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Review Article

Simulation in paediatric urology and surgery. Part 1: An overview of educational theory

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Summary
Surgical training has changed radically in the last few decades. The traditional Halstedian model of time-bound apprenticeship has been replaced with competency-based training. Advanced understanding of mastery learning principles has vastly altered educational methodology in surgical training, in terms of instructional design, delivery of educational content, assessment of learning, and programmatic evaluation. As part of this educational revolution, fundamentals of simulation-based education have been adopted into all levels and aspects of surgical training, requiring an understanding of concepts of fidelity and realism and the impact they have on learning. There are many educational principles and theories that can help clinical teachers understand the way that their trainees learn. In the acquisition of surgical expertise, concepts of mastery learning, deliberate practice, and experiential learning are particularly important. Furthermore, surgical teachers need to understand the principles of effective feedback, which is essential to all forms of skills learning. This article, the first of two papers, presents an overview of relevant learning theory for the busy paediatric surgeon and urologist. Seeking to introduce the concepts underpinning current changes in surgical education and training, providing practical tips to optimise teaching endeavours.

Introduction

Healthcare education has evolved rapidly in the past two decades, with changes especially evident in surgical training. Implementation of government initiatives (such as Modernising Medical Careers and the European Working Time Directive), reduction in working hours, and increased awareness of patient safety has led to fewer opportunities to acquire surgical technical skills in the operating room environment [1–3]. There has also been a shift from the traditional Halstedian model of time-bound apprenticeship to one of competency-based training [4]. The Halstedian model achieved surgical expertise as a byproduct of clinical service, involving opportunistic learning from many hours in the clinical environment with the patient as the principal learning resource. While direct experience of a clinical event does result in effective learning, use of simulation as a tool for deliberate practice has been demonstrated to be more effective than traditional teaching and safer for the patient [5]. Simulation-based methodology is now an integral part of training in various surgical subspecialties, especially for technical skills learning. The evidence base for surgical skills simulation is growing [6]; however, there is a lack of standardisation of methodology in the majority of these studies [7,8].

It is important to recognise that the role of simulation in surgical education is broader than technical skill acquisition. Many adverse incidents in surgical practice arise from failure in non-technical domains such as communication, teamwork, or situational awareness rather than technical expertise [9–11]. Simulation can be employed to promote the learning, practice, refinement, and assessment of both technical and non-technical skills in a patient-safe environment. In addition to allowing learners to make mistakes without adverse patient impact, simulation also allows for specific rehearsal of rare or unique situations.

The aim of this review is to provide an overview of essential theoretical principles that underpin contemporary medical education and to promote the practical application of these theories to paediatric urological practice.

Key educational concepts relevant to surgical education

Mastery learning

The concept of mastery learning is intuitively applicable to competency-based surgical

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training [12]. First described in the 1970s, the principles of mastery learning share foundations with a traditional apprenticeship. In mastery learning, a complex task is divided into individual steps which the learner must become competent to perform before proceeding to learn the next step [13]. This progressive achievement and demonstration of competent performance forms the basis of a competency-based surgical training programme, into which simulation-based learning can easily be implemented. Individual tasks, may be performed and assessed in simulated environment prior to patient contact. Operations of lesser complexity, such as herniotomy, circumcision, or orchidopexy, can be mastered before attempting those of greater complexity, such as pyeloplasty. While this scaffolding exists informally in apprenticeship models, decreasing work hours and trainee caseload demands greater structure and efficiency of skills learning. Simulation can provide opportunities for practice when they do not exist clinically. There are many mastery domains in surgical practice: clinical, procedural, patient interaction, operative decision-making, teamwork, collaboration, and professionalism.

Mastery learning acknowledges that individual learners progress at differing pace in differing tasks, with the endpoint being reliable achievement of benchmark performance rather than time. The mastery learning model also does not finish when a surgeon becomes competent. Maintenance of optimal surgical skills through practice, reflection, innovation, and successful adoption of new techniques can also be viewed through this framework.

The key characteristics of a mastery learning model in simulation education programme have been summarised by McGaghie et al. [6,14], recognising the important of relevant learning objectives specific to context of specialty and learner level, (see Table 1).

Practical tips

1. Construct learning opportunities to allow the surgical trainee to discover their level of ability, and then achieve mastery through focused effort.
2. Subdivide procedures into individual steps which a trainee needs to learn progressively to achieve overall mastery.
3. Use simulated activities for early learning, requiring demonstration of competent performance in a simulated environment (such as bench trainer) prior to patient contact.

Deliberate practice

Deliberate practice is another key educational concept applicable to surgical training. Long recognised as a characteristic behaviour of elite performers in other domains [15], deliberate practice describes planned, purposeful repetition of aspects of a task to improve an individual's performance beyond its current level [16]. Deliberate practice requires several elements to uniformly improve performance [17]; including well-defined goals, motivation to improve, provision of feedback, and opportunity for repetition resulting in gradual refinements of performance [16]. Principles of deliberate practice are closely aligned to mastery learning and both can be applied to task components in pursuit of mastery. Applied to simulation-based learning, deliberate practice has been consistently shown to produce superior learning than traditional medical education in achieving clinical competence [5]. Common examples of deliberate practice in paediatric urology include hand-tying of a fine suture with the correct tension, or an intracorporeal suture tying.

Practical tips

1. Learner's current ability should be assessed, by observation in clinical or simulation setting prior to determination of focus for practice.
2. Activities should involve repetitious tasks for continuous improvement.
3. Feedback should be provided at each stage to enhance efficiency of learning.

The relevance of each step can be reinforced by applying the skill learnt to different operations or clinical encounters.

Experiential learning

Experiential learning involves learning through direct encounter. Kolb [19] described this as a learning cycle composed of four phases of experience, reflection, conceptualisation and experimentation; summarised in Fig. 1. The provision of feedback is essential for the reflective phase of the cycle, helping to shape cognitive modification of performance (abstract conceptualisation) before applying this to practice. In the experiential learning theory, the learner needs to actively engage with the environment; whether this

Table 1 Key characteristics of a mastery learning model for simulation-based medical education [6,14].

Key characteristics of a mastery learning model
1. Use of an assessment with an established minimum passing standard
2. Definition of learning objectives aligned with the passing standard
3. Baseline assessment
4. Instruction that targets learning objectives
5. Reassessment after instruction
6. Progression to the next unit only after achievement of the passing standard
7. Continued practice if the minimum passing standard was not achieved
8. Learners $\geq$18 years old

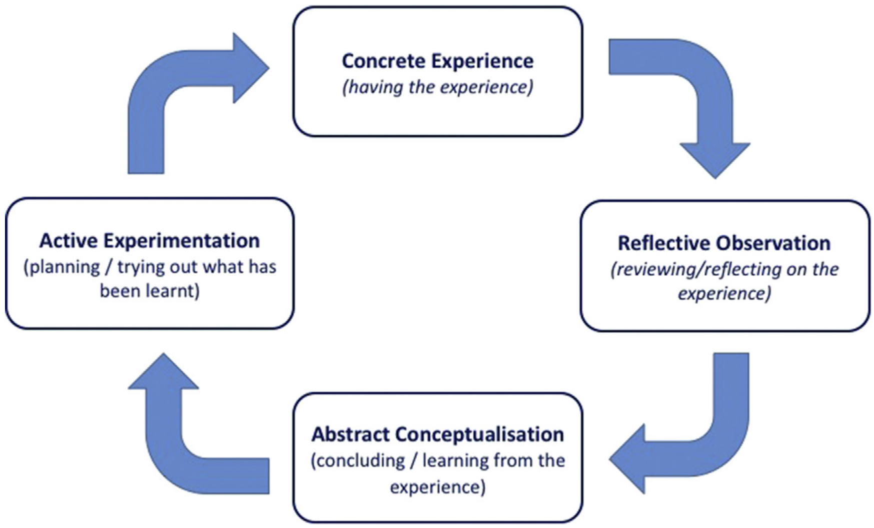

Figure 1 Kolb's learning cycle [19].

is the operating room, outpatient clinic or emergency department. The supervisor then offers their observations in feedback to aid the learning cycle and promote further development. This theory applies to all aspects of paediatric urological practice. Examples would include communication skills with parents, obtaining informed consent, conducting a ward round effectively or an actual operative procedure.

Practical tips

1. The surgical educator should be aware of the cycle of experiential learning; proving opportunity, promoting reflection and contributing feedback.
2. Trainees should be encouraged to reflect on their own performance and conceptualise modifications before repeating the experience to actively test the refinements. Feedback should link changes in observed performance back to the previous experience.
3. Recognise the vital role of "reflection on performance" before repeating a task in improving both performance and efficiency of learning.

Feedback

Feedback is defined as information that is communicated to a learner intended to modify behaviour and enhance learning [18]. Not only is feedback essential for learning [19–21], it has been shown to be the most important factor in skill development [22]. In surgical training, structured feedback from an expert trainer focused on the performance of a task has been shown to reduce operative time, improve economy of movement, instrument smoothness and error scores in intraoperative surgical performance [23]. In practice, however, the majority of feedback provided to surgical trainees is unstructured and informal, or based on knowledge required for a task rather than actual performance [22].

Most contemporary training programmes now embed work-based assessments throughout training, providing structure for feedback on performance. These include many forms including the Mini-Clinical Evaluation Exercise (mini-CEX), Direct Observation of Procedural Skills (DOPS), Case-Based Discussions (CBDs) and also Procedure-based Assessments (PBAs) [24,25].

Feedback can also be structured using one of several simple frameworks. The most common of these is Pendleton's model [26], involving four steps: (a) the learner describes what they think went well in the activity; (b) the supervisor adds their observations of the positive aspects of performance and reinforces those already identified by the learner; (c) the learner describes what could be improved next time and how this might be achieved; (d) the supervisor adds recommendations for improvement and helps learner identify learning opportunities.

Although Pendleton's model is an established method for structuring feedback, many educators find it formulaic. Discussing areas for improvement late in the process can prolong learner anxiety or reduce focus on this vital purpose of feedback [27].

An alternative framework, termed the "Plus/Delta" ($+/\Delta$) feedback model, is popular in clinical simulation [28] and operative feedback. The "Plus" step focuses on things that went well and "Delta" identifies those aspects that need to change, as well as ways to achieve change. It can be a very time-efficient process, suited to deliberate practice within mastery learning. There are many other feedback models that may be used, and often an individual surgical trainer will find one that resonates with them.

Feedback is best provided as close to a learning experience as possible; however, it should be delayed in high-tension environments, until both supervisor and learner are in more appropriate mental state. It should be conducted in a neutral setting, away from peers and patients, with sufficient time and minimal chance of interruption. The time that is devoted to giving feedback is dependent on the individual learner, the points that need to be discussed and the current educational relationship.

Practical tips

1. Feedback is vital to learning.

2. Use a structure to provide feedback: framework or work-based assessment form.
3. Feedback needs to be specific and constructive: identifying areas of performance that could be improved and ways to achieve this.
4. Feedback should be ongoing, supporting improvement in technical and non-technical performance throughout a training term.

Fidelity and realism in simulation-based medical education

The terms fidelity and realism are used interchangeably in the simulation-based medical education (SBME) literature, there is no consensus as to their actual definition [7]. "High-fidelity" is often presumed to apply to technologically advanced simulation modalities, describing how close to reality a simulator is in physical or visual appearance. This belief has been challenged by the works of both Dieckmann et al. [29] and expanded by Rudolph et al. [30], who conceptualise fidelity as having three distinct aspects; physical, conceptual, and experiential/emotional.

The physical fidelity describes the simulation activity itself in terms of how it moves, feels, and interacts with the learner. It is also related to the environment itself, which is often important in learner engagement into the educational experience. There has been a historical bias within the surgical educational fields for the exact replication of tissue and anatomical structure for educational processes rather than the other aspects of fidelity. Although in the early surgical training years a knowledge of anatomy may be centred on this aspect of fidelity alone. Technological advancements in additive manufacturing are making astounding progress towards making high-fidelity anatomic replicas more widely accessible to learners [31].

The conceptual fidelity relates to the actual events occurring in the simulation activity and whether the actions that occur are linked in a manner in which is believable for the learner [29]. This facilitates engagement of the learner into the activity or "buy-in" to the exercise. An example of this would be the use of a mannequin whose blood pressure drops if there is uncontrolled haemorrhage. If conceptual fidelity is not present in a simulation activity, realism is dissipated and hence learner engagement is lost.

The experiential and emotional fidelity is related to overall learner response to the simulation activity [29]. This response includes the emotions and also the cognitive states of the learners before, during and after the activity. This can be a powerful educational tool for the simulation experience but needs to be managed sensitively in a debriefing session.

The realism of a simulation activity is how close the overall activity is to clinical reality. This therefore includes all of the aspects of fidelity and the fiction contract, which then leads to an overall engagement of the learner. This relationship is demonstrated in Fig. 2 [32]. The fiction contract is an acknowledgement that an activity in SBME exists somewhere between the real and unreal world [29]. Therefore, the learner and the educator acknowledge the limitations ahead of the activity. An example is a mannequin's capillary refill time that does not change despite a massive haemorrhage.

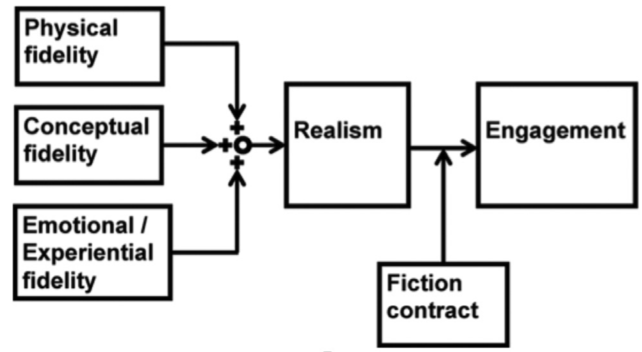

Figure 2 A Model of fidelity, realism, and educational engagement in simulation [32].

In constructing a surgical simulation task, it is important not to prioritise excellent visual realism ahead of the capacity to meet the learning objective. A simulator that confers good functional realism and is thus affordable, readily accessible and encourages self-directed practice may well generate greater skill development than one with greater "realism".

Conclusion

Many of the theories described in this article will seem very familiar to experienced surgical educators, although they may not recognise the described terms. Understanding the basis of changes in contemporary surgical education can enhance current educational practice by helping trainers understand the ways trainees learn, as well as promoting behaviours that promote life-long skill development.

In the current environment of time constraints and limited faculty resources, employing practical contemporary educational techniques can improve efficiency and effectiveness of teaching and supervisory endeavours, maximising the educational value of clinical encounters. Simulation-based learning can be integrated into all aspects of surgical training: technical and non-technical; common and rare; self-directed and team-based.

In the next article in this series we will outline the different modalities of SBME and practical tips how to incorporate simulation training into everyday busy schedules.

Conflicts of interest

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