquisition while reducing tutor workload (Bryan et al., 2005; Quezada et al., 2019).

When using self-assessment, several factors need to be considered. Coach-initiated feedback results in more attempts during training, and this is most likely due to their ability to recognise and intervene when a trainee is struggling (Patnaik et al., 2022). This is impossible during self-learning, Self-learning, therefore, should be encouraged in senior trainees with sufficient mental representation, to avoid frustration in junior trainees. Men are nearly twice as likely to overestimate themselves (Edwards et al., 2003) while females underestimate their surgical abilities (Minter et al., 2005; Sommers et al., 2001). Evans et al (2005) however, noticed no difference was noted between males and females on when global rating scale. This characteristic in females may disadvantage females during their training. Training program directors will have to intermittently monitor the performance to avoid these errors from compounding. Global rating scales are more accurate and reliable than checklists, especially for complex assessments like complete surgeries (Martin et al., 1997). The sample for this study only had two females, who engaged in self-guided training and considered DP to be important in SBST. No additional information about the above phenomenon was elicited during the interview.

A correlation between self-assessed proficiency and the learning curve ceiling was identified by (Jowett et al., 2007). As DP aims to increase the learning ceiling to the level of EP by eliminating arrested development, recalibrating self-assessment would provide higher skill gains. Non-deliberate practice often leads to arrested development. A DP-guided SBST approach focusing on self-assessment should be developed in Sri Lanka to optimise the training,

6.5.4.1.3 Peer assessment

There are several advantages of peer feedback, including reducing faculty teaching pressure, increasing learner motivation, and producing a non-threatening learning environment (Ten Cate & Durning, 2007). Individuals are more able to assess peers' ability than their own accurately (Colthart et al., 2008). During peer feedback, however, men receive more positive comments than women, and are rated higher than women (Bryan et al., 2005).

Faber et al (2023) reported that utilising senior trainees in assessing intraoperative performance for formative feedback has proven effective and increases assessment frequency than consultants alone. Even with the same feedback rubric, however, (Zhou et al., 2023) noticed that the quality of feedback from instructors was superior compared to peers. Peer-feedback, therefore, may not be a replacement for trainer-feedback.

6.5.4.1.4 Other feedback

Because few participants had experienced high-fidelity training, the interviews did not discuss automated feedback. Most VR simulators incorporate automated complex metrics and feedback into SBST. Personalised human feedback has produced better outcomes than automated VR feedback (Hashimoto et al., 2015).

6.5.4.2 Timing of feedback

This had two broad aspects: the value of feedback at different stages of competence of the trainer, and the chronological relationship of feedback to the training activity.

Although not explicitly highlighted by the study participants, there is evidence to suggest that feedback in the early years is more beneficial (George et al., 2017). Early assessments also permit early remedial measures if the performance is inadequate.

Most trainers provide feedback during or immediately after the surgery, which is encouraging. There is evidence that feedback beyond 72 hours does not contribute to learning, as it regularly lacks details and is often limited to global comments (Williams et al., 2014). This is a direct violation of the principles of DP (immediate feedback indicative of the performance). Immediate auditory feedback is proven to reduce the attempts to reach proficiency in surgical training (Al Fayyadh et al., 2017). Lack of immediate feedback also discourages trainees from attending skills training (Meier, 2010). Concurrent feedback during surgery, however, increases cognitive overload. Concurrent feedback could also cause an overreliance on the tutor (Winstein &

Schmidt, 1990), performance declines when the feedback stops (Hatala et al., 2014), and may impair skill acquisition if intense (Stefanidis, Korndorffer Jr, Heniford, et al., 2007). Even simulator-integrated automatic feedback should therefore not be continuously used, and should be best restricted to periodic reinforcement (Andersen et al., 2017). Summary feedback immediately after the procedure is therefore better (Hatala et al., 2014).

The trainer feedback can be asynchronous, through video recording and online distribution through a guided web-based skill assessment tool (Meier, 2010) or in-person (Hu et al., 2017). This has reduced the time commitment of the faculty. Unsupervised video feedback is as effective as direct expert feedback in both learning and retention of skills (Seifert et al., 2020). Video feedback also produces more teaching points, educational needs assessments, more questions discussed, and greater self-reflection and critical thinking (Hu et al., 2017), and therefore is a good utility to base the feedback session.

6.5.4.3 Content of feedback

Narrative feedback could take many forms, and the participants reported a predominance of vague feedback on all three domains. Feedback relevance and specificity are directly related to performance gains (Zhou et al., 2023). Trainers should therefore strive to provide specific and detailed feedback. Specific challenging goals lead to better task performance than vague goals (Locke & Latham, 2002). This needs to be corrected to improve SBST, as the participants reported a predominance of vague feedback. Furthermore, focusing on knowledge and skill acquisition leads to better learning than a goal of reaching an arbitrary performance level (Locke & Latham, 2006). Our results show limited attempts at guiding trainees towards this goal. This too should be emphasised to the educators.

The feedback could focus on both the process and the outcome (Cannon-Bowers et al., 2010). Feedback on the process enables immediate understanding of actions and consequences. The concurrent feedback, however, could overwhelm the trainee during high cognitive load. Process feedback also prevents learners from seeing the consequences of their choices, like surgical complications. If only outcome feedback is used, incorrect techniques and suboptimal performance may be maintained until the end of the session (Cannon-Bowers et al., 2010). Unless the task is simple or the learner is experienced, process feedback is superior (Bangert-Drowns et al., 1991; Earley et al., 1990). Outcome feedback, however, produces superior learning outcomes in complex learning tasks (Korsgaard & Diddams, 1996). In complex tasks with cognitive and psychomotor demands, the use of outcome feedback needs careful planning (Cannon-Bowers et al., 2010).

The use of validated measures to indicate trainee autonomy (e.g. Zwisch scale), preparedness (e.g. SIMPL performance scale), and complexity (e.g. Complexity scale) will also facilitate the use of DP. The use of short rating instruments with global scales aligned with the clinician's way of thinking has been recommended by guidelines (Williams et al., 2016). For high reliability, ten separate evaluations of a resident are needed for each year (Williams et al., 2003). Only a minority of the trainers interviewed used an objective tool like OSATS in providing feedback, while most provided unstructured feedback. OSATS is an effective tool in evaluating open and MIS (Niitsu et al., 2013). When a more detailed assessment is required, Global Operative Assessment of Laparoscopic Skills (GOALS), which assesses five domains including depth perception, bimanual dexterity, efficiency, tissue handling, and autonomy, can be used (Vassiliou et al., 2005). This has been validated for several complex MIS (Gumbs et al., 2007; Hogle et al., 2014) but lack procedure specificity or thresholds for credentialling (Beard et al., 2011; Hatala et al., 2015). Performance-related feedback also encourages competence-based education (Stahl & Minter, 2020). This enables divergence from the classical time-based training, which has been criticised for its failure to produce independent surgeons at completion of training (George et al., 2017). Suboptimal feedback reduces the potential gains from simulation training (Blackhall et al., 2019). A formative tool can improve the efficiency of practice by providing the feedback necessary to engage in DP (K. M. McKendy et al., 2017) and should be encouraged.

Self Determination Theory hypothesises that learners function positively when others support their autonomy rather than control their behaviour (Ryan & Deci, 2000). Provision of choice is the cornerstone of autonomy supportive (AS) skills training (Su & Reeve, 2011). Providing autonomy enhances learner motivation, leading to deeper information processing, improved retention, and transfer (Wulf, 2007), and a significantly higher score and retention with greater positive emotions (Patnaik et al., 2022). Conversely, neglecting the learner perspective, intrusion, and pressure are the hallmarks of a controlling coaching style (Reeve, 2009). Controlling environments produce greater stress among trainees (Reeve & Tseng, 2011), most likely due to cognitive overload. When training in OR, indiscriminate AS is impractical and unsafe (Patnaik et al., 2022). SBST with AS will be an effective alternative.

6.5.4.4 Repetition

While supervised training is the best, even unsupervised, unsupported training is better than no intervention (Brydges et al., 2015). Patnaik et al (2022) identified that coach-initiated feedback leads to significantly higher repetition. A minority of our trainee-participants recognised the importance of repetitive practice. Trainers should therefore be instructed to pay close attention to actively provide feedback.

To be effective, repetitive practice must include regular, spaced-out sessions. Compared to massed practice, distributed practice is more efficient for psychomotor skills learning (Mackay et al., 2002; Shea et al., 2000) and consolidation (Zirkle et al., 2007). This is most likely due to cognitive reflection and mental rehearsal in the intervals between sessions, as it requires the trainee to retrieve key elements of the skill being learned from memory for each practice session (Rowse 2015). Having a few sessions is only marginally effective and does not develop mastery learning (Nakata et al., 2017; van Tetering et al., 2020). Although the pedagogical evidence for distributed practice through SBST is well established (Mackay et al., 2002; Moulton et al., 2006), the optimal inter-training interval for learning and consolidation, however, is still debated (Stefanidis, Walters, et al., 2009). Wang et al (2020), who mandated a 5-hours a week/ 30-hours a month repetitive practice after completion of clinical duties or during leisure time, identified a significant increase in skill level and confidence among trainees. An inter-training interval of 1 day was insufficient for improving performance (Kesser et al., 2014). While simple tasks require only brief rest periods. complex task training requires extended rest for optimal learning (Fann et al., 2010). Despite better retention, the slower learning rate is the biggest limitation of longer intervals (Bahrick et al., 1993). Research suggests that neural processes continue to evolve for hours after ending the session (Karni et al., 1998) and that learning continues during rest periods (Stefanidis, 2010). These are consistent with the better memory consolidation through distributed practice (Shea et al., 2000). Distributed practice with tutoring produces better results (Andersen et al., 2017). Tutoring, however, also encourages risky behaviours with increased morbidity compared to practising alone (Andersen et al., 2017).

Basic MIS skills are best acquired through daily practice (Zoog et al., 2009). A training program with a simulator-tutored session followed by two untutored practice sessions was found to produce the best results (Andersen et al., 2015), as practice time without feedback is essential to develop own learning strategies. Retention of skill is better in those who also get exposure afterwards the training session (Rowse 2015). Most current MIS training using simulation happens as bi-annual events and should be based on these findings.

A Mastery Goal Orientation (MGO) is associated with a reduced cognitive load, lower test anxiety, and decreased fatigue (Fatunmbi et al., 2022). This could therefore lower the effort constraint and permit more effective practice for longer. Zhou et al (2023) et al noted, however, that repetition without feedback does not improve performance. These findings, however, may be due to the junior nature of participants, who cannot self-correct their performance.

For deficiencies identified at the end of the training programme, additional training is mandatory. This is often implemented in the form of a fellowship. Fellowships, however, should not be seen as a mandatory component for meaningful autonomy, as it would then undercut the surgical training experience (Bohnen et al., 2020). Fellowships could also take away training opportunities from junior trainees, thereby establishing a vicious cycle in training.

In addition to these granular benefits of feedback, there is an overarching benefit to trainees and trainers, who are not even a part of an SBST / DP intervention. Frequent assessment and feedback on performance normalises the practice and establishes a culture of feedback and mentorship (George et al., 2017).

6.5.5 Improving training

One main suggestion for improving training volume and exposure was allowing trainees to move between trainers. Rotations among a variety of settings provide a robust operative experience and expose trainees to more role models (Polk Jr et al., 2012). This also encourages independence and increases trainee motivation.

To quantify the adequacy of training, accurate nationwide data on the operative experience of trainees must be collected. This data should have an interim evaluation (Bell, 2009). Standardised assessment tools for operative performance should be developed and validated (Larson et al., 2005) for this quantification. Operative skill should be made a required competency for board certification, and tools to objectively assess it must be developed. Current assessment is limited to the realm of medical knowledge (Bell, 2009).

Parallelly, development in pedagogical schemes for training surgery is required. One suggested scheme was modules consisting of reading material, basic skills training, video review of the procedure, and simulation of key operative steps (Bell, 2009).

6.6 SBST and DP

6.6.1 Areas ignored by both SBST and DP

Most studies had recruited medical students or laparoscopy naïve surgical trainees as participants. Laparoscopic surgery is not a skill taught in early surgical training. Some studies(Nickel et al., 2015) even assessed them on all aspects of performing procedures that surgeons usually perform after years of experience. In contrast, Madan et al (2007) admitted that their tasks were not sufficiently complex, and the error detection lacked sensitivity. Participant selection, therefore, had not been ideal in most studies.

While SBST has many advantages, the cognitive investment in being scrubbed in for a surgery may help reinforce technique and skill acquisition (Rowse & Dearani, 2019). This is never reproduced in task training, and the cost of reproducing this in SBST will be prohibitive.

Modern surgical training and accreditation standards aim to ensure that surgeons are competent and capable. Unlike in sports and music, however, where the objective is to achieve the highest level of performance and competition between the participants results in a zero-sum game, the current benchmark for surgical skills is set at the "safe-for-independent-practice" threshold. This resembles arrested development in DP and may be lower than ideal. Acknowledging this difference opens a valuable opportunity for improvement in surgical training.

By considering a shift in our training approach, we can move beyond this basic level and better foster the development of EP. The question of whether this enhanced focus should include all trainees or be directed toward a select group invites constructive discussion and exploration. Together, we can work towards elevating surgical standards for the benefit of both surgeons and patients.

6.6.2 Factors disregarded in DP

Although the DP provides a comprehensive framework for training programme design, several aspects of SBST have been ignored. Fundamental to this is the dissonance between the DP framework which aims to achieve expert performance in all participants through structured training. In surgical training, Atkins et al (2005) noted that 27% showed no improvement following SBST.

6.6.2.1 Session structure

Although several studies assessed the learning curve (R. Aggarwal et al., 2007; Crochet et al., 2011; Hashimoto et al., 2015), their findings are based on task training. These cannot be extrapolated to the expert-level performance of a complete surgery. The learning curves for surgical skill acquisition through simulation(Roberts, 2006) and the minimum number of sessions required remains largely unknown. The different learning curves among learners with varying levels of experience (Grantcharov et al., 2003) further confound this.

DP does not prescribe a minimum number of sessions but emphasises the outcome. Course creators will therefore need to look beyond DP in deciding the length. This obscurity also provides opportunities for scholars and researchers.

Pearson et al (2002) investigated the role of coordination drills before learning the actual surgical skill and found that students learned to knot faster if they first practised coordination drills. Similar findings were reported by Yiasemidou et al (2017), who recognised that practising basic laparoscopic skills improved subsequent surgical performance.

6.6.2.2 Transferability of skills

The findings of Ericsson indicate limited transferability of even domain-specific skills and no relationship between associated skills(Ericsson et al., 1993) (e.g. digit symbol score and playing the piano). DP framework assumes minimal transfer in skills between apparently similar domains(Kirkman, 2013). Several authors had explored and confirmed the transferability of skills between trainers(Hamilton et al., 2002; Loukas et al., 2012) and simulation to real-world performance(Hamilton et al., 2002). The evidence, however, is contradictory. The results of Hassan et al (2015) and Thomaier et al (2017) indicated minimal transfer of skills between simulators. Stefanidis et al (2008) identified that the EP demonstrated in the simulator was not visible in the operating room.

Norman et al (2006) believe that preservation of the procedural elements of tasks may primarily be responsible for transferability between SBST and practice. This is further supported by the observations of Hashimoto et al (2015), who noticed that the benefit is primarily for tasks directly aligned with the training. SBST was introduced to overcome several training limitations, and the transferability of the learned skill is the primary academic consideration. Further scholarly and research efforts are required to both deduce the transferability of skills to the operating room, and ways of maximising this transfer.

6.6.2.3 Cognition and theoretical knowledge

Pape-Koehler et al (2013) identified significant benefits in cognitive training for tasks that required understanding of the anatomy (knowledge of structures). Surgical aptitude relies heavily on anatomical knowledge, which is better taught using multimedia than conventional teaching. This may explain the results observed. Similar benefits can be expected in certain other domains as well. Although the DP framework does not explicitly focus on the role of cognitive training in skills learning, these findings provide an important consideration in designing courses. Assessment of the anatomical knowledge of participants may facilitate identifying appropriate starting levels, and supplementary multimedia-based lessons would improve the overall outcomes. Trainees who only practised the cognitive portion of the training task performed worse than those who practised both the cognitive and psycho-motor portions of the task (Long et al., 2019).

Although mental representation in DP refers to some elements of the thought process, DP does not explicitly focus on the theoretical knowledge and cognitive aspect. Multiple studies (Immenroth et al., 2007; Nickel et al., 2015; Pape-Koehler et al., 2013; Pearson et al., 2002) identified that cognitive training, in addition to skills training, leads to better learning. The study by Pape-Koehler et al(2013) even better cognitive and motor skills were observed in the group that followed multimedia-based training, exceeding the performance of practical training and combined training groups.

6.6.3 Alignment between SBST and DP

Simulation-Based Surgical Training (SBST) and Deliberate Practice (DP) are both grounded in the principle of skill acquisition through repeated, structured engagement with task-specific challenges. Both frameworks emphasise the need for repetition, feedback, and progressive difficulty to drive performance improvement. The conceptual compatibility between these approaches was affirmed in the quantitative findings, where over 90% of expert surgeons acknowledged the value of simulation centres for skills acquisition. Similarly, trainers and trainees expressed a belief that simulation contributes meaningfully to skill development, particularly in early-stage laparoscopic training. This illustrates a strong theoretical alignment between SBST and DP in terms of goals and pedagogical underpinnings.

Despite this theoretical alignment, both quantitative and qualitative data pointed to significant gaps in how SBST is implemented relative to the DP model. While many ES reported having access to simulation resources, fewer than 40% indicated that they used simulation regularly for formative assessment or structured feedback—key elements of DP. Qualitative interviews echoed these findings. Trainees often described simulation as “one-off” or “sporadic” experiences, lacking consistent follow-up or reflection. Trainers, although supportive of SBST in principle, cited systemic barriers such as lack of time, insufficient training in giving feedback, and absence of formalised curricula. These issues contribute to a model of simulation use that is opportunistic rather than deliberate.

6.6.3.1 Participants and motivation

Almost all the studies included in the two systematic reviews recruited participants in Bloom (1985) phase 1 of learning. Phase 1 ends when DP begins (Ericsson et al., 1993). In real life, SBST is offered to trainees with suitable experience levels. As the fundamentals of DP were ignored, the outcomes may have been significantly better if trainees of appropriate skill levels were chosen. Hashimoto et al(2015), however, identified that DP can enhance learning, irrespective of the stage of competency. DP can enhance SBST by permitting development beyond the level achieved through mastery learning. Studies, where all components of DP were fulfilled, have shown to improve performance beyond the level produced by SBST alone (Crochet et al., 2011; Hashimoto et al., 2015).

The mixed methods study therefore included surgical trainees of varying experience levels. Our findings, however, are limited by the low awareness and poor understanding of DP by all categories of participants. The findings do indicate that expert surgeons had adhered to principals of DP, which may have contributed to their skill acquisition.

The “motivational constraint” described by Ericsson (1993) significantly limits skill acquisition. As DP lacks enjoyment or extrinsic motivation, intrinsic motivation, founded on the belief that DP improves performance, is essential for its success. If the learners are not sufficiently motivated, they are unlikely to continue the training and thus improve. As most studies in the reviews, including ones explicitly investigating DP, failed to consider assessment or enhancement of learner motivation, the witnessed improvements could have been further enhanced through DP. The trainees included in this study demonstrated no reduction of motivation with increasing seniority as found previously (Lund et al., 2022). The trainers must maintain the positive learning environment and motivation, to encourage deliberate practice. As newer simulation modalities like VR improve learner motivation (Sattar et al., 2019), SBST using VR may have involuntarily promoted DP. Further research is required to elucidate the actual effects.

6.6.3.2 Tasks

Surgical skills are inherently complex, and practising the entire movement sequence has produced the best outcomes (Brydges et al., 2007; Dubrowski et al., 2005; Schaverien, 2010). Multiple factors, including contextual interference (Schaverien, 2010) and improved inter-limb coordination (Schaverien, 2010; Wenderoth et al., 2003), contribute to this.

Most of the studies in the reviews used task trainers. Procedural training, teaching the intricacies of the whole procedure in addition to the skills, in a setting where mistakes are tolerated without repercussions(Roberts, 2006), is the next logical level of complexity. Organising the learning tasks sequentially with increasing complexity and allowing the learner to progress is a hallmark of DP (Ericsson et al., 1993) but was ignored in most studies.

The poor integration of SBST in the local training, and the lack of DP based guidance was highlighted by all categories of participants. This meant that there was minimal tailoring of the learning task through simulation. The graded exposure was confined to choosing the right patient to operate or performing only parts of the surgery. Nevertheless, the importance of stepwise progression in training was acknowledged by all groups.

The instructions provided are crucial in optimising performance. Better instructions benefit subjects with lower cognitive ability compared to high-ability subjects (Ericsson et al., 1993). Studies have also shown that students with lower visual-spatial skills can perform equally well through DP (Ericsson, 2015). SBST programmes must therefore have explicit instructions for the task, preferably demonstrations by the trainer. The tasks should be easily understood following brief instructions. There was a wide variation in the instructional styles described by the participants, but there was little emphasis on the importance of pre-task instructions or demonstration of the skill.

Several studies (Kanumuri et al., 2008; Loukas et al., 2012; Youngblood et al., 2005) reported a performance ceiling. Laparoscopic skills are complex and mastering them requires time. The performance ceiling noticed here most likely represents the limit that the particular activity and degree of feedback can produce. The primary purpose of DP was to overcome this “arrested development“ (Ericsson et al., 1993), thereby promoting an almost unlimited growth in performance. The main purpose of recruiting expert surgeons for the study was to explore the behaviours of a group of surgeons with the highest performance ceiling. The results indicated that adherence to principles of DP was commoner in those with higher performance levels.

6.6.3.3 Feedback

SBST and DP consider feedback to be one of the most important elements contributing to learning SBST should, therefore, always be accompanied by formal assessment and feedback (Portelli et al., 2020). The DP framework is prescriptive on this feedback. Several studies showed improvements in control groups using box trainers (Brinkmann et al., 2017; Nickel et al., 2015). Box trainers provide the haptic feedback VR cannot offer. Additionally, these studies used identical training programs, with tutor feedback for both groups. The improvements seen in the control groups are most likely due to these feedback mechanisms. Pearson et al (2002) noticed that one-to-one instructions improved performance, even without practice. Tanoue et al (2008) reported an increase in errors in the control group where the participants practised without supervision, indicating that repetition without feedback can even be detrimental. The participants, however, indicated the lack of structured feedback or the use of validated tools to provide feedback.

Cumulatively, these observations demonstrate the utility of feedback irrespective of the simulator used and further strengthen the role of DP in improving SBST. The study by Crochet et al (2011) confirmed the additional gains DP brings to SBST, above standard VR training. SBST should therefore include immediate, informative feedback with remedial training.

6.6.3.4 Repetition

Concentration and self-monitoring are imperative to DP, so practising for long periods without exhaustion is impossible. This “effort constraint“ (Ericsson et al., 1993) is believed to be due to the “reactive impedance“ (Schaverien, 2010), where fatigue and boredom reduce the performance. It is assumed, like other learning, skills learning is better when repeated frequently (distributed practice) than intense short-term training (massed practice) (Roberts, 2006). Although this had not been assessed in any of the included studies, Moulton et al (2006) demonstrated distributed practice consistently provide better learning outcomes. The participants in this study, however, did not highlight this. One potential reason could be the vague line between service delivery and training on patients. This often prevents repeated performance of a task, which while minimizing effort constraint, may also impede learning.

Though the optimal schedule for distributed practice has not been established, programmes promoting practice over several weeks have shown greater skill development (Crochet et al., 2011). Further research on this area will benefit future SBST design.

6.6.3.5 Outcomes and performance

There is a fundamental dissonance between DP and modern surgical training. Training and accreditation aim to produce a surgeon capable of independent practice (George et al., 2017). As a result, this arbitrarily remains the achievement objective of SBST as well. DP, however, attempts to achieve expert performance.

Although surgical expertise is widely acknowledged as a concept, it remains poorly defined (Kirkman, 2013). Furthermore, although DP heavily relies on identifying this level, it does not define how to identify or quantify it. The standard metrics used in identifying surgical expertise have inherent limitations (Kirkman, 2013). None of the SBST attempted to train surgeons at this level (late-stage II / stage III).

This ambiguity in identifying EP in surgical practice has hampered the use of DP in SBST, limited comparison between studies and limited its use in accreditation. A guideline on identifying EP would overcome these limitations, and further research is needed on identifying suitable endpoints as EP. Both ES and trainers in this study encouraged the administrative bodies to both declare the desired threshold and provide objective assessment tools.

6.6.3.6 Best practices and future design

Despite these limitations, the study also identified pockets of effective alignment between SBST and DP principles. In some departments, simulation was embedded into structured teaching programmes, featuring defined learning objectives, repeated exposure to core procedures, and real-time expert feedback. Practices such as stepwise progression through simulation tasks and use of validated assessment tools (e.g. OSATS) mirrored the DP emphasis on performance monitoring and incremental challenge. Trainers who had undergone faculty development in educational methodology were more likely to provide reflective feedback and to use simulation as a scaffold for ongoing skill refinement. These examples point to emerging best practices that, if expanded, could help integrate SBST more effectively within a DP framework.

The findings underscore that simulation has the potential to serve as an ideal platform for DP, but only when supported by intentional curricular design and educational infrastructure. Effective alignment requires protected time for practice, structured feedback mechanisms, and recognition of simulation as an essential—not optional—component of training. This has implications for how institutions resource faculty development, assess competency progression, and integrate simulation into formal training pathways. Embedding DP into SBST requires a shift from viewing simulation as a supplementary activity to a central pillar in developing EP.

6.7 Limitations

6.7.1 Comparison of structured practice, purposeful practice, and DP

RQ1.2 aimed to compare structured practice, purposeful practice, and Deliberate Practice, to characterise the key elements and identify the utility of each in SBST.

Despite an extensive literature search, no publications focusing on simulation or surgery and PP/SP were identified. Only a review by Anders Ericsson (2020) provided any pedagogical insight into *Purposeful Practice*. The papers by Ericsson et al (2019) and Hutterman et al (2014) used the term *Structured Practice* for training that focusses on structured activities but lacks other components of DP. This pedagogical gap needs to be explored in future research.

6.7.2 Systematic reviews

The synthesis of evidence from existing literature through a systematic review and evaluation of adherence to DP principles faced several methodological challenges. Firstly, the included studies were highly heterogeneous in design, participant population (ranging from medical students to residents), simulation modality (e.g., box trainers, VR, cadaveric), and measured outcomes. This variability limited the ability to conduct a meaningful meta-analysis and required a narrative synthesis approach. As a result, while general trends were identified, specific effect sizes and comparisons across interventions remain tentative.

Secondly, there was a notable absence of studies employing robust, high-level outcome measures. Most studies assessed outcomes at Kirkpatrick levels 1 or 2 (reaction and learning), with very few evaluating behaviour change or patient-level outcomes (levels 3 and 4). This limits the ability to draw conclusions about the real-world impact of DP-informed training on surgical performance and patient safety.

Additionally, the scoring framework used to assess adherence to DP principles, although grounded in Ericsson's model, has not been previously validated in the literature. While it allowed structured evaluation and comparison, the lack of standardisation in applying DP across studies made scoring inherently subjective. This introduces potential bias and variability in interpreting adherence levels.

Publication bias also remains a concern, as studies demonstrating positive effects of simulation and DP are more likely to be published. Furthermore, many studies had small sample sizes, short follow-up periods, or single-institution settings, further limiting the external validity of the findings.

6.7.3 Mixed methods study

This thesis adopted a mixed methods design to investigate the role of DP in developing EP in surgery and the barriers to its implementation. Integrating quantitative and qualitative data provided a nuanced understanding of the efficacy of DP-informed SBST and the contextual challenges of its adoption. Like all research designs, however, this approach is not without limitations.

The study aimed to explore trainee and trainer perspectives on DP implementation, identifying perceived enablers and barriers. While the semi-structured interview format allowed for rich, in-depth data, the scope of sampling was limited to a single institution. Although efforts were made to include a range of training levels and disciplines, the institutional culture, available resources, and local educational policies may not reflect broader national or international contexts, particularly in lower-resource environments. Additionally, self-selection bias (Elston, 2021) may have influenced the findings. Participants who volunteered to be interviewed may have had stronger opinions about surgical training, whether positive or negative, than those who declined. This could result in over-representing individuals who are more reflective or engaged with educational reform, skewing the thematic landscape.

The researcher's positionality also warrants discussion. As a surgical educator and clinician, the principal investigator brings valuable insider knowledge to the interpretation of data but also risks confirmation bias (Oswald & Grosjean, 2004). While strategies such as reflection and peer debriefing were employed to enhance trustworthiness, complete bracketing of assumptions is inherently problematic in qualitative research. Additionally, while the study achieved thematic saturation, the number of participants may still be considered modest. A larger and more diverse sample may have uncovered additional themes, particularly around organisational and systemic barriers.

While offering the strength of triangulation, the mixed methods design also introduces complexity and potential weaknesses. A central challenge is the integration of qualitative and quantitative findings in a meaningful and coherent manner. There are inherent philosophical and practical differences between the approaches (Palinkas et al., 2011). Qualitative interviews yield rich, nuanced themes, whereas surveys yield structured numeric measures; aligning these formats requires deliberate strategy. Additionally, the volume and complexity of data generated from these two approaches also impede integration, and this has been acknowledged previously (Nessle et al., 2023). The risk of incongruent or conflicting results is not uncommon and must be reconciled rather than ignored. For example, a high survey score on the perceived importance of availability of simulation resources and interview reports of limited access reflect on converging views on the same aspect; resolving such discordance requires interpretive care. Similar challenging integrations were required throughout the study and required additional analysis steps (e.g. data transformation).

Although this study used a convergent design with clear points of connection between phases, limitations in either component could influence the validity of the integrated conclusions. Furthermore, while the sequential interpretation of findings allowed for richer explanation, there is an inherent risk of privileging one data set over the other. In this study, the quantitative literature first informed the theoretical framework, which could have subtly shaped the interpretation of qualitative findings. Although the themes emerged inductively, the lens through which they were viewed was necessarily shaped by prior findings and the researcher's clinical background. Braun and Clarke (2019) argue that the researcher actively interprets the data, drawing connections between different pieces of evidence to identify patterns and meanings, and creating a narrative that explains the significance of the themes. The researcher articulates the assumptions and values that contextualize the finding. I have attempted to adhere to these in conducting this research.

The mixed methods approach also demands a high level of methodological expertise, both in educational theory and empirical techniques. Balancing depth with breadth can lead to certain areas, particularly statistical analysis or deeper sociocultural critique, receiving less attention than they might in a single-methodology study.

Lastly, this study does not quantitatively assess long-term clinical outcomes or patient safety improvements associated with DP-based training. These remain critical endpoints for future research.

6.7.4 Regional context

The regional context in which this study was conducted inevitably shapes the authenticity and transferability of the findings. Surgical education in Sri Lanka is situated within a nationally regulated but regionally embedded system, where institutional culture, available resources, supervisory practices, and local healthcare demands exert considerable influence on training experiences. As such, while the study captures authentic accounts of DP as it manifests in this specific environment, the patterns identified may not map directly onto contexts characterised by different regulatory structures, educational resources, or professional cultures. This limitation does not undermine the internal validity of the study but does necessitate a cautious approach when drawing broader inferences.

At the same time, recognising the situated nature of these findings opens an opportunity to consider the ways in which regional variation itself can inform theory and practice. Differences in medical education systems across regions—whether in resource allocation, pedagogical traditions, or assessment mechanisms—highlight the importance of interpreting deliberate practice not as a universally uniform construct, but as one that interacts dynamically with local conditions. This underscores the need for future comparative research that examines how DP principles are enacted across diverse educational and cultural contexts, thereby enhancing both the robustness and global applicability of the theoretical model.

7 Conclusions

"Theory surely leads to practice. But practice also leads to theory.

And teaching, at its best, shapes both research and practice" (Boyer, 1990)

Thomas Boyer (1990) was one of the earliest educationists who recognised the bidirectional relationship between theory and practice. This study attempts to reflect on the "overlapping academic neighbourhoods" (Polanyi et al., 2000) of SBST and DP to identify areas of improvement and future research. The findings comprehensively explore how Deliberate Practice (DP) has and can be effectively applied within surgical training to foster EP. It also highlights the structural and cultural barriers to its implementation.

Through systematic reviews and a mixed methods approach comprising surveys and qualitative inquiry, this study explored how DP can be operationalised within Simulation-Based Surgical Training (SBST), evaluated its effectiveness, examined the barriers to its implementation, and offered a roadmap for surgical educators and policy makers to reform training programs.

7.1 Summary of Key Findings

DP, as conceptualised by Ericsson and others (1993), is characterised by focused, repetitive practice on tasks with immediate feedback and opportunities for correction. It necessitates high levels of motivation, structured task design, informative feedback, and repeated efforts aimed at skill refinement.

In response to RQ1, the systematic review demonstrated strong evidence supporting DP's efficacy in enhancing psychomotor skills, skill retention, and transferability—particularly when feedback and repetition were explicitly incorporated. It however highlighted inconsistent adherence to DP principles in published studies. For RQ1.1, the evidence revealed that while feedback and repetition are the most frequently implemented DP components, individualised task difficulty and motivational scaffolding are often underutilised. RQ1.2 found limited comparative literature on structured, purposeful, and deliberate practice, with interview participants rarely distinguishing between these models, revealing a critical pedagogical gap.

The systematic review undertaken in this thesis revealed that when DP principles, particularly repetition, structured feedback, and increasing complexity, were implemented into SBST, the outcomes—ranging from technical skill acquisition to retention and transferability, were significantly enhanced (Ericsson, 2015; Hashimoto et al., 2015). Despite this, the analysis of included studies revealed that many training programs incorporate DP elements inconsistently. Few studies addressed all core tenets of DP, such as motivation, scaffolded task design, immediate informative feedback, and repetition under effort constraints. Those that did demonstrated improved learning outcomes, highlighting the necessity of comprehensive integration. Although the two studies focussed on different surgical skill domains, the findings on the effectiveness of DP and importance of different components were largely similar. This is a good indication on its widespread adaptability to all forms of skills training.

For RQ2, findings from the mixed-methods study indicated that DP is rarely implemented in a structured manner within SBST. Simulation is commonly available but used sporadically, with limited incorporation of key DP elements. RQ2.1 showed that most training environments prioritise efficiency and service delivery, leading to limited protected time and a lack of feedback mechanisms—both essential for DP. The qualitative data further reinforced this gap, with trainees and trainers highlighting the inconsistency of practice opportunities, lack of protected time for simulation, and the undervaluation of educational theory in curriculum design. Moreover, learners reported variability in feedback quality and emphasised the value of timely, specific feedback linked to defined performance criteria. Trainers also acknowledged the importance of feedback but highlighted barriers such as competing clinical responsibilities and limited training in educational methods. Notably, RQ2.2 revealed clear differences in how ES and trainees engage with DP. Experts more often reported reflective practice and self-assessment, whereas trainees relied on opportunistic learning shaped by external constraints.

Finally, the study explored barriers and solutions through RQ3, finding that institutional constraints such as time pressure, inadequate faculty development, and limited curricular integration significantly hinder DP-based SBST. The study also highlighted the tension between service commitments and educational needs. Modern surgical training environments and increasing administrative burdens often prioritise immediate clinical output over long-term educational investment. RQ3.1 uncovered cultural resistance, under-recognition of DP as a formal method, and poor feedback literacy as further barriers. Consequently, opportunities for structured feedback, guided practice, and critical reflection—pillars of DP—are limited. In addressing RQ3.2, participants recommended integrating DP into curricula, establishing protected practice time, and developing trainer capacity for structured feedback as practical and actionable solutions.

Together, these findings affirm the relevance and utility of DP in advancing surgical education while underscoring the systemic and cultural changes needed to fully realise its potential within simulation-based training environments.

7.2 Contribution to Knowledge

This thesis makes several novel contributions to the field of surgical education. First, it collates, synthesises and evaluates the existing knowledge on the application of DP in the context of laparoscopic surgery. Psychomotor complexity and restricted operative autonomy make structured skill acquisition essential in this area. The systematic review is among the first to appraise adherence to DP principles across studies, using a novel scoring rubric based on Ericsson's framework. The clear gradient of outcomes between high- and low-DP adherence studies strengthens the argument for a full-spectrum DP approach. This offers a new lens for educators and researchers to assess the pedagogical rigour of training interventions. Integrating DP with existing learning theories bridges the gap between theoretical understanding and practical curriculum design. By mapping DP's core elements to the stages of surgical skill acquisition, this thesis presents a pedagogical model that is both evidence-based and applicable to real-world training programs.

Second, the qualitative component adds depth to the understanding of how DP is perceived and experienced by surgical trainees and trainers. Thematic analysis revealed that while there is broad recognition of the importance of repetitive practice and feedback, real-world barriers—such as limited faculty availability, institutional inertia, and cultural resistance—undermine implementation. The insights also emphasised the importance of intrinsic motivation and the need for psychologically safe learning environments, echoing findings from educational psychology.

Third, this study reframes DP not merely as a technique for skill improvement but as a pedagogical philosophy. In doing so, it challenges the traditional "tea-steeping" model of surgical education and supports the transition toward a competency-based, learner-centred approach. Integrating DP into curricula would signify a deliberate departure from passive learning towards active, goal-oriented training. By leveraging the strengths of SBST—including controlled environments, reproducibility, and low-stakes feedback—it is possible to replicate the conditions necessary for EP development without risking patient safety (Issenberg et al. 2005; Kneebone 2003).

7.3 Practical Implications

The findings of this research have significant implications for surgical training programs. First, they suggest that simulation should not be viewed as a supplemental activity but as an essential pedagogical tool for deliberate skill acquisition. Training programs should transition from time-based to competency-based models, prioritising individual learner progression. The incorporation of DP into SBST should become standard practice, particularly for technically demanding areas such as Minimally Invasive Surgery (MIS), where traditional apprenticeship is insufficient (Choy & Okrainec, 2010; McGaghie, 2008). Programs should mandate regular simulation sessions embedded within the training schedule, with clearly defined goals, expert feedback, and progressive difficulty.

Second, curriculum designers should consider re-engineering simulation-based training around DP principles. This includes defining performance benchmarks based on expert performance, tailoring practice tasks to learner level, and ensuring feedback is specific, timely, and actionable (Stefanidis, 2010). Importantly, this must be coupled with protected time for trainees and structured faculty involvement—currently one of the most significant bottlenecks. Programs that offer distributed practice and progressively increasing challenge have been shown to improve skill acquisition and retention (Bjerrum et al., 2018).

Third, institutions must address the system-level barriers to DP implementation. Protected time for simulation and training, as well as structured faculty development programs, are essential. Trainers need to be equipped not only with clinical expertise but also with skills in assessment, feedback, and instructional design (Ericsson, 2015; Issenberg et al., 2005). This necessitates a shift in faculty roles—from clinical overseers to educational mentors. Furthermore, policies recognising and rewarding educational contribution (e.g., promotion and tenure criteria) could incentivise greater faculty participation in structured teaching and feedback. This aligns with broader Competency-Based Medical Education (CBME) frameworks that advocate for outcome-driven, individualised learning pathways.

Finally, incorporating DP-aligned tools such as the SIMPL app and Zwisch scale for measuring autonomy may provide objective evidence of trainee progression and guide feedback delivery (George et al., 2014).

The findings of this study indicate that systematic incorporation of DP principles into surgical training can address several barriers currently limiting skill acquisition, including insufficient structured feedback, lack of repeated practice opportunities, and inadequate integration of simulation into curricula. While the study demonstrates the theoretical and empirical basis for change, to translate these findings into practice, a sequential implementation strategy is proposed. They are informed by the Consolidated Framework for Implementation Research (CFIR) (Damschroder et al., 2009) and principles of knowledge translation (Straus et al., 2013).

1. Stakeholder Engagement and Consensus Building

Early engagement of key stakeholders—including surgical faculty, simulation centre directors, postgraduate training committees, and hospital administration—is essential to ensure alignment with institutional priorities. The survey and interview data in this thesis highlighted faculty commitment as a key facilitator of DP adoption, suggesting that securing leadership endorsement would be a critical first milestone.

2. Resource Mapping and Infrastructure Development

As identified in both the quantitative and qualitative strands, access to simulation facilities, task trainers, and protected training time are crucial. An initial audit of existing resources should be undertaken to determine what can be repurposed and where investment is required. Collaboration with simulation units could streamline scheduling and maximise utilisation.

3. Curricular Integration and Formalisation

DP activities should be embedded into the surgical curriculum, with explicit learning objectives, structured feedback processes, and performance benchmarks. The study's findings on the need for progression tracking (Section 6.5) suggest that inclusion of objective assessment tools (e.g., OSATS, GOALS) will help standardise expectations and monitor improvement over time.

4. Faculty Development and Champion Identification

Faculty need training in delivering high-quality, timely feedback and in structuring DP sessions. Identifying a small group of "practice champions" from within the faculty who model and advocate for DP will provide visible leadership and help maintain momentum.

5. Pilot Programme and Creation of an 'Enclave' of Good Practice

A targeted pilot within a single department or subspecialty could serve as a proof of concept. This enclave would implement the full DP model—structured sessions, defined performance targets, and rigorous feedback—and serve as a living example for other departments. Outcomes from this enclave could be used to generate local evidence of effectiveness, encouraging wider adoption.

6. Evaluation, Feedback Loops, and Iterative Refinement

Consistent with the mixed methods design of this study, evaluation should combine quantitative performance data (e.g., improvement in skill scores) with qualitative feedback from trainees and faculty. Regular review cycles would allow iterative refinement of the DP programme, ensuring responsiveness to emerging challenges.

7. Scaling and External Dissemination

Once the enclave has demonstrated sustained improvement, lessons learned should be disseminated through institutional seminars, professional society meetings, and peer-reviewed publications. This not only promotes external adoption but also strengthens the institution's role as a leader in surgical education innovation.

By following these steps, the institution can move from research evidence to tangible, replicable models of best practice. Establishing an enclave of good practice will provide a sustainable demonstration site where deliberate practice is not only advocated but consistently enacted, offering a benchmark for surgical training excellence.

7.4 Theoretical Implications

This thesis reinforces DP as a viable and effective model of skill acquisition in high-stakes, complex domains such as surgery. It bridges motor learning theories with practical surgical education. It offers a structured developmental pathway by mapping the cognitive, associative, and autonomous stages of learning to simulation modules and surgical curricula. While traditional models emphasise task exposure and time, DP emphasises structured learning with clearly defined goals and continuous feedback. This is especially important in contexts where performance plateaus or "arrested development" is likely (Hashimoto et al., 2015; Issenberg et al., 2005).

This work also emphasises the role of mental representations in DP—the learner's ability to visualise and self-correct performance is critical to skill refinement (Ericsson, 2015). Trainers play a pivotal role in developing these representations through explicit instruction and feedback, echoing Bloom's principles of mastery learning (Bloom, 1968; Guskey, 2007).

7.5 Future Directions

Several areas warrant further investigation. First, future studies should aim to quantify the long-term impact of DP-based simulation on clinical performance and patient outcomes. Multi-centre randomised controlled trials with robust follow-up metrics—including transferability to clinical practice (Kirkpatrick Level 4 outcomes), patient safety, complication rates, and surgical autonomy—are essential to establish causality and would provide stronger evidence for policy reform.

Second, there is a need to explore the application of DP in advanced surgical training, as most current research focuses on novices. Understanding how DP principles can support the transition from competence to expertise among experienced trainees could significantly enhance surgical education.

Third, there is also a need to develop and validate assessment tools that can capture the nuanced progression from competence to expertise, including metrics for mental representation, adaptability, and decision-making under pressure.

Finally, research should explore how to scale DP-based training within resource-constrained environments. Innovations like mobile-based simulators, remote coaching, and low-cost task trainers may help democratise access to high-quality surgical education. Future work should also examine how these tools can be integrated meaningfully within educational frameworks, and not merely as technical add-ons.

7.6 Final Thoughts

Surgical education is at a critical juncture. The limitations of time-based apprenticeship models are well documented, and the expectations of modern healthcare demand not just competent but expert practitioners. Deliberate Practice offers a robust, evidence-based framework for cultivating expertise in a structured, measurable, and learner-centred way.

This thesis has demonstrated that DP is not merely a desirable educational strategy but essential for developing EP in surgery. Training systems must evolve from passive exposure to structured, feedback-driven learning in a field where precision, judgment, and consistency can mean the difference between life and death. One limitation of DP is that the trainer must be in careful control of all elements in the learning environment for optimal used of DP. While this is easily achievable in SBST, DP yields less well for hands-on surgical training.

Real change, however, requires more than evidence—it requires cultural, structural, and institutional transformation. Educators must shift their focus from quantity of experience to quality of learning. Institutions must invest in protected time, faculty development, and pedagogically sound curricula. Trainees must embrace the discomfort of effortful practice and take ownership of their progress. Most importantly, we must place patient safety and excellence at the centre of surgical education.

In conclusion, by aligning surgical education with the principles of Deliberate Practice, we can bridge the gap between current competence and future excellence, ultimately improving patient outcomes and advancing the field of surgery.

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9 Annexures

9.1 Data collection forms

Name

Email address

Demographics

1. Age –
2. Sex –

Level of training

Number of years in Training

Motivation

Please indicate your usual level of motivation for skills training, on a scale of 0-100

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 10 20 30 40 50 60 70 80 90 100

Not at all motivated — Extremely motivated

What are your expectations from surgical skill training?

1. improve my identity, autonomy, self-confidence

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 10 20 30 40 50 60 70 80 90 100

2. Develop my personality.

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 10 20 30 40 50 60 70 80 90 100

3. Gain confidence in my potentialities.

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 10 20 30 40 50 60 70 80 90 100

4. Acquire skills to be a more responsible and autonomous person

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 10 20 30 40 50 60 70 80 90 100

1. Considering all laparoscopic procedures that you are involved in, how often do you give feedback on trainee performance? (Please indicate as a percentage)
2. Please indicate the frequency feedback you provide for your trainees, on the following table. The total percentage of each row should be 100%

	0	1	2	3
Task (A description of the event around which feedback was given)	Not described	*Vague* -lacking either content or value (No specific behaviour was identified with regards to the learning goal for the task e.g. 'You did great')	Content or value described *generally* (A general description of the behaviour was identified with regards to the learning goal for the task e.g. 'General examination done, Inspection of the chest done, auscultation done')	Specific – Content or value specifically described (A good description of the steps to the particular task/skill provided e.g. Positioned the patient correctly to examine the chest, when examining for aortic regurgitation had the patient lean forward and exhale
Percentage				
Gap (The recognition of a difference between their performance and that of a comparative standard)	No gap described	Gap alluded to (No suggestions geared toward identified behaviour. e.g. 'Your technique was awful')	Gap *generally* described (Concise issue raised but limited suggestions provided to learner e.g. You looked very uncomfortable examining that chest')	*Specific* gap identified (Concise issues identified and learner provided with information to close a gap in knowledge e.g. 'Your exam of the chest was appropriate, but percussion technique was inadequate. You may be more comfortable if you position your fingers on the chest this way')
Percentage				
Action	No learning	Learning goal or plan *alluded* to	*General* goal or plan described	*Specific* goal or plan described

(Using the feedback to create a future learning goal or plan)	goal or plan	(Feedback terminated with no plans for follow-up or re-evaluation e.g. 'Great job')	(Broad action plan is suggested but not specific to behaviour or encounter e.g. 'Read more around your cases')	(Clear plan to modify or reinforce behaviour e.g. 'Read this article on chest examination, practice the percussion technique and I will watch you examine the next patient with pneumonia')
Percentage				

3. Which of the following do you use in training surgical trainees

		Never	Occasionally	Regularly
Setting learning goals	OSATS			
	milestones			
Assessment	OSATS			
	OSCE			
	board examinations			
Formative feedback	OSATS			
	surgical simulators			
Repetition of performance	Surgical simulators			
	Cadavers			
	Animal labs			
Motivation	Surgical simulators			
	Self-directed learning (learner-cantered approach)			

4. Please choose the most appropriate answer regarding <u>your own practice and training</u> (developing your skills)

	When I practice	1 Never	2 Very rarely	3 Rarely	4 Sometimes	5 Often	6 Very often	7 Always
1	I know what I am doing							
2	I know what I need to achieve							
3	The steps I perform during surgery is part of a long-term practicing plan.							
4	I analyse technical problems I encounter (e.g. difficulty in laparoscopic suturing)							
5	I check the effectiveness of the technique I am using.							
6	Problems encountered during surgery require specific thinking and planning.							
7	I spend time analysing and understanding surgical skill related problems							
8	I know how to fix all the skill-related problems I find							
9	I do not know how to achieve the skill(s) I want							

10	I do not know how to fix skill-related problems							
11	I evaluate the effectiveness of my practice							
12	If my skills do not improve, I change my strategy of practicing							
13	I perform repetitive steps of surgery mindlessly, over and over.							
14	I repeat steps of a surgery without a purpose.							
15	I repeat mistakes without fixing them.							
16	I divide skills difficult to learn into smaller tasks.							
17	If a problem is difficult to fix, I try to break it up into smaller ones.							
18	I focus on short problematic steps of a surgery							
19	I analyse the way I practice in order to improve it.							
20	I refine the way I practice.							
21	I read academic papers about practice.							

22	I know how to use my body efficiently to perform surgery							
23	I rush my surgical steps							

5. When do you use debriefing after a procedure to provide feedback to your trainees?

	Never	Rarely	Sometimes	Often	Always
To think critically about the performance					
To deconstruct events and errors					
To provide new information to improve practice					

6. How would you rate the importance of the following factors for simulation training?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
The benefits of feedback	Effective learning				
	Slow decay				
	Assess / monitor progress				
Repetitive practice	Correct errors				
	Polish the performance				
	Make skills effortless and automatic				
	Shorter time for skill acquisition				
	Skill transfer				
The simulation centre	Availability according to learner schedules				
	Convenient location				
Integration of the program into the curriculum					

Having a range of difficulty levels					
Having a wide range of clinical variations					
Providing individualized training to trainees					
Performance measures	Tangible, objective measures				
	Virtual reality metrics				
A positive learning environment					

7. In your opinion, how can practice be defined?
8. What is the main purpose of practicing?
9. Which methods and aspects make practice particularly effective?
10. Which ones can be considered non-effective?
11. How can practice's effectiveness be measured?
12. In your opinion, what is the relationship between practice's quality and quantity?
13. Which leads to faster and better results?
14. Which activities other than surgical training can improve practice effectiveness?

9.2 Interview guide

Facilitator's welcome, introduction and instructions to participants

Facilitator: Welcome and thank you for volunteering to participate in this discussion. You have been asked to participate as your point of view is important. I know you are very busy and I value your time. The purpose of this interview is to discuss your opinions about the laparoscopic training you have had, and about the use of simulation in training.

You can leave this discussion at any time if you change your mind. Anything you have said up until that point will be deleted.

Anonymity/rules

Facilitator: Although this interview is being recorded, I would like to assure you that the discussion will be anonymous and anything that anyone says in the group will be kept confidential. After the discussion, the audiotapes will be transcribed. During the transcription process you will be given a pseudonym so you can't be identified.

There are no right or wrong answers – the idea of this group is to understand the range of perspectives. Due to the limited time available, I may have to re-direct our discussion with a few questions.

Setting the scene

Facilitator: Do you have any questions?

Actions: Consent forms—handout and complete preliminary questionnaire.

Facilitator: For the purpose of transcription, can you all introduce yourselves please? If you can tell me your name and where you are working.

Interview outline

The following sequence will be followed in the interviews. The discussion themes will be the same, but questions for trainees and surgeons will be different.

Semi-structure interviews – Trainees

Research question	Examples of data gathering questions	Further considerations
RQ1.2 – What are the differences between, and the difference in benefits of, structured practice, purposeful practice, and deliberate practice in surgical simulation?	• How do you train yourself in laparoscopic skills? • What do you believe you need to do to develop good laparoscopic skills? • What are the elements you consider important in a simulation training program for laparoscopy?	• Evaluate the components of the training programmes • What are the differences between, and the difference in benefits of, structured practice, purposeful practice, and deliberate practice in surgical simulation?

RQ2.1 – What is the current use of simulation in surgical training, and how do they adhere to principles of deliberate practice?	• How do you use simulation-based training yourself?
	    ○ Can you describe your rules or expectations?
	• Are you familiar with the term deliberate practice in the context of simulation-based education?
	    ○ If yes, what do you understand it to mean?
	    ○ If no, interviewer to explain.
	Deliberate practice is the repeated act of intended cognitive or psychomotor skills with the goal of improving overall performance. Feedback is a key element of deliberate practice.
		• Evaluate the familiarity with each component of DP

	• Do you use DP in simulation-based training? • If you could do things differently for better training, what would you do and why? • Do you feel simulation prepares you for the real practice setting, and if not, what would you change and why?	

RQ2.2 – What are the similarities and differences in the use of DP between expert surgeons and trainees?	• Have you noticed a difference in the way you are trained in laparoscopy by surgeons of different skill levels?
	  ○ How?
	  ○ When?
		• Identify differences in the use of different components of DP

RQ3.1 – What are the barriers to the use of deliberate practice based simulation in surgical training?
RQ3.2 – What are the potential solutions to overcome these barriers?
	• What are the problems you have encountered in using DP for training laparoscopic skills?
	  ○ How?
	  ○ When?
		• Identify barriers to the implementation of each component, and potential solutions

Semi-structure interviews – Trainers and expert surgeons

Research question	Examples of data gathering questions	Further considerations
RQ1.2 – What are the differences between, and the difference in benefits of, structured practice, purposeful practice, and deliberate practice in surgical simulation?	• How do you train your trainees in laparoscopic skills? • What do you believe students need to do to develop good laparoscopic skills? • What are the elements you consider important in a simulation training program for laparoscopy?	• What are the differences between, and the difference in benefits of, structured practice, purposeful practice, and deliberate practice in surgical simulation? • Evaluate the components of the training programmes
RQ2.1 – What is the current use of simulation in surgical training, and how do they adhere to principles of deliberate practice?	• What do you believe students need to do to develop good laparoscopic surgical skills? • How do you use simulation-based training for your trainees? • What makes you provide simulation experiences the way that you do? ○ Can you describe the rules or expectations of both you and your students within these environments? • Are you familiar with the term deliberate practice in the context of simulation-based education?	• Evaluate the familiarity with each component of DP

	○ If yes, what do you understand it to mean? ○ If no, interviewer to explain. Deliberate practice is the repeated act of intended cognitive or psychomotor skills with the goal of improving overall performance. Feedback is a key element of deliberate practice. • Do you use DP in simulation-based education? • If you could do things differently to help trainees develop their skills, what would you do and why? • Do you feel simulation prepares students for their place within the real practice setting, and if not, what would you change and why?	
RQ2.2 – What are the similarities and differences in the use of DP between expert surgeons and trainees?	• Do you think deliberate practice relevant to surgical training? • Have you used DP for yourself in leaning laparoscopic skills? ○ How? ○ When? • Do you use DP for in training your trainees in laparoscopy? ○ How? ○ When? • What do you like about DP?	• Identify differences in the use of different components of DP

	• If you were designing a future laparoscopic simulation programme, how would you improve it using DP? •	

RQ3.1 – What are the barriers to the use of deliberate practice based simulation in surgical training?
RQ3.2 – What are the potential solutions to overcome these barriers?
	• What are the problems you have encountered in using DP for training laparoscopic skills?
	    ○ How?
	    ○ When?
	• Do you use DP for in training your trainees?
	    ○ How?
	    ○ When?
		• Identify barriers to the implementation of each component, and potential solutions

9.4 Feedback during training

Table 9-1 Feedback provided / received

	Feedback	*Surgeon*	*Trainers*	*Trainees*
Task	*Task was not described during feedback*	*45 (25-50) range 15-70%*	*10 (5-20) range 10-60%*	*30 (25-30) range 20-40%*
	Feedback on task was Vague, lacking either content or value *No specific behaviour was identified with regards to the learning goal for the task* *e.g. 'You did great'*	*30 (25-40) range 20-75%*	*30 (10-30) range 15-50%*	*40 (30-40) range 25-60%*
	Task content or value described generally *A general description of the behaviour was identified with regards to the learning goal for the task* *e.g. 'You inserted the first port correctly'*	*15 (10-25) range 0-40%*	*40 (15-50) range 25-70%*	*30 (30-30) range 10-35%*
	Task content or value specifically described *A good description of the steps to the task/skill provided* *e.g. You applied good retraction, and dissected in the right tissue plane, before making the incision to enter the peritoneal cavity*	*5 (6.25-8.75) range 0-10%*	*20 (10-50) range 10-70%*	*10 (20-15) range 0-20%*
Gap	*Gap was not described during feedback*	*32.5 (5-70) range 10-100%*	*10 (10-20) range 10-90%*	*30 (5-30) range 20-35%*
	Gap alluded to *No suggestions geared toward identified behaviour.* *e.g. 'Your technique was awful'*	*32.5 (10-35) range 0-40%*	*30 (10-35) range 0-50%*	*30 (20-40) range 20-50%*
	Gap generally described, *Concise issue raised but limited suggestions provided to learner.* *e.g. You looked very uncomfortable inserting that laparoscopic port*	*22.5 (2.5-35) range 0-80%*	*35 (10-40) range 20-50%*	*30 (30-30) range 20-35%*

		Specific gap identified. Concise issues identified and learner provided with information to close a gap in knowledge. e.g. Your skin incision was adequate, but the direction of port entry was wrong. As a result, the port tunnelled and you were finding it	*7.5 (12.5-17.5) range 0-25%*	*20 (30-60) range 10-60%*	*10 (30-20) range 0-20%*
Goal		*No learning goal or plan during feedback*	*20 (1.25-47.5) range 0-80%*	*10 (5-20) range 10-30%*	*30 (10-30) range 20-30%*
		Learning goal or plan alluded to Feedback terminated with no plans for follow-up or re-evaluation e.g. 'Great job'	*30 (10-40) range 10-50%*	*30 (10-30) range 20-40%*	*30 (20-35) range 20-50%*
		General goal or plan described Broad action plan is suggested but not specific to behaviour or encounter e.g. 'Read more around your technique'	*30 (22.5-37.5) range 5-50%*	*40 (20-50) range 30-50%*	*30 (30-30) range 20-40%*
		Specific goal or plan described Clear plan to modify or reinforce behaviour e.g. 'Read this article on safety of laparoscopic port placement, and practice holding the port correctly. I will watch you insert the ports during your next case	*10 (10-20) range 0-30%*	*20 (10-25) range 10-30%*	*10 (10-20) range 0-20%*

Each cell represents the median value with IQR. The value ranges from 0-100.

Table 9-2 Pairwise comparison of participant categories (p values)

		Trainer-Trainee	Trainer-Surgeon	Trainee-Surgeon
Task	Not described	0.012	0.003	0.603
	Vague	0.116	0.911	1.0
	General	0.003	<0.001	0.095
	Specific	0.014	0.001	0.243
Gap	Not described	0.025	0.08	1.0
	Vague	1.0	1.0	1.0
	General	0.024	0.031	o1.0
	Specific	0.064	0.014	0.552
Goal	Not described	0.003	0.195	0.973
	Vague	0.82	0.891	1.0
	General	0.014	0.04	1.0
	Specific	0.347	0.31	1.0

Mann-Whitney test, Statistically significant values indicated in bold.

9.5 Phase 3 – Quotations

Early laparoscopic era

Expert surgeons	*Trainers*	*Trainees*
Only cholecystectomies were done. So, then that was my initial training By the time I finished my first year, I was able to handle gall bladders	*Some of the trainers, they're also getting trained and I'm learning from them, and I think that's not good enough for me to learn.*	
The team members came to train My Boss actually I also observed. And after that I assisted my consultant.	*I couldn't get a consultant to assist me*	
All my training was actually after I came and worked here. Even at that time, even the consultants here were not very familiar. They were taking a long time	*Good selection of patients, Low threshold for conversion, and doing with people who were good assistants*	
Younger surgeons are you all are doing very well, and do more numbers than us	*Zero exposure to laparoscopic surgery and laparoscopic training*	
One or two surgeons was doing laparoscopic cholecystectomy. only about 10% of surgeons were doing laparoscopic surgery before 2000	*Trainers themselves were just getting acclimatized to laparoscopy and laparoscopic surgery*	
Urology was in infancy, started about now nearly 15 to 20 years back	*As time went on and then our senior registrars also took part in our training,*	

No structured training

Expert surgeons	Trainers	Trainees
I had assisted a lot of that, not anything else	*We never had a training in a model or a beetle,*	
During the peripheral appointment, again I was able to assist for laparoscopic cholecystectomy	*There was formal training but the short period of time*	
Not a very structured training	*There was no formal training*	
Opportunistic learning by assisting holding the camera	*I had not gone through a proper training*	
First exposure to laparoscopic training probably occurred when I was a senior registrar	*As a registrar I would say I was probably way below the skill levels the trainees are currently*	

Present laparoscopic training

Expert surgeons	Trainers	Trainees
Lack of standardized training programs: A standardized curriculum that incorporates deliberate practice is essential	*Sending the trainee depending on the audit; you can call for the audit and then if we find that they are doing a fair number of laparoscopies, sending the trainee*	*Although the PGIM prospectus lists the competencies, the training programmes are conducted by different Universities and societies. Each institution or trainer does thing differently.*
There are other people who can train. So, for that component you can go and work with them and get trained under them. So our training problem I think is not structured and not organised in terms of laparoscopic surgery.		
Did you have any structured trainings - no	*Not structured and not organized*	
I never had a chance to undergo structured training programme	*I try to adhere to protocol but that is not structured again*	

Expert surgeons	Trainers	Trainees
Few months observing. Very little formal training	*We don't check whether they have done their work. We just look at the logbook, and the number of surgeries performed. How they perform, the outcome is not known*	*In Sri Lanka, the foundation of surgical training is laid with a strong emphasis on clinical exposure*

Hit and miss an opportunistic way	*I try to adhere to protocol but that is not structured again. So, we have a beetle. So, I asked him to work at least 10 hours before they start practicing on a patient.*	*My role involves not only continuing my own training but also mentoring junior trainees* *When mentoring junior trainees, I emphasize the importance of these training methods.*
Consultant is not following that, outsiders can't do it	*We make them more confident and more efficient in their surgical work, but still, we have to give them some freedom.*	*I also think some people don't understand how to train juniors. So sometimes it's difficult to make sure everyone gets similar simulation training.*
Then step by step. So probably the best one to start off is the lap appendix minimum	*First, I don't allow them to do laparoscopic appendix because that is most of them being unsupervised*	
	Get to assist. Assist me then I teach them a lot of steps about the surgery	

Expert surgeons	Trainers	Trainees
present day trainees are doing much better than people who are above 5-10 years ago	what we have is a basic surgical skill which teaches some basic laparoscopic skill	My training began early in my training with basic skills courses, where we learned the fundamental techniques like camera navigation, tissue manipulation, and suturing
learning from mistakes		
opportunistic learning by assisting holding the camera		initial years focused on general surgery principles and basic procedures. Around my

		4th year, I developed a strong interest in minimally invasive techniques, particularly laparoscopic surgery
	when they go to the periphery they'll be more confident and they will have more skills gather more, you know, real hands on skills	certainly differences, but also many similarities (Sri Lanka vs Australia)
self-trained watching others watching online	structure development of their laparoscopic skills starting from and understanding of the mechanics of laparoscopy	I believe the core surgical principles and skills are universal.
	online modules which deal with different aspects of laparoscopic surgery	

Approach to laparoscopic training

	Expert surgeons	Trainers	Trainees
Pre-learning	*Problems of pneumoperitoneum the Physiology associated*	*Indications, contraindications, all that they know. So, there are articles related to that about particularly my time.*	*Problem based interactive sessions*
	Structure development of laparoscopic skills starting from and understanding of the mechanics of laparoscopy	*On their skill list, their ability to diagnose conditions that you see and interpret what you see*	

	One of the things is to start off is to get them to understand how the camera work		
	Structure development of their laparoscopic skills starting from and understanding of the mechanics of laparoscopy	*One of the things is to start off is to get them to understand how the camera work*	*Online modules which deal with different aspects of laparoscopic surgery*
Decision making	*Discuss the case and then we study the images and then we try to anticipate the difficulties, especially by studying the vascular anatomy of the kidney,*	*They have a very good clinical sense. That's one of the first thing. No longer safe to proceed. Couple of people they call only after they have damaged something irreversible*	
	Various tactics you can use to you know different same thing can be done in different ways,	*Lot of adhesions, large, distended gall bladder, that is difficult. Understand immediately and i want them to call for help*	
		That has evolved because I am more confident in my own laparoscopic skills	
		Ability to know when to bail out	

	Expert surgeons	*Trainers*	*Trainees*
Current situation	*Beatle, we got rather late, actually, to be honest with you, practise was straight away on patients*	*Basically, I think they get a lot of opportunities to practise to do the surgery.*	*Traditional emphasis on hands-on experience*

		First time when I did the that was actually on a patient	*In Sri Lanka, our training is quite hands-on from an early stage. We get significant operative experience, often out of necessity due to high patient volumes.*
	Practice was straight away on patients	*Most training still happens in operating room with real patients.*	
Problems	*In the long term, even if you convert many at the start, you will subsequently become a better laparoscopic surgeon later because you stopped at that right point, and it doesn't discourage you from doing laparoscopy*	*I have come across several cases where they don't call the consultant in time. By the time they call some of them, it's too late. There are couple of people that call only after they have damaged something irreversible*	
	I think it's very unfair for the patient because the first time I operated a live patient, and I think that shouldn't happen	*Learning from mistake*	
Solutions	*Close to major vessels we straight away we went for open surgery because our priority was to get the cancer clearance.*	*I would always be there for the procedure*	
	Doesn't matter even conversion	*Determination, patience and put (patient) safety first.*	
		Morbidity may improve (with simulation)	

	Expert surgeons	Trainers	Trainees
Supervision	*My performance goes down by about 30-40% at any point of time, if I know that I am being scrutinised.*	*I allow them to operate on their own, but I see how they call me (when they're in trouble). One of the key criteria that I use to assess their ability to judge themselves.*	*Training the trainers is essential*
	Some sort of training programme to train the trainer so that trainer will be can Competent in doing it confidently	*I don't believe that being there like a hawk can improve their training. Because I don't perform well when I'm being watched. We make them more confident and more efficient in their surgical work, but still we have to give them some freedom.*	*incorporating more structured mentorship programs would be beneficial.*
	availability of experienced mentors	*Giving them instructions here, but I don't scrub in*	
	Certainly, helps to have good backup and others who are capable of taking you through a difficult procedure.	*I'll be there with them throughout the procedure. Taking over when they go wrong is a good option*	
	Having good mentors, I think, is important. To discuss and call for help at any time, which I think important because they know that there is somebody who can bail them out.	*Thinking about it (SBST), not adequately. We should probably tell them, especially when we have the opportunity to do it. They need to do it more often.*	
		My motto is anyway from the beginning there are no bad trainees but only bad trainers	

Feedback	*I think the most important quality of a training is to self-reflect*	*Opportunistic feedback based on what we see then and then certain things that we see*	*I also think some people don't understand how to train juniors. So sometimes it's difficult to make sure everyone gets similar simulation training*
		I don't have a structured way of giving feedback	
		ensure that they know that we are there for them	
		easy to train them. Only thing I see is overconfidence in some	
		some people are more skilled than the others	
		not everyone is equally competent	

Expert surgeons	*Trainers*	*Trainees*
Early stages we had training on the basic principles, so that of course helped with learning during the practise	*Basic those are the things that they will learn during the basic laparoscopy programme plus a little bit of hands-on hands on, skills to experiment*	*Association of General Surgeons organised a very effective workshop*
Programme in India for about 10 days, it was a proper laparoscopic training programme where they we were training suturing and talks about the complex procedures	*So, I was actually a trainer, not a trainee. OK, but I got the chance to experience the training*	*What we have is a basic surgical skill which teaches some basic laparoscopic skill*
	In a course, you may be there. You may listen. You may not. It's time constraint. It's sometimes it's too quick and too quick to grasp	
Formal training but short period of time training		

	Expert surgeons	Trainers	Trainees

Deciding on competence	*Unfortunately, I think there are no benchmarks for how many cases do we have.*	*Once they assist about assist about 15 to 20 cases to me, I get them to do the surgery*	
	Benchmark is something we have to follow, but ours, the training programme is 2 years was actually too short	*Develop better and ensure that by before the end of the first year they have at least some degree of basic competencies*	
Assessing competence	*Then let's say this amount of surgeries you have to do has to be signed. So that is that structured*	*Pre board certification assessment. I think we should go through the whole thing and see whether they have had laparoscopic exposure in not*	
	Check whether they have participated in the course, and we give them a certificate of participation, but not a level of achievement not a not a certificate of achievement	*Then only you should say ok you have achieved this, go to the next level and then then there should be a next level training programme*	
	Certification I think to see that they have achieved a certain skill level even at the basic course	*Supposed to do a particular number of a particular type of operation during the training period and the competencies that they're supposed to be achieved during each of their milestones that could give both the training and the trainer a realistic expectation of what they want to achieve*	
		Which someone has to sign it. They achieve these objectives and targets. Once you achieve certain amount	

		of competency based on that training assessment probably we can go to a second person to to review his performance	
Allowing progression	*Some people can learn it faster than the others, so I don't think there's a huge difference*	*Depending on that I gradually give them more freedom*	
Remedial measures	*Extending the training programme would be quite useful especially when it comes to laparoscopy*	*The thing is that they might need some kind of extended training Programme. So, I think we should not be hesitating as trainers to say that "well, these two years were not enough for you. So, you have not actually achieve the targets and the benchmarks. So, I want to do another six months"*	
	training is at different levels. Learn different things. You think they can benefit from the same workshop.	While simulation can provide a controlled environment for skill development, hands-on experience is crucial for developing clinical judgment and decision-making abilities	

Expert surgeons	Trainers	Trainees
first thing is that all training centres are not equipped with the manpower and the skill	sometimes they (theatres) are closed in the afternoon. So I think if we can improve that would be we can improve the training	

<table>
<tr><th></th><th>Expert surgeons</th><th>Trainers</th><th>Trainees</th></tr>
<tr><td rowspan="3">Current situation</td><td rowspan="2">Beatle, we got rather late, actually, to be honest with you, practise was straight away on patients</td><td>Basically, I think they get a lot of opportunities to practise to do the surgery.</td><td>Traditional emphasis on hands-on experience</td></tr>
<tr><td>First time when I did the that was actually on a patient</td><td rowspan="2">In Sri Lanka, our training is quite hands-on from an early stage. We get significant operative experience, often out of necessity due to high patient volumes.</td></tr>
<tr><td>Practice was straight away on patients</td><td>Most training still happens in operating room with real patients.</td></tr>
<tr><td rowspan="2">Problems</td><td>In the long term, even if you convert many at the start, you will subsequently become a better laparoscopic surgeon later because you stopped at that right point, and it doesn't discourage you from doing laparoscopy</td><td>I have come across several cases where they don't call the consultant in time. By the time they call some of them, it's too late. There are couple of people that call only after they have damaged something irreversible</td><td></td></tr>
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</table>

	Doesn't matter even conversion	*Determination, patience and put (patient) safety first.*	
		Morbidity may improve (with simulation)	

Expert surgeons	*Trainers*	*Trainees*
Early stages we had training on the basic principles, so that of course helped with learning during the practise	*Basic those are the things that they will learn during the basic laparoscopy programme plus a little bit of hands-on hands on, skills to experiment*	*Association of General Surgeons organised a very effective workshop*
Programme in India for about 10 days, it was a proper laparoscopic training programme where they we were training suturing and talks about the complex procedures	*So, I was actually a trainer, not a trainee. OK, but I got the chance to experience the training*	*What we have is a basic surgical skill which teaches some basic laparoscopic skill*
	In a course, you may be there. You may listen. You may not. It's time constraint. It's sometimes it's too quick and too quick to grasp	
Formal training but short period of time training		

Expert surgeons	Trainers	Trainees
first thing is that all training centres are not equipped with the manpower and the skill	sometimes they (theaters) are closed in the afternoon. So I think if we can improve that would be we can improve the training	

Training outside Sri Lanka

	Expert surgeons	*Trainers*	*Trainees*
Role	*Most of my early laparoscopic exposure came during my overseas training*	*One of us have to go for training this kind of and I went for Singapore*	*Laparoscopy was both countries, robotic was only in Australia*
	Training in laparoscopic surgery in India, after that training programme, I came back and then I invited some of my Indian friends to come and help me to start the laparoscopic course		*In Singapore, they have more... High-tech simulators, including virtual reality... And robotic simulators.*
			Australian training system is more structured and offers a greater emphasis on simulation-based training
Problems	*Given a good training atmosphere but very competitive. They go to competitive centres. Yeah, the locals are fighting for the hands-on cases. That is a common problem. So that is also not standardized.*	*Opportunity for me to do a complete procedure was very minimal. because there were numerous trainees there who all got preference. I was there as a fellow.*	
		Foreign training we can't depend on that much really, because some people get into the nice places.	
Solutions	*Collaborate with international institutions to access their*	*There are so many centres close by like in India, Pakistan, they are more than*	*Maybe we can... Bring experts from countries like Singapore... To conduct workshops.*

	expertise and resources	*willing to take trainees.*	*2-year training position in the UK to further develop these skills*
	9.5.1.1 Pedagogy of surgical training		
	Expert surgeons	*Trainers*	*Trainees*
Regular practice	*Numbers certainly do matter if you have a lot your learning curve can be improved*	*Urethroplasty also has the steep learning curve. So that is one thing we did, rather mixing up and scheduling all laparoscopies every day. We kept one list so that way I could take them through.*	*We can practice specific scenarios repeatedly*
Individual variation	*Everyone exposed to the same environment wont be able to get the same skills, that's a fact of life, especially in surgery*	*You have to judge individually the Trainees abilities. Some people are just slow to catch up and they are suturing techniques are poor. Sometimes for them it took a longer period*	*Laparoscopy may have a longer the learning curve*
	My experience with these people that some people, of course were very slow to catch up and others were quite good. So there is there was no sort of real standardization now in training.	*They are different, others even, who had no experience or hands on experience at all. Some learn very quickly; some take little time. So I'm very careful about it.*	*Experts also seem to be better at identifying their own problems to correct, and to find small details to improve. Trainees often need to work on bigger, more obvious skills.*

	Some people can learn it faster than the others, so I don't think there's a huge difference	*There will be outliers who might not be achieving the same goals*	
Other factors	*Having better hand skills than what we were probably they picked up because of various other reasons*	*Now I have been doing more than 25 years is but even in the last workshop I learned a lot*	*There's also... A culture issue. Some people think... Only operating on real patients is "real" training.*

Self-evaluation

	Expert surgeons	*Trainers*	*Trainees*
Importance	*Evaluating progress can be challenging, especially in the beginning when improvements are incremental, but over time, you start to notice significant advancements in your skills.*	*If you take Doctor Palanivelu anyway. He's pretty much a self-made laparoscopic. He's a pioneer*	*After each real surgery, I reflect on what went well and what I need to work on*
	Largely self-taught		*I notice that ES are better at self-assessment.* *They can identify their own weaknesses more accurately*
Video review	*Make use of video recordings to self-assess.*		*I record my practice sometimes on my phone to review later and get feedback from my trainer, to see where I can improve.*

Adoption of DP in surgical training

Clinical demands

	Expert surgeons	Trainers	Trainees
Clinical demands	*The challenge, however, was balancing this practice with the demands of clinical work.*	*I don't know how we can adapt that to surgical training because of the clinical demands especially.*	*Another challenge is time constraints. Surgical trainees in Sri Lanka have heavy clinical workload, leaving little time for structured simulation practice.*
			Demanding clinical workload often leaves limited time for dedicated simulation training
How to learn	*Better appreciation about what I can handle and what the potential problems because of the experience I have gained and so I can see what a train either so that has evolved to the point we are now*	*Casualty I think is not controlled, and supervision is not that good*	*In Sri Lanka, our training is quite hands-on from an early stage. We get significant operative experience, often out of necessity due to high patient fs.*

Training opportunities

	Expert surgeons	*Trainers*	*Trainees*
Variation in exposure	*The rest of it pretty much dependent also on the number of cases. And this is something that we can't equate for*	*Case load exposure will be variable between hospitals, cities, unit*	*Opportunities they get me vary depending on the unit*
	In Sri Lanka, like in many other countries, the training in laparoscopic surgery has evolved significantly over the past decade. Initially, most of our training was heavily reliant on hands-on experience in the operating room.	*Impossible to establish a perfect system in clinical medicine and in clinical surgery: Equity of access, Case load*	*Another issue is the variability in training quality across different institutions. Some trainees have better access to resources and mentorship than others, which can create disparities in skill levels.*
	Procedures were done in Sri Lanka but we were not exposed.	*Most of the time these arises only for the first years. Second year senior registers in their second six months who are fairly independent* *Laparoscopy was making only about 20% of our workload*	*Depends on the surgeon they are working. It's some surgeons do more laparoscopy and whereas others may do very little so therefore, they may not get the necessary exposure or the training*
Trainer competence and attitudes	*Senior surgeons also not fully convinced of value of simulation, preferring traditional apprenticeship model.* *Reluctant to release us to go and attend training sessions.*	*I myself was in my early learning so the consequence of that was that the trainees also got less to do because I was in my learning curve*	*Cultural factors. In Sri Lanka, we often focus on theoretical knowledge rather than practical skills. We need to change our mindset to prioritize hands-on training.*

	Little by little, I think as medical students and as junior trainees, even as house officers and then later in their first year as their registrars, they learn about the basic things during registrar time	*I do not encourage them (junior trainees) to do it because eventually I do not know what they are going to do as surgeons*	
	I doubt whether there would be any inadequacy of training	*That certainly helps with understanding the basics of laparoscopy, because during the surgery itself, sometimes difficult to learn the basics, maybe the coupling effect, Etcetera. This basic those are the things that they will learn during the basic laparoscopy programme plus a little bit of hands-on hands on, skills to experiment*	
Structure	*I don't think we had any or very little I would say formal training during the training with the supervisors I have worked with. Maybe holding a camera and they get to dissect the gall bladder off the liver*	*The first few cases, generally I I assist them straight away so they assist me for first few cases in four to five.*	

Inherent problems with MIS

	Expert surgeons	Trainers	Trainees
Problems in visualization and	*Laparoscopic anatomy is slightly different*	*Dissection difficulties, anatomy and identifying anatomy, because of the additional fibrosis*	
	Not the amount of blood, but sometimes the blood is a nuisance		
Problems of motion	*One of the biggest challenges initially was adapting to the loss of depth perception and the need for hand-eye coordination in a 2D environment, which is quite different from open surgery. The lack of tactile feedback also made it difficult to judge the force applied to tissues.*	*In laparoscopic surgery, where hand-eye coordination and spatial awareness are critical, simulation allows us to refine these skills before stepping into the operating room.*	
		High degree of hand-eye coordination, spatial awareness, and precision	
	even a little additional fibrosis makes dissection difficult	*even a little bleeding, significantly affects your vision*	

Suggestions for improvement

	Expert surgeons	Trainers	Trainees
Curriculum design and implementation	*I think there should be a structured programme in our training*	*Better organised curriculum, at the moment it's very haphazard*	*Definitely adding structure is important*
	Important to have a structured programme	*More registrars should undergo a basic laparoscopic surgical skill course*	*PGIM can standardize the curriculum, it will ensure that all*

	Introduce a protocol, some kind of a training programme for each and every already person and with some benchmark figures you know to say that this many are we actually doing	*I think the importance of the training centre should be emphasised. The fact that unless you are not doing, not sticking to this laparoscopy programme. If your unit is not good enough or not giving the proper training for them to have either a personal referral system where the trainee should spend some time with some place where they could be done, it could be the regional centre or any other place.*	*trainees across country receive consistent training.*
Competence based learning	*Always there will be outliers who might not be achieving the same goals. So, if there's a guidance that probably will help.*	*Trainee should not leave the unit without being competent in doing a sort of a basic laparoscopic,*	
	Let's say you work for 10 hours that 10 hours should be marked in logbook. And then let's say this amount of surgeries you have to do has to be signed. So that is that structured	*(guidance on) the types of operations and the competencies that they're supposed to achieve during each of their milestones. That could give both the trainee and the trainer a realistic expectation of what they want to achieve.*	
Self-learning		*Wherever possible, do the background work. Read up and learn about the instruments, the stack, the technology*	*My advice would be to embrace the learning process. Laparoscopic surgery is challenging, but with persistence and the right approach, you can master it.*

Elective training	*That exposure to certain cases is less maybe they will during the appointment, you give them a week to come and work in some place so that few weeks that they get that additional exposure.*	*So, each one has different ways of doing things, and I think my way of doing it is correct, but if you know the perfect way of doing it, they get the chance to see different people performing*	*Get trained by many people, rather than seeing one person's way of doing things*
SBST		*If they can do regular simulations, so one session at least maybe once a week or so, they can come and work with beads or dissecting the skin of the chicken, whatever. So that will help them develop the hand coordination etc, that will improve the learning curve, probably shorten the learning curve*	

Current state of SBST

Expert surgeons	*Trainers*	*Trainees*
In Sri Lanka, we're making progress, but simulation isn't as ubiquitous.	*In Sri Lanka, while simulation is gaining popularity, its implementation is still in its early stages.*	*In the UK, simulation is deeply integrated into surgical training programs. They have dedicated simulation centres with a wide range of tools - from basic suturing models to advanced virtual reality laparoscopic simulators.*
It is essential. I considered it essential	*With advancements in technology, simulation-based training has become an integral part of our education.*	*When I first started, training was heavily reliant on observing senior surgeons and gradually assisting in procedures. However, over the years, there has been a significant shift towards incorporating simulation-based training.*
I believe future of surgical training, even in resource-limited settings, will involve more simulation and deliberate practice. Technology is making	*In future they should be taken through dry lab*	
	In a course, you may be there. You may listen. You may not. It's time constraint. It's sometimes it's too quick and too quick to grasp	

Role of simulation in surgical training

	Expert surgeons	*Trainers*	*Trainees*
Basic skills	*Will give you a feel of the instrument. It gives you some degree of hand eye coordination.*	*I think ideally if they can do a little bit of dry lab work where they get a little bit of hand eye coordination before you come into theatre*	*By the time you step into the OR, you're not only familiar with the instruments and procedures but also confident in your ability to handle unexpected situations*
	Little bit of hand eye coordination before you come into theatre	*if you have more simulated training that they can perform during their initial training period that that will help them with obtaining more hand skills*	*had to use simulation as new trainees to learn basic skills before working on patients*
Advanced skills	*These technologies have the potential to provide immersive experiences that more closely replicate the challenges of actual surgery.*		
Other	*During the surgery itself, sometimes difficult to learn the basic*	*Confidence is very important for a trainee.*	*It will also make it less stressful to be in theatre*
	Laparoscopy may have a longer the learning curve	*For junior trainees, definitely. Maybe simulation training and more opportunities*	

Intended outcomes

<table>
<tr><th></th><th>Expert surgeons</th><th>Trainers</th><th>Trainees</th></tr>
<tr><td rowspan="2">Learning outcomes</td><td rowspan="2">Your learning curve can be improved</td><td rowspan="2">First time in a theatre means it's a totally different ball game altogether. They pick up fast, that's true.
But if they have the opportunity to train and practise before they do better surgery</td><td>Better training with maybe suturing</td></tr>
<tr><td>Ability to practice on a virtual platform before operating on a real patient has significantly reduced the learning curve and improved my confidence.</td></tr>
<tr><td rowspan="4">Patient outcomes</td><td>Patient outcomes, morbidity, mortality can be improved</td><td rowspan="4">Recognizing the value simulation brings to skill development and patient safety.</td><td>It also allows us to make mistakes in a safe environment and learn from them without compromising patient safety</td></tr>
<tr><td rowspan="3">Leads to better outcomes, as surgeons are more skilled, confident, and capable of handling the complexities of laparoscopic surgery.</td><td>Reduces the risk to patients and helps trainees build confidence and competence.</td></tr>
<tr><td>Ensure that trainees have a strong foundation before they perform procedures on actual patients.</td></tr>
</table>

			When mentoring junior trainees, I emphasize the importance of these training methods.
	Expert surgeons, on the other hand, seem to engage in more nuanced deliberate practice.		Trainees, myself included, tend to concentrate on mastering fundamental

	They're often pushing the boundaries of their specialty		techniques and building a broad base of skills.

Infrastructure

Expert surgeons	*Trainers*	*Trainees*
Some larger teaching hospitals have started to incorporate basic simulation tools, like laparoscopic box trainers. However, access is limited and it's not yet a formal part of most training curricula	*We have simulators in the unit. We have simulators in the theatre. We don't get them to train.*	*Advanced simulators are expensive, and there are no places in Sri Lanka that can afford to have them. So we're stuck with low tech box simulators*
Simulation is not very common in Sri Lanka, unfortunately. We have some basic simulators in our medical school, but they are not very advanced	*Availability of well-equipped simulation centres is limited, restricting opportunities for regular practice*	*We as trainees should advocate for better simulation resources in our countries. We can share research... About its benefits and push for... Changes in our training programs. If we show initiative... Maybe we can help bring positive changes.*
Another limitation is the gap between simulation and actual surgery. No matter how advanced a simulator is, it cannot fully replicate the nuances and pressures of a real surgical procedure.	*The main barrier is lack of resources. We don't have enough simulators for all trainees. And the simulators we have are often outdated.*	*Opportunities for advanced surgical techniques, especially minimally invasive surgery like laparoscopy and robotics, are limited*

In Sri Lanka, we mostly use... Box trainers for laparoscopic skills.	*We can expect more sophisticated and realistic simulation models. Virtual reality and augmented reality can provide immersive training experiences*	*Biggest contrast was probably in the availability of resources and advanced technologies. In the UK, I had access to state-of-the-art laparoscopic equipment and simulation facilities*
Box trainers are physical models that mimic the abdominal cavity. Trainees can practice basic skills like suturing, cutting, and manipulating instruments in a 3D space.	*Have a little beetle wherever they can easily have access to, and should practise*	*In Sri Lanka, simulation is... Not used as much as in Singapore. We have some basic... Laparoscopic simulators, but not many*
	Limited resources	*We don't have many opportunities to practice complex procedures*

Access to simulators

Expert surgeons	*Trainers*	*Trainees*
Not at home, but some convenient place. When there are free times, they should be able to play with that.	*(need to be) easily accessible*	*In Sri Lanka, we use simulation but not as much as some other countries. We have basic models for practicing suturing and some laparoscopic simulators. But advanced simulators are limited*
simulation more accessible and affordable.	*We could establish partnerships between institutions to share*	*The main barrier is lack of resources. We don't have enough*

	resources and expertise. Perhaps create regional simulation centres	*simulators for all trainees. And the simulators we have are often outdated. There's also a lack of dedicated time for simulation. Our schedules are very busy... With clinical duties.*
	First and foremost is the issue of resources. High-fidelity simulation equipment is expensive, and many institutions simply can't afford it. Even maintaining basic simulation tools can be challenging given budget constraints.	*Availability of well-equipped simulation centres is limited, restricting opportunities for regular practice*
	I've had to be more creative. I've set up a basic laparoscopic box trainer at home	*I try to make most of limited resources we have*

Content and delivery

	Expert surgeons	Trainers	Trainees
	Pyeloplasty was again a bit of a hurdle because it needed a lot of training in lab suturing. What happened was that we practiced suturing on the lap trainer. It's still available in our department and knotting and things like that	*So we have a beetle. So I asked him to work at least 10 hours before they start practicing on a patient.*	*My training began with basic skills development, such as knot-tying and suturing, which I practiced using simulators and box trainers.*
	Dry lab training. I think it's useful I am not a big fan of wet lab training on, for instance, live animals. I'm not very sure whether it is actually necessary one in our context when we have the opportunity to do it (in patients)	*I think definitely the dry lab training. I will go for dry lab training and then I would introduce to operating*	*Practicing in the Beatle,*
Basic training		*I always tell them to go and train dry lab trainer*	
Advanced training	*VR simulators often come with feedback systems that can assess a trainee's performance in real-time, providing metrics on precision, speed, and even the economy of movement.*	*Traction counter traction you get haptic feedback.*	

	In Sri Lanka, while simulation is gaining popularity, its implementation is still in its early stages. The availability of simulation facilities and the integration of simulation into the training curriculum are areas that need improvement.	*More Hands-on workshop, particularly using animal model Same operation that we do on human, and there is bleeding*	
Remedial training		*If I feel that his dexterity and his hand eye coordination is not good, probably I would take over and ask and go back to Beatle and practise some more and come back*	

Attitudes

	Expert surgeons	*Trainers*	*Trainees*
About trainees	*I don't think it will take anybody more than six months to get trained in robotics (when required).* *Our training should be robotic training compatible*	*Don't punish them or we don't reprimand them for making mistakes, but we ensure that they know that we are there for them*	
About trainers	*To be a laparoscopic trainer, there should be some amount of accreditation*	*Education is crucial - not just for trainees, but for senior surgeons and hospital administrators*	*Of all the trainers I've worked with, I don't think all of them have been taught how to train. There is a shortage of people trained in simulation-based education.*

			While simulation is valuable, the guidance and feedback from experienced surgeons are irreplaceable. Establishing more structured mentorship programs could help bridge the gap between simulation and real-life surgery.
About SBST	*Lack of standardization and formal integration of simulation into our training curricula.*	*Another issue is the variability in training quality across different institutions.* *Some trainees have better access to resources and mentorship than others, which can create disparities in skill levels.*	*Access to simulators and trainers is limited. We don't have many experienced trainers who can teach us how to use simulators effectively. Second, funding is a problem* *Some senior surgeons may not fully appreciate the value of simulation, seeing it as a distraction from clinical duties.*

Limitations affecting broader SBST use

	Expert surgeons	*Trainers*	*Trainees*
Curriculum	*Lack a standardized curriculum for simulation and deliberate practice*	*Case load exposure will be variable between hospitals, cities, units. But if you have that basic structure then I think it will help*	

	The availability of simulation facilities and the integration of simulation into the training curriculum are areas that need improvement.	*We don't make it compulsory that is the reason, I think. When they get an opportunity where we tell them, but I think we're not enforcing it enough.*	
Cultural factors	*Cultural factors. In Sri Lanka, we often focus on theoretical knowledge rather than practical skills. We need to change our mindset to prioritize hands-on training.*	*There's also a cultural aspect to consider. While this is changing, there's still sometimes a perception that "real" learning happens only in the operating room.*	
Time		*There's also a lack of dedicated time for simulation. Schedules are very busy with clinical duties.*	*Another major hurdle is time. Our healthcare system in Sri Lanka faces immense patient volumes.*
			Surgeons and trainees are often stretched thin, making it difficult to allocate dedicated time for simulation and deliberate practice.

Improving SBST

	Expert surgeons	*Trainers*	*Trainees*
Structure	*We could explore online learning platforms and virtual coaching*	*Online modules which deal with different aspects of laparoscopic surgery*	
	Certainly, helps with understanding the basics of laparoscopy, because during the surgery itself, sometimes difficult to learn the basics	*Certain amount of time in a model or in a dummy and get basic competence, and then gradually under supervision*	*We (in SL) mostly use them for simple skills training, like suturing and knot-tying*
	Maybe suturing at a second stage and then advance the work at a third stage so that gradual progression in training	*Definitely adding structure is important*	*Better training with maybe suturing, Beads and they play with the instruments and the camera. That's the first step*
	Trainees of all stages. Same workshop when you sit there, of course, because your perception of that particular problem is different depending on your experience	*Should be done in three or four stages, one is at the most junior stage where you watch others do it. Secondly, when they started doing their first few hands on, then only they get an insight into what actually they are talking about. Then they should participate. And thirdly, when they are little confident and doing it, then again, they must go and see and discuss that each and every point*	

Integration	*Programme should include stepwise, you know Some sort of a target, so I would have introduced that I should have introduced that and so then in that case there will be some sort of standardisation of the training programme*	*But if you have that basic structure then I think it will help with each trainer to take them through*	*Integrate simulation more formally into training curriculum.*
	Lack of standardization and formal integration of simulation into our training curricula.	*Availability of simulation facilities and the integration of simulation into the training curriculum*	*In Singapore, simulation is an integral part of surgical training. There are dedicated simulation centres equipped with state-of-the-art technology, and trainees are encouraged to use them regularly*
	Integrating simulation into formal curricula is essential.	*Lack of standardized simulation curricula means that the quality and content of training can vary significantly between institutions.*	*Trainees are encouraged to use them regularly (Australia)*
	Developing standardized curricula that integrate deliberate practice can ensure a structured and effective training approach	*incorporating simulation training into the clinical curriculum, such as during off-duty hours or elective periods*	*Some larger teaching hospitals have started to incorporate basic simulation tools, like laparoscopic box trainers. However, access is limited and it's not yet a formal part of most training curricula*

			Yes, and we could align the simulation exercises with what we're learning clinically. For example, if we're doing a rotation in colorectal surgery we could focus on simulations of laparoscopic colon resections. This would make it more relevant and engaging.

Expert surgeons	*Trainers*	*Trainees*
There should be some Certification. Then only you should say OK you have achieved this, Go to the next level and then then there should be a next level training programme	*Looking to see how many procedures a trainee does, what procedures they do and the morbidity and mortality,*	*I think we should make it a formal requirement. Maybe trainees could have a logbook of simulation hours. Just like we do for real surgeries.*
	Recognizing and rewarding trainees for their participation in simulation-based training	*We could also have regular assessments on simulators to track our progress*

Orchestration

	Expert surgeons	*Trainers*	*Trainees*

Increasing opportunities	*Simulation training and more opportunities*	*Should have at least one central place (for simulation), one proper high End training centre, rather than every university or every hospital trying to have their own training centres*	*For resource limitations, we could explore more affordable simulation options. A surgeon had made a low-cost box trainer with a plastic box and a webcam*
Increasing opportunities	*We need to focus on cost-effective simulation solutions*	*Do regular simulations, so one session at least maybe once a week; will improve the learning curve*	*For those who are interested, there should be free access to Simulators*
Increasing opportunities	*I think expanding access to high-quality simulation tools is crucial. We should also invest in creating standardized training programs that ensure all trainees receive the same level of education, regardless of where they are based.*	*Significant investment in simulation centres and equipment is crucial to provide adequate training facilities.*	*Collaboration between hospitals and societies to share resources* *Dedicating a mandatory amount of time each week for deliberate practice session*
Content	*While high-fidelity simulators are great, a lot can be achieved with more basic tools. We could develop low-cost, locally produced simulation models. For laparoscopic training, simple box trainers can be incredibly effective.*	*Maybe dissecting a cadaver or, you know, pig gall bladder. So they develop basic skills in relation handling of instruments*	

Supervision	*We should... Train more faculty in simulation-based education*		*I think remote training will become more prominent, allowing trainees from different parts of the country—or even the world—to access high-quality education without the need to relocate.*
	While simulation can provide a controlled environment for skill development, hands-on experience is crucial for developing clinical judgment and decision-making abilities.		*While simulation is valuable, the guidance and feedback from experienced surgeons are irreplaceable. Establishing more structured mentorship programs could help bridge the gap between simulation and real-life surgery.*

Understanding of DP

	Expert surgeons	*Trainers*	*Trainees*
Una war		*I don't know what that is*	
Incor rect			*deliberate practice was more structured and formal part of training program.*
Superficial understanding	*focused practice and skill development*	*Both experts and trainees recognize the importance of continuous improvement and lifelong learning, usually through structured learning. However, the focus and methods often differ.*	*It made me be more proactive in my own learning and training, by structuring my training*
Deep understanding	*very focused on specific skills you want to improve. You have a clear plan, and practice deliberately to achieve their goals*		*don't neglect mental practice. Visualize procedures in detail when you can't access physical simulators. This can be surprisingly effective*

			Deliberate practice is very important for surgical training. It means focusing on specific skills, getting feedback, and improving step by step. *In simulation, we can practice difficult procedures many times without risk to patients.*
			idea is to push the boundaries of your current abilities, work on your weaknesses, and gradually expand your skill set.
			My advice is to be patient and persistent. Deliberate practice is a long-term investment, but it pays off in the end
			As trainees, we often practice broader skills. But the principle is same focused repetition and feedback.

Mental representation

Expert surgeons	*Trainers*	*Trainees*
Watching how different experts performs surgeries	*Experts also seem to be better at identifying their own problems to correct, and to find small details to improve. Trainees often need to work on bigger, more obvious skills.*	*I also believe in the power of mental rehearsal*
	Deeper understanding of surgical principles and can apply them more effectively during practice	*This mental practice has been shown to enhance performance and confidence.*

Motivation

Expert surgeons	*Trainers*	*Trainees*
Focus more on refining very specific techniques and might spend hours perfecting a single movement	*Addressing cultural barriers: Promoting the benefits of deliberate practice through educational initiatives and workshops can help dispel misconceptions like not spending too much time on simulation training*	*First, you have to be interested in your learning. Don't wait for perfect conditions or resources.* *Use whatever you have and be creative. Even simple tools can be effective.*
	when they get an opportunity where we tell them, but I think we're not enforcing it enough.	*I make a schedule to practice regularly, even if it's just for short periods - F*
	determination, patience and put (patient) safety first.	*I focus on my weakest skills and try to improve them gradually.*
		Don't wait for perfect conditions. Even if you don't have high-tech simulators. You

		can still apply the principles. Set specific goals. Practice regularly and seek feedback.
		Don’t rush the learning process—focus on building a strong foundation.

Task design

Overall task design

Expert surgeons	*trainers*	*trainees*
set specific goals for each practice session. don't just practice aimlessly. know what you want to improve and how you can know if you’re progressing.	*maybe suturing at a second stage and then advance the work at a third stage so that gradual progression in training*	*trainees had regular, scheduled simulation sessions.*
there was immediate feedback.	*programme should include stepwise, you know some sort of a target, so I would have introduced that I should have introduced that and so then in that case there will be some sort of standardisation of the training programme*	*identify areas for improvement, and tailor the training to their specific needs*
		for example, I practiced suturing, knot tying, and instrument manipulation separately.
		the objectives of the training were clearly informed at the beginning.

Stepwise approach

	Expert surgeons	*Trainers*	*Trainees*
Task allocation	*Lot of it probably has to be done in a stepwise manner*	*Supervised graded exposure* *Lot of it probably has to be done in a stepwise manner*	*Stepwise progression but under supervision*
		I am completely hands off following their initial training, so they get their training in a very graded way.	*I would have held the camera,* *Help with some ports, but nothing more than that*
		They assisted me first. Then I generally judge the trainees	*Placing ports holding the camera would be the primary thing that a senior registrar would do*
Selecting case difficulty	*We started with very simple cases like large Renal cyst, decortication. Later on it was simple Nephrectomy. It was the next thing simple nephrectomy before pathological kidneys thereafter, because it was kind of a self-training.* *Radical nephrectomy, and thereafter, pyeloplasty, and then ureteric work.* *Next step was to get into the pelvic surgeries and actually we started doing radical prostatectomies.*	*When I'm quite confident in (them) doing cholecystectomy and appendectomy, when they were with me for some time, I introduce them to do colorectal work*	*I moved on to more complex tasks, like handling tissue and performing specific procedures like cholecystectomy or appendectomy.*

Steps within the surgery	So, step wise each case they moved on and the most difficult part was the pedical control. So that was the last step	Small amount of exposure in terms of dissection (as juniors). We do the proper training when they become senior registrars. I gradually I do the crucial parts like, you know, identifying the Calots triangle. The easy ones I get them to dissect the gall bladder. Teach them the various clipping and then how things can go wrong and things like that	I'd focus on specific skills, gradually increasing difficulty and complexity.
	Stopped at that right point and it doesn't discourage you from doing laparoscopic		
	To learn laparoscopic skills and obviously one is safety and doing it to bail out		
	Convert it at the earliest sign of, you know non progression	When you're taking them stepwise. Of course, it's I find that it's much easier because they finish one step and then like colonic reflection, and then move on	

Feedback

Expert surgeons	Trainers	Trainees
Promote culture of continuous improvement and normalize seeking feedback. Perhaps having respected senior surgeons would help.	I am completely hands off following their initial training, so they get their training in a very graded way.	In our culture, there is sometimes resistance to admitting areas for improvement or seeking feedback, because people think that indicates you are not good
Actively seek feedback from experienced surgeons and mentors	We very openly discuss, and registrars who are little backward and sort of bit reluctant to	Experienced surgeons can provide invaluable guidance and feedback

	talk naturally start talking very early	
Feedback is crucial in this process. Whether it's from a mentor, a peer, or the simulation software itself		*We need guidance from our seniors to help us focus our practice.*
Seek feedback constantly and be open to constructive criticism. It's through feedback and deliberate practice that you'll truly grow as a surgeon.		*Another problem is the lack of trained faculty to guide us. Many senior surgeons didn't train with simulators themselves. So, they don't always see the value or know how to integrate it into our training*

Timing of feedback

Expert surgeons	*Trainers*	*Trainees*
Assistant was at least someone who could communicate and express their opinion freely during the process	*Then at the end of the procedure.* *It's all completed in theatre verbally* *We sit and discuss why it took long time, why was it difficult*	*If the consultant was in theatre, I ask them as well.*
	We talk all the time feedback during the procedure as well as immediately after during, you know having a little chat in the side	
	I don't have a structured way of giving feedback *That type of post scenario discussion is there all the time and one thing in my theatre we talk all the time*	
So correction on then and there real time correction and then later on also I think we discussed specially we have to convert or this there's non progression in that we discuss why exactly that happened	*Two ways when they are operating, assisting during particular operation. One thing real time feedback as and when they are doing certain things. I might tell them, OK, this is not the way, or this is a better way of applying traction when you're operating.*	
	Real time feedback as it goes on you discuss it after the procedure or it's just in the theatre while it happens	
	I do is it's then and there most of the time you know if they are dissection is crude and they are, But I feel that they are getting lost there.	
	When I'm assisting, I tell them I just show them exactly what	

Content

Expert surgeons	*Trainers*	*Trainees*

Key is to get feedback, either from a mentor, peer, or even through video review of my simulations, and then use that feedback to guide my practice	*Discussions on the steps of a particular operation*	*Seek feedback whenever possible. Ask seniors to observe your technique and provide constructive criticism.*
Analysed the results post operative complications and things	*Thinking carefully about each step, getting feedback, and always trying to improve little by little.*	*I also ask senior surgeons... For feedback on my technique*
Virtual reality simulators they give you right down movement, left arm movement, unnecessary movement and then he takes the requirement out of supervision	*The way you come in or way you comment has to be acceptable to them. The moment. It is not that they don't take the opportunity. Take that chance to come back to us or ask us for any advice*	*Artificial intelligence could provide more personalized feedback. It could analyse our movements and suggest improvements.*
I actively seek feedback from my seniors and reflect on each case, identifying areas for improvement.	*They ask questions from me and then it is a kind of a practical feedback*	*Feedback is critical. I often ask attending surgeons for their input after a case, and I review my performance in simulations as well*
	Specific formats or sets or anything? Nothing objective	
	I do DOPS for them	
	No scientifically proven feedback method that I use	
	They get the feedback automatic feedback	

Repetition

Expert surgeons	Trainers	Trainees
	I asked him to go back to the beetle and practice at least 2 hours before they start suturing during surgery	We need lot of repetition to build foundation skills, as we're just starting.

Expert surgeons	Trainers	Trainees
		learn from experienced surgeons by observing their techniques, asking questions

Video analysis

Expert surgeons	*Trainers*	*Trainees*
Have watched a sufficient or large number of videos. There are fair amount of them available	*Some of them used YouTube and YouTube videos very widely*	*Anatomy and also the different views*
Free videos online because they understand the different problems people may encounter during surgery and different way people dissect, so they're a lot a lot, especially for senior training, which they can learn by watching videos	*One person, I think, published a paper also on that YouTube assistance*	*Video analysis to identify areas where I could improve my dexterity and efficiency*
. I always first would advise them to go through all YouTube videos	*Images, videos, illustrations and certain expert comments*	*Surgeons in Australia routinely record their surgeries and watch them later.*

		Video analysis to identify areas where I could improve my dexterity and efficiency.
Key is to get feedback, either from a mentor, peer, or even through video review of my simulations, and then use that feedback to guide my practice		*We also receive feedback from our supervisors or through video review, which helps us identify areas for improvement.*
		I record my practice sometimes on my phone to review later and get feedback from my trainer, to see where I can improve.
I practice regularly, recording my sessions for self-review.		*Video record your practices to watch later and correct yourself.*

Expert surgeons	*Trainers*	*Trainees*
I don't know how we can adapt that (DP) to surgical training	*Standardized curriculum that incorporates deliberate practice is essential to ensure consistency and effectiveness.*	*I believe future of surgical training, even in resource-limited settings, will involve more simulation and deliberate practice. Technology is making simulation more accessible and affordable.*
With more deliberate practice and simulation, trainees could have better skills before operating on real patients. This would	*Developing standardized curricula that integrate deliberate practice can ensure a structured and effective training approach*	*AI-powered simulation platforms can provide personalized feedback and adaptive learning experience*

improve patient safety		
	Allows trainees to practice dealing with difficult cases and complications without risking patients. They can then perform better in real emergencies.	

Expert surgeons	*Trainers*	*Trainees*
Need to foster a culture of deliberate practice beyond just simulation. Encouraging reflective practice, structured feedback, and continuous improvement in all aspects of surgical training can lay the groundwork for more formal simulation-based training.	*Addressing cultural barriers: Promoting the benefits of deliberate practice through educational initiatives and workshops can help dispel misconceptions*	*We also need to create protected time for simulation in our training programs.*
My advice would be to embrace simulation and deliberate practice early on. Don't be discouraged by the initial difficulties—everyone struggles with the transition to laparoscopic surgery at first. Focus on developing your basic skills and take full advantage of the simulation resources available to you.		*Develop a culture of deliberate practice in our medical schools, encouraging students and trainees to focus on practical skills training.*

Also, seek feedback regularly and use it to guide your practice. Remember that proficiency comes with time, repetition, and a commitment to continuous improvement		