Chapter 1

Integrating Technical and Nontechnical Skills in Hands-On Surgical Training

Alexander PB Alken, Cornelia Fluit,
Jan-Maarten Luursema and Harry van Goor

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.73044

Abstract

Safe and effective surgery requires high-quality technical and nontechnical skills. Although the importance of nontechnical skills has become increasingly clear, today's surgical curricula still lack formal training in nontechnical skills. In this chapter, we discuss how to integrate technical and nontechnical skills training into surgical curricula and provide strategies on how to teach both skill sets concurrently in a hands-on setting.

Keywords: surgical training and teaching, operating room teaching, technical skills, nontechnical skills, communication and team skills, integrated technical and nontechnical skills training, concurrent technical and nontechnical skills training

1. Introduction

The operating room is a hectic and dynamic teamwork environment requiring safe surgical practice. To achieve this, surgeons have to develop highly effective technical and nontechnical skills that are both built upon formal training [1]. Since technical and nontechnical skills are strongly associated to another [1] and have to be applied concurrently in the real-life operating room, these skills also have to be trained concurrently [2–5]. However, to date, the training of nontechnical skills is still not effectively and fully implemented in surgical curricula [1].

Surgical curricula have always had a strong focus on the development of surgical technical skills, aiming for high-level psychomotor skills, swift eye-hand coordination, and dexterity [6]. Since it became clear that adverse events in surgery are not so much caused by deficiencies and errors in technical skills but rather by deficiencies and errors in nontechnical team and communication skills, the attention for nontechnical skills training has been increasing [1, 7].

In this chapter, we discuss how to effectively integrate technical and nontechnical skills in surgical curricula, focusing on teaching behaviors, training strategies, and simulated and real-life operating room training. We address the current knowledge on acquiring technical skills in the section "How do we learn and teach surgical technical skills?" and nontechnical skills in "How do we learn and teach nontechnical skills in surgery?". We discuss training settings used for concurrent technical and nontechnical skills training in "Environments used for teaching nontechnical skills next to technical skills in surgery." We address frameworks that can be helpful to integrate technical and nontechnical skills teaching in the section "Effective frameworks for integrated technical and nontechnical skills teaching." Finally, we share our view on how to successfully establish a surgical curriculum with integrated technical and nontechnical skills training and teaching in "Integrating technical and nontechnical skills training during hands-on surgical teaching in a curriculum".

We realize that nontechnical skills of surgeons encompass more than communication and team skills, such as clinical decision making and stress coping [5]. In this chapter, the term 'nontechnical skills' refers to the social team and communication skills necessary for successful surgery, encompassing effective communication (e.g., sharing information efficiently), collaboration (e.g., assisting other team members when needed), coordination (e.g., timely asking team members for requests), leadership (e.g., directing team members), and situational awareness (e.g., asking for information updates regarding the patient's condition) [8, 9].

2. How do we learn and teach surgical technical skills?

Technical skills are core skills of a surgeon. They refer to all goal-directed psychomotor actions. Handling a scalpel to gain access to a patient's abdomen and handling a needle to repair a ruptured vein are examples of technical surgical skills. We discuss the current knowledge available regarding the learning, training and teaching of technical skills, and surgical technical skills in particular.

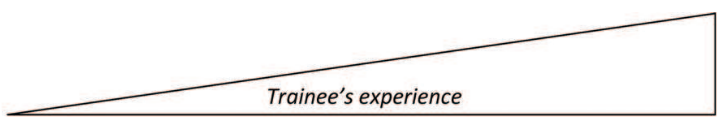
To understand how technical skills are acquired, two main principles are important. First, the acquisition of technical skills is not a linear process [10]. At the start of training, trainees are completely unfamiliar and inexperienced. There are many untrained aspects of the skill that can be improved relatively easily resulting in a rapid growth of trainees during their first trials. After the first trials, however, the basics of the skill are acquired and the speed of progress starts to slow down. All aspects of the skill are familiar but now have to be optimized, which requires much more time. The second principle regarding the acquisition of technical skills involves the way a skill is cognitively approached by trainees. In the beginning stages of learning, trainees depend on explicit rules to perform the skill that demands extensive cognitive effort. In later stages, the skill is partially or completely automated and trainees are less dependent on rules. Performing the skill then requires far less cognitive effort and enables trainees to focus on other actions, activities, or aspects in the training or working environment [10]. Both principles are important for designing the training and the teaching that is to be provided.

http://dx.doi.org/10.5772/intechopen.73044

Distributed, short training sessions with sufficient resting periods in between are most effective to acquire technical skills [10]. Effective training stimulates trainees to engage in deliberate practice, meaning that trainees repetitively train skills in a dedicated and conscious manner according to clear and achievable learning goals. Training of skills has to be simple at the start and complexity should gradually increase over time in accordance to each trainee's individual progress and needs. Teaching has to contain demonstrations, instructions, and immediate feedback intensely in case of novice trainees [10] to prevent the wrong acquisition and automation of skills [11]. But as trainees progress, this intensity should be reduced accordingly and feedback should be increasingly given reflectively [10] (**Figure 1**). Highly frequent feedback stimulates the initial acquirement of skills in the short term, whereas less frequent feedback seems to stimulate the retention of the learned skills in the long term. If tasks enable trainees to derive perceptual feedback and trainees are able to evaluate and improve their skills themselves, no feedback may be required. Under such circumstances intense feedback can even hamper learning [10]. Feedback has to be provided in a constructive manner [12]. Based on first-hand observations, teachers should provide specific information to trainees regarding what went well and what needs to be improved [12]. All teaching has to occur in a calm, supportive, and respectful way to create a safe and effective teaching climate [13, 14]. The use of neutral, nondisturbing language is essential in achieving this [15]. When teaching technical skills, the information density should be limited to how to perform the skill without focusing on other aspects or additive information (e.g., other options and the environment) [11]. Such information can prevent trainees from learning because executing the task and simultaneously processing the teaching require trainees to process too much information, which can easily cause cognitive overload. It is also important that trainees can learn by exploring and committing errors to experience firsthand what works best and what possible consequences are [10]. Simulation training plays an important role here.

2.1. Effective teaching behavior

Research to effective surgical skills teaching is primarily based on trainees', teachers', and educational experts' perceptions of effective teaching. Furthermore, research relating teachers' teaching behaviors to the actual acquisition of trainees' skills is scarce, especially in surgical and other medical training. This makes it hard to determine evidence-based how teachers exactly should teach. A recently conducted systematic review study on technical skills teaching in medicine, sports, and music found that feedback, instructions, suggestions for improvement, and demonstrations by teachers improved the skills development in trainees (Medical



Timing	Concurrent	Reflective
Frequency	High	Low
Information density	Low	High

Figure 1. Changes in feedback on technical skills according to the trainee's progress.

Teacher, paper under review [16]). It was also found important that teachers stimulated trainees to verbalize their thoughts and reasoning processes. A safe training environment was also found to be important. However, it remained unclear how these behaviors should exactly look like in order to effectively improve the acquisition of skills in trainees. Only one behavior was found to be sufficiently supported by evidence and was described elaborately: instructions and feedback that made trainees externally focus on the task and the effect was more effective than instructions and feedback that made trainees internally focus on how to exactly move their body parts. It may be more effective to explain by "When suturing, move the needle in a circular motion as if you are going to make a full circle." than by "When suturing, move your wrist with a turning motion.". However, results were only shown in psychomotor sport skills teaching. It is unclear whether it is also effective in surgical hands-on training.

3. How do we learn and teach nontechnical skills in surgery?

Most nontechnical skills trainings are built upon (the combination of) three approaches: theory-based, demonstration-based, and simulation-based training [1]. In the theory-based training, trainees are classroom-like taught what nontechnical skills are, why they are important, and how they can be applied in the operating room. Demonstration-based training adds demonstrations of nontechnical skills to the theory-based approach. Trainees observe, for example, video-recordings of a simulated operation and discuss the behaviors they have seen, possible consequences, and solutions. Both approaches are low cost and easily organized. Both approaches improve trainees' knowledge, awareness, and attitudes. However, there are no possibilities for trainees to apply and train nontechnical skills by doing. Simulation-based approaches do have a training-by-doing component. Trainees apply and train nontechnical skills hands-on in a safe environment, varying from simple bench-top models to full-scale simulated operating rooms with, for example, a patient simulator. This enables the hands-on training of basic and advanced nontechnical skills in a realistic and multidisciplinary team setting. Simulation training is easily compatible with the theory-based and demonstration-based approaches. Simulation has been shown to improve skills acquisition, both in training and in the real-life operating room. Drawbacks are that simulation training is costly, demands extensive organization since realistic operating teams have to be composed, and requires guidance by trained teachers. Blended approaches in which theory, demonstrations, and simulations are combined are advocated. Theory and demonstrations should be the focus in the early stages of nontechnical skills training. In following stages, nontechnical skills should be applied and trained in simulated settings [1, 4]. Simulation has been shown to be most effective in acquiring nontechnical skills [2]. Nontechnical skills training should be long-term, structured according to learning goals, trainees' individual needs and experiences, and firmly embedded into surgical training curricula [1, 4]. Multiple and distributed training sessions are considered most effective [2].

Although simulation training has been shown to be effective within different surgical specialties [2], the applied interventions are often minimally described [17]. As a consequence, it remains unclear how nontechnical skills teaching should exactly look like to be effective [1].

Most commonly used are debriefing sessions immediately after simulation in which reflective feedback on nontechnical skills is provided by a teacher [2]. Debriefing sessions are considered highly important for teaching nontechnical skills. Trainees receive feedback on their nontechnical skills performance, but also reflect on their nontechnical skills [15]. Teacher feedback on nontechnical skills has to be based on first-hand observations of trainees' performance and has to address specific strong points, weaknesses, and suggestions for improvement. It should always be provided in a respectful way and with a neutral tone of voice. Teachers have to structure their feedback based on observations and evaluations according to nontechnical skills assessment tools [1, 15]. Training is essential to enable surgical teachers to effectively analyze and teach nontechnical skills [1, 2, 15]. Extensive training and coaching by nontechnical skills experts are required.

4. Environments used for teaching nontechnical skills next to technical skills in surgery

4.1. The operating room

To date, surgical trainees generally learn nontechnical skills informally and unstructured *as they pass by* in the real-life operating room [1]. Teaching in the operating room is a challenging task in itself since the patient's safety is the most important aspect that often pushes teaching and training to the background [18]. Teaching as it occurs in the operating room is almost entirely focused on technical skills [15]. The same goes for debriefing sessions after the operation [19]. Nontechnical skills teaching remains to be undertaught [15] and surgical teachers are not sufficiently trained to teach nontechnical skills [1]. Nontechnical skills are not yet a part of the surgical educational culture and teachers are inclined to avoid it, often unaware. This means that the real-life operating room is not the best place to teach and train nontechnical skills, especially when trainees lack technical experience.

4.2. Simulation

Simulation offers surgical teachers the possibility to put the teaching of trainees in the forefront [18]. Trainees can train and apply skills and build experience in a safe environment without any risks for patients. For the training of technical skills, synthetic bench top models, box trainers, virtual reality simulators, animal cadavers, human cadavers, and live animal models are commonly used [20, 21]. Recently, nontechnical skills have slowly been added to the skill sets trained by simulation. Possibilities to integrate nontechnical skills next to technical skills training have been developed, for example by using simulated operating rooms with live animal models [22], manikins, and/or synthetic or hybrid models [18].

4.3. Animal model simulation

Using an animal model adds to the reality of the experience in a simulated operating room. Trainees have to deal with real bleedings, time pressure, and hectic teamwork within realistic operating teams [22]. This reality is considered to contribute to the transfer of the acquired nontechnical skills to the real-life operating room [2]. However, our research showed that integrating technical and nontechnical skills during a training using live animal models remained difficult and resulted in a main focus on the teaching of technical skills and hardly on nontechnical skills [22, 23]. It was assumed that the use of a live animal made training activities too unstable to properly teach nontechnical skills next to technical skills. The animal's condition can really deteriorate without being able to pause the situation. Like in the real-life operating room, the main focus may remain on keeping alive the animal patient and on the technical skills necessary to do so. The teaching of nontechnical skills may easily shift to the background. Furthermore, the occurrence of stress caused by real bleedings, for example, is known to cause cognitive overload. This may have further limited the teachers in teaching nontechnical skills [22].

4.4. Simulated human patient operation

A simulated operating room equipped with an operating table, equipment, instruments, and synthetic or virtual reality models offers more opportunities for integrating nontechnical next to technical skills teaching than other environments [20]. The use of synthetic or virtual models creates the possibility to teach and train surgical procedures and the necessary technical skills in an authentic setting. By adding a realistic operating team, the teaching and training of nontechnical skills are possible. Such simulation setting not only offers extensive debriefing possibilities after simulation, for example with the help of video-recordings but also offers the possibility to freeze the condition of the patient in time. Pause and reflect procedures focused on nontechnical skills can then follow immediately, even in acute situations [22]. While still in the simulation, trainees receive feedback and have the opportunity to immediately apply and train the improved nontechnical skills during the remainder of the simulation. However, no research has yet been conducted to the effectiveness of such pause and reflect procedures.

5. Effective frameworks for integrated technical and nontechnical skills teaching

Many frameworks are available for teaching surgical skills and skills in general. We discuss four approaches that in our opinion are superior at the moment in contributing to the effective integration of technical and nontechnical skills teaching in surgery.

5.1. The Peyton four step approach

The Peyton four step approach is a widely accepted method to teach and train technical medical and surgical skills [11] (**Table 1**). During the first step, the teacher shows the trainee how to perform the skill without any instruction. This is to enable the trainee to entirely focus on the performed motor skills without potentially distracting verbal information. During the second step, the teacher shows and explains the skill according to manageable, logically sequenced part-tasks (steps within the skill). Explanations should be limited to only the key information

	Teacher	Trainee
1	Performs	Observes
2	Shows and explains	Observes
3	Performs	Instructs
4	Observes	Explains and performs

Table 1. Peyton four step approach for technical skills.

to prevent cognitive and information overload. In the third step, the teacher performs the part-tasks according to the instructions provided by the trainee. This enables the teacher insight into the trainee's understandings and misunderstandings and helps the teacher to adjust the teaching. During the fourth step, the trainee first verbalizes what to do in each part-task (the teacher checks whether the part-tasks are understood) and then executes the skill (the teacher checks whether the skill is performed correctly). Misunderstandings or mistakes have to be immediately corrected to teach the skill correctly and prevent the wrong automation of the skill. Although widely used, the evidence for the effectiveness of the Peyton four step and similar approaches is limited [11].

5.2. The Zwisch model

The Zwisch model guides teachers in tailoring their teaching and granting autonomy in accordance to each individual trainee's level for each surgical procedure [24]. The model's first stage, 'show and tell,' applies to inexperienced trainees. The teacher performs the procedure, shows, and explains how it is done, while the trainee observes and assists. This step looks similar to the second step of the Peyton approach; however, the Zwisch model does also allow teaching beyond the key information (e.g., background information, other options, and information on team skills) if the trainee's level of experience allows this. When the trainee is familiar with the entire procedure and is able to actively assist (e.g., anticipating on the progress of the procedure), the trainee moves on to the second stage, 'smart help.' In this stage, the teacher switches between self-performing and assisting the trainee in performing the procedure. The trainee performs most of the procedure based on the teacher's continuous instructions and feedback. This stage continues until the teacher deems the trainee able to perform the entire procedure with this 'smart help.' During the third stage, 'dumb help,' the trainee performs the procedure entirely while the teacher assists and only provides feedback and instructions for fine-tuning the trainee's skills. The final step is called "no help" during which the teacher monitors the trainee performing the procedure and only provides minimal advice. The Zwisch model is supported by psychomotor learning theories [24]; however, research on the effectiveness is mostly lacking.

5.3. The BID model

The three-phase briefing-intraoperative teaching-debriefing (BID) framework [25] has been shown to be effective in structuring the teaching before, during, and after hands-on surgical training in the operating room [13, 14]. The briefing phase is characterized by discussing and setting learning goals for trainees to work on during the intraoperative phase [25, 26]. Trainees come up with learning goals or teachers do suggestions, for example, based on their prior experiences with the trainee. Generally, trainees are inclined to focus on technical skills [14] so teachers may have to stimulate trainees to formulate nontechnical learning goals. Research suggests that if clear learning goals on nontechnical skills are lacking the teachers' attention for nontechnical skills will be minimal [22]. The teacher and trainee should agree to focus on one or two learning goals [25], which help the teacher, but also the trainee, to focus on what has to be taught and trained during the intraoperative phase. The briefing generally takes only a few minutes.

The teaching during the intraoperative phase should be aimed at achieving the learning goals and form the guidelines for the teacher to structure the training [25]. How to effectively teach during the intraoperative or the hands-on training phase is discussed in the sections concerning the learning of technical and nontechnical skills.

The final phase is the debriefing during which the teacher and trainee reflect on the achievement of the learning goals [25]. Research showed that teachers during the debriefing are inclined to emphasize what went wrong with a focus on technical skills and without sufficient elaboration on how to improve [14]. A teacher-trainee dialog should be established containing honest and specific strong points, weaknesses, suggestions, and solutions for future practice based on the formulated learning goals. Also the underlying schemes why trainees acted the way they acted during the intraoperative phase should be discussed [25]. This provides both the trainee and the teacher insight into the trainee's thoughts, beliefs, and reasoning processes. This offers reflection and deeper learning for trainees and provides teachers with the opportunity to specifically develop or improve trainees' schemes regarding technical, and in particular nontechnical skills. Along this process, teachers should preferably ask open questions. Debriefing sessions should always result in individual learning goals for trainees' future performance [15]. The use of video-recordings of the trainee's performance has been shown to be effective in debriefing [2]. It helps and teaches trainees to reflect. Mistakes can be discussed and remediated.

5.4. The 4 C/ID model

The 4 component instructional design (4 C/ID) model is specifically designed for the teaching of complex skills [27, 28] (**Figure 2**). The model distinguishes four components for designing a successful training program: learning tasks, supportive information, procedural information, and additional part-task training. The learning tasks are at the core of the 4 C/ID model and encompass the training of whole-task procedures in an authentic and realistic training setting *from the very start*. Whole-task procedures require trainees to combine knowledge, skills, and attitudes and enable them to train these aspects in a realistic relation to each other. This is an important contrast to classical learning theories, which generally prescribe the division of complex tasks into subtasks for training. The 4 C/ID model considers such an approach only effective for the learning of simple skills or skills that can be automated through training. Obviously, confronting a trainee with a new, complex task at

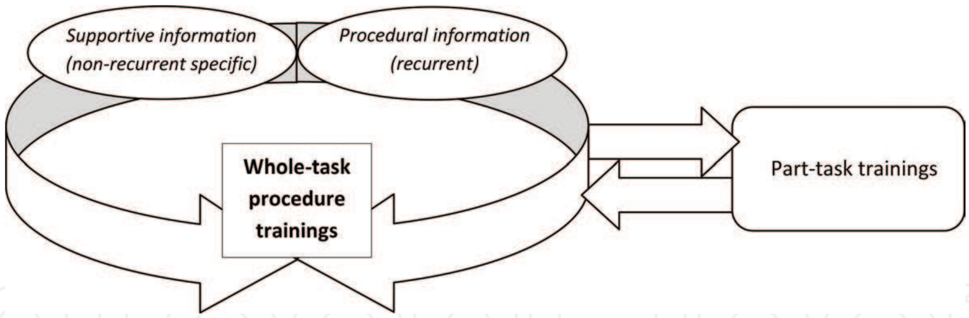


Figure 2. The 4 components of the 4 C/ID-model.

the very start of training will induce cognitive overload and hinder learning. To prevent this, the whole-task training should start with the simplest or most simplified version of this task. This requires much less information processing, reasoning, and problem-solving. As trainees improve, they develop schemes and automate skills that then require less cognitive resources and enable them to focus on other aspects of the skill. As trainees' capabilities improve, the complexity of training should gradually increase accordingly. Whole-task training will improve the effective transfer of the trained skills to real practice, which also requires the whole task to be performed [27, 28]. Regarding the training of technical and nontechnical skills, the 4 C/ID model would require trainees to train these skills concurrently from the very start. Training should gradually progress from the simplest to the most complex version of a surgical procedure.

Supportive information should be available for trainees during training [27, 28]. Supportive information encompasses knowledge that trainees need for reasoning and problem-solving during nonrecurrent, situation-specific aspects of the learning task, for example, information on consequences based on patient-specific characteristics (technical skills) or operating team composition (nontechnical skills). Procedural information encompasses knowledge of recurrent procedural aspects of the learning task [27, 28]. Preferably, this information is provided to trainees during training when the situation requires it, for example, conducting a physical test on the patient (technical skills) or working with a checklist (nontechnical skills) during the operation. Supportive information and procedural information encompass the teaching activities applied by the teacher. The final component of the 4 C/ID model is additional part-task training [27, 28]. Although whole-task training is key and remains the focus during the entire training program, some skills require a high level of automation and additional training. Such skills can be trained and automated in separate training sessions.

The development of and research to integrated technical and nontechnical skills training in surgical specialties are very scarce [5]. Currently, modules are focused on developing technical skills or nontechnical skills, but barely on integrating and developing both skill sets concurrently. Although the 4 C/ID model is built upon solid learning principles and theories, to our knowledge, its effectiveness has not yet been investigated in relation to surgical teaching. Nevertheless, we believe this model helps to integrate technical and nontechnical skills teaching successfully.

6. Integrating technical and nontechnical skills training during hands-on surgical teaching in a curriculum

In this section, we put the aforementioned theory together and share our view on how to effectively integrate technical and nontechnical skills training and teaching in surgical curricula, using both simulated settings and the real-life operating room. We advocate a surgical curriculum to be organized in different training modules. Each training module is composed out of different training sessions. In these training sessions, the actual teaching and training takes place. We provide recommendations on three main aspects: learning goals and assessment; training modules and training sessions; and teaching and training within training sessions.

6.1. Learning goals and assessment

To ensure the formal and structural training of nontechnical skills next to technical skills, long-term learning goals on nontechnical skills have to be formulated next to long-term learning goals on technical skills. Long-term learning goals are formulated by program directors in cooperation with surgical teachers. All have to be achieved by trainees during the curriculum. The long-term learning goals on nontechnical skills can be based on research (for example, the studies conducted by Hull et al. [8] and/or Yule et al. [9]) combined with specific needs of the workplace.

Based on the long-term learning goals, the program directors and surgical teachers formulate short-term learning goals (**Figure 3**). Short-term learning goals have to be achieved by trainees during the training modules within the curriculum. Short-term learning goals address both general and procedure-specific technical and nontechnical skills. General learning goals apply to all surgical procedures. Procedure-specific learning goals specifically apply to distinctive surgical procedures.

The formulated short-term learning goals are the guidelines for the surgical teachers and trainees to formulate personal learning goals for each individual trainee. These personal learning goals enable teachers to tailor the teaching to each individual trainee's needs, experience, and interests. Personal learning goals are specific and achievable. They can be achieved in one or in multiple training sessions.

Each trainee's individual performance and progress is assessed and monitored with assessment instruments on technical skills (like the Objective Structured Assessment of Technical Skills (OSATS)) and nontechnical skills (like the Observational Teamwork Assessment for Surgery (OTAS) [8] or Nontechnical Skills for Surgeons (NOTSS) [9]). The trainees' progress on nontechnical skills is structurally analyzed after each training session and documented with the purpose to provide trainees with feedback and personal learning goals and to improve future performance in upcoming training sessions. Each training module finishes with a summative pass or fail test for trainees on technical and nontechnical skills concurrently, according to the short-term learning goals.

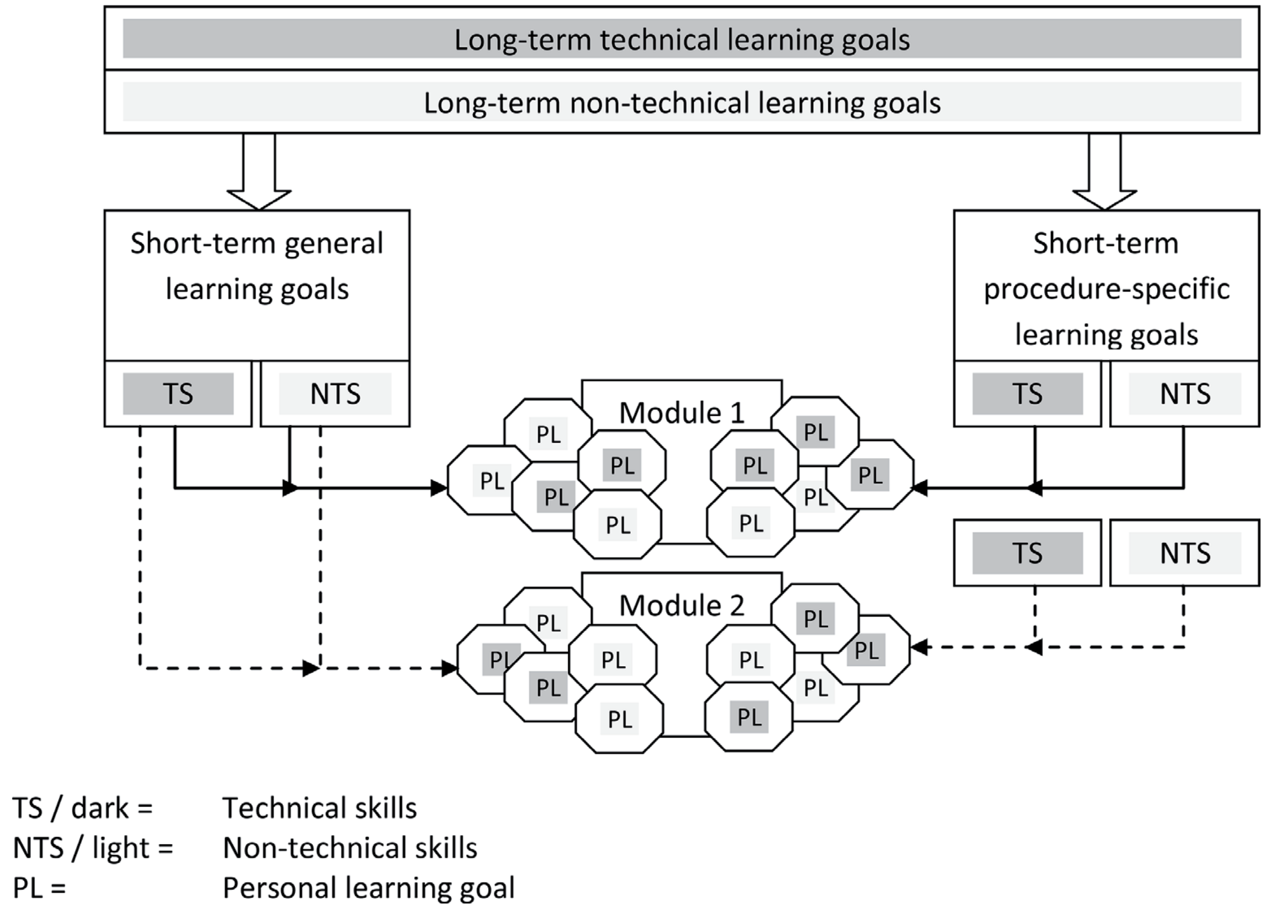


Figure 3. Modular structure of a curriculum for integrated skills' teaching and learning.

Surgical teachers have to be trained and coached in observing, assessing, and teaching nontechnical skills by nontechnical skills teaching experts. Teachers should regularly reflect on their nontechnical and technical skills teaching abilities based on peer observations and feedback. Assessing the teachers' abilities is not a goal in itself but rather a method to strive for perfection, learn from each other, and stay up-to-date regarding effective surgical teaching research and frameworks.

Preferably, nontechnical skills are integrated over the entire line of surgical education, starting in undergraduate medical education all the way through to continuing postgraduate surgical education. It may well be that technical skills require more training and teaching effort to develop than nontechnical skills. The perfect ratio is not known. However, effective nontechnical skills can only be achieved through a formal, structured, and sufficient installation of training possibilities.

6.2. Training modules and sessions

We advocate that surgical training curricula are composed out of training modules focused on specific surgical procedures (e.g., a laparoscopic cholecystectomy module, an open inguinal hernia repair module, etc.). What training modules are exactly incorporated in a curriculum is decided by the program directors depending on the relevance of the modules and the intentions of the curriculum. Technical and nontechnical skills are integrated from the start of a module so trainees learn that both skills are connected and have to be applied and trained concurrently.

6.2.1. Integrated training sessions

A training module consists out of several distributed training sessions. Two types of training sessions are distinguished: integrated training sessions and focused training sessions. Integrated training sessions focus on the teaching and training of both technical and nontechnical skills concurrently within the same training session, in a simulated setting, or in the real-life operating room. If trainees have no prior experience, a training module may typically start with an integrated training session in which trainees purposefully observe and analyze their teachers' technical and nontechnical skills (e.g., based on observational assignments and observational instruments) while their teachers are performing simple versions of the procedure in the real-life operating room. The following integrated training sessions are gradually organized, in accordance to each trainee's individual level, progress, and needs, from:

- *Simple or simplified versions to complex versions of the procedure*

  Gradually moving from simple to complex ensures that trainees do not experience cognitive overload and can start performing procedures or components of procedures themselves in an early stage.

- *Highly controlled simulated to barely controlled real-life training environments*

  Gradually working from a highly controlled to a barely controlled environment ensures there is sufficient room for teaching technical and nontechnical skills, especially in the early stages of training. A highly controlled environment is characterized by simulation, which enables pause and reflect procedures and learning from mistakes. A typical barely controlled environment is the real-life operating room. As trainees start to perform skills themselves, they start in a simple simulation setting (e.g., bench top models). Depending on the trainee's progress, simulated environments become gradually less controllable, increasingly realistic and more and more replaced by training in the real-life operating until the point of independent practice is reached.

- *Teaching of high intensity to teaching of low intensity*

  The teaching intensity gradually fades from strict guidance and intensive teaching in trainees who are inexperienced to distant observation by the teacher with reflective feedback only when trainees are experienced. The Zwisch model can help teachers to determine the necessary teaching intensity.

- *Low trainee contribution to high trainee contribution*

  Trainee contribution gradually increases on the way to independent practice. Trainees first train and apply only the simple components of the procedure, scattered throughout the integrated training sessions. The more complex components are still performed by the teacher. Since full procedure training is important, trainees then purposefully observe and analyze the technical and nontechnical skills still performed by their teacher or assist their teacher during the complex components. As trainees progress, next to the already trained components, increasingly more complex technical and nontechnical components of the procedure are added until trainees can perform the entire and complex versions of the procedure independently. The Zwisch model can be helpful for teachers to gradually grant trainees more autonomy.

6.2.2. Focused training sessions

Although the integration of nontechnical next to technical skills training is key, there is also room for focused training. When surgical procedures require skills that need to be automated (e.g., suturing) or require deeper understanding (e.g., models for closed loop communication), supplementary focused training sessions are installed with the specific goal to solely focus on, train, and acquire specific skills. If skills like suturing or closed loop communication are concurrently trained next to other technical and nontechnical skills, it may cause cognitive overload. Then, teaching and training best occurs separately until the skills are partly or fully automated. As soon as these skills are acquired, trainees apply them in the integrated training sessions. By then, trainees are experienced on that part of the procedure and have more cognitive resources available to focus on other important technical and nontechnical skills. Focused training sessions typically occur in a simulated setting, with or without a teacher being present, depending on the possibility for perceptual feedback. With some skills, after the teacher explained the skill by the Peyton four step approach, for example, the trainee can independently practice to automation with at-home training kits, simulators, etc. **Figure 4** provides examples of training in simulated settings, both for focused training (A and B) and integrated training (C).

6.2.3. Individualized modules

When applying the aforementioned training and teaching principles, it is important to realize that there is no one size fits all approach. In close and continuous consultation, surgical teachers and trainees individualize each training module and the training sessions within each training module, according to each individual trainee's experience, progress, needs, or interests. Skills and abilities that are already obtained move to the background to enable focus on other skills and abilities. The length of each training module is flexible and different per individual trainee depending on the trainee's speed of progress. Different training modules do not necessarily succeed each other but rather run parallel or partly parallel if similarities in difficulty, techniques, and trainee requirements allow. The basic principle is and remains the training of entire surgical procedures in which both technical and nontechnical skills have to be applied, starting simple and gradually move on to a highly complex endpoint. Along this process, ideally, trainees are guided by two or maximum three teachers within a module; that way, teachers get to know their trainees' strengths and weaknesses, which helps the teacher to tailor the teaching, but also offers trainees feedback from different perspectives.

Figure 4. Three simulated training settings, ranked from least realistic and most controlled (A) to most realistic (B) and least controlled (C). (A) A focused training session regarding technical laparoscopic skills using a virtual reality simulator. Basic laparoscopic skills are automated before trainees apply them in the operating room. (B) A focused training session regarding nontechnical communication and team skills using a human patient simulator with video recordings for debriefing (view from control room). Additional training may occur next to training in the real-life operating room. (C) An integrated training session using an animal model. Such training is scheduled best if trainees have gained sufficient experience regarding the necessary technical and nontechnical skills.

6.3. Within training sessions

Good teaching during training sessions is important to develop trainees. Teaching best occurs supportive and in a safe environment. This requires teachers to take time and be calm, approachable, and respectful. Good teaching contains instructions, explanations, demonstrations, and honest feedback with suggestions for improvement tailored to each individual trainee's needs and level. Effective feedback is constructive, nonoffensive, and neutrally formulated. The trainee's strong points and weaknesses are addressed based on and illustrated with first-hand observations. The goal of feedback is to improve or maintain the trainee's level of performance in the future.

The BID model can be helpful to structure the teaching within training sessions. During the briefing, the teacher and trainees briefly discuss and agree on personal learning goals for the upcoming training session, the guidance expectations, and the training activities. Guidance can range from strict and continuously to distant and minimal. Training activities can vary from observing to performing the entire procedure. In integrated training sessions, the teacher and trainee work on one technical and one personal nontechnical learning goal. In focused training sessions, the teacher and trainee work on either one or two technical or one or two nontechnical personal learning goals.

During the hands-on training phase, the actual teaching and training take place. How the teacher teaches depends on the nature of the training session (integrated or focused) and the trainees' experience. Observational learning, a high level of teaching intensity, and a low level of trainee contribution are typical for inexperienced trainees. Distant monitoring, a low level of teaching intensity, and a high level of trainee contribution are typical for experienced trainees. The Zwisch model can help teachers to grant autonomy and determine the teaching intensity.

During technically focused training sessions, trainees are preferably only taught how to perform skills technically (by the Peyton four step approach, for example). Teaching is predominantly directive and instructive and trainees' mistakes are corrected immediately. During nontechnically focused training sessions, teaching may occur more reflective, in debriefings or pause and reflect procedures. If, for example, a communication model is new to trainees, they may first receive short instructions, then observe good and wrong examples, and then immediately apply the skill in a simulated setting. The trainees learn by the feedback provided and reflective questions asked by the teacher. Central questions may be: Why did it go the way it went (addressing both positive and corrective aspects)? Why did you act the way you acted? What are the (possible) consequences? What are the solutions for future practice? Video-recordings of the trainees' performance may be helpful.

In integrated training sessions, teaching focuses on both technical and nontechnical skills concurrently. However, if some technical or nontechnical skills are not yet sufficiently understood or trained, also within integrated training sessions, there can be episodes of pure technical and nontechnical skills teaching. More focused training sessions may be required and can be installed according to the teacher's insight or on the trainee's request.

Each training session closes with a debriefing. A debriefing can typically start with the teacher asking the trainee what he or she thinks went well and needs to be improved, with a special focus on the trainee's personal technical and nontechnical learning goals. The teacher has observed and analyzed the trainee's performance, preferably by using OTAS or NOTSS (nontechnical skills) and OSATS (technical skills). Observations may focus on a few points, adjusted to the trainees' personal learning goals. The teacher provides feedback in a dialog with the trainee and tries to get thoughts, beliefs, and reasoning processes clear. The teacher supports the trainee in his or her development by adding knowledge and expertise to the discussion. The briefing finishes with the trainee formulating future personal learning goals or intentions for the next training.

Author details

Alexander PB Alken[1]*, Cornelia Fluit[2], Jan-Maarten Luursema[1] and Harry van Goor[1]

*Address all correspondence to: sander.alken@radboudumc.nl

1 Department of Surgery, Radboud University Medical Center, Nijmegen, The Netherlands

2 Health Academy, Radboud University Medical Center, Nijmegen, The Netherlands

References

[1] Hull L, Sevdalis N. Advances in teaching and assessing nontechnical skills. Surgical Clinics. 2015;**95**(4):869-884

[2] Dedy NJ et al. Teaching nontechnical skills in surgical residency: A systematic review of current approaches and outcomes. Surgery. 2013;**154**(5):1000-1008

[3] Dawe S et al. Systematic review of skills transfer after surgical simulation-based training. British Journal of Surgery. 2014;**101**(9):1063-1076

[4] Whittaker G et al. Teamwork assessment tools in modern surgical practice: A systematic review. Surgery Research and Practice. 2015:1-11. Article ID 494827

[5] Brunckhorst O et al. The relationship between technical and nontechnical skills within a simulation-based ureteroscopy training environment. Journal of Surgical Education. 2015;**72**(5):1039-1044

[6] Agha RA, Fowler AJ, Sevdalis N. The role of non-technical skills in surgery. Annals of Medicine and Surgery. 2015;**4**(4):422-427

[7] Gjeraa K et al. Non-technical skills in minimally invasive surgery teams: A systematic review. Surgical Endoscopy. 2016;**30**(12):5185-5199

[8] Hull L et al. Observational teamwork assessment for surgery: Content validation and tool refinement. Journal of the American College of Surgeons. 2011;**212**(2):234-243.e5

[9] Yule S et al. Surgeons' non-technical skills in the operating room: Reliability testing of the NOTSS behavior rating system. World Journal of Surgery. 2008;**32**(4):548-556

[10] White C, Rodger MW, Tang T. Current understanding of learning psychomotor skills and the impact on teaching laparoscopic surgical skills. The Obstetrician & Gynaecologist. 2016;**18**(1):53-63

[11] Nicholls D et al. Teaching psychomotor skills in the twenty-first century: Revisiting and reviewing instructional approaches through the lens of contemporary literature. Medical Teacher. 2016;**38**(10):1056-1063

[12] LeBlanc VR et al. 18 Simulation in Postgraduate Medical Education. Members of the FMEC PG consortium. 2011:1-26

[13] McKendy KM et al. Perioperative feedback in surgical training: A systematic review. American Journal of Surgery. 2017;**214**(1):117-126

[14] Timberlake MD et al. What do we know about intraoperative teaching?: A systematic review. Annals of Surgery. 2017;**266**(2):251-259

[15] Spanager L et al. Comprehensive feedback on trainee surgeons' non-technical skills. International Journal of Medical Education. 2015;**6**:4

[16] Alken A et al. Teaching complex surgical psychomotor skills in the OR: A systematic review. Journal of Surgical Education. Submitted

[17] Gordon M, Darbyshire D, Baker P. Non-technical skills training to enhance patient safety: A systematic review. Medical Education. 2012;**46**(11):1042-1054

[18] Kneebone R et al. Distributed simulation—Accessible immersive training. Medical Teacher. 2010;**32**(1):65-70

[19] Ahmed M et al. Actual vs perceived performance debriefing in surgery: Practice far from perfect. The American Journal of Surgery. 2013;**205**(4):434-440

[20] Palter VN, Grantcharov TP. Simulation in surgical education. Canadian Medical Association Journal. 2010;**182**(11):1191-1196

[21] Sadideen H et al. Simulators and the simulation environment: Getting the balance right in simulation-based surgical education. International Journal of Surgery. 2012;**10**(9):458-462

[22] Alken A et al. Integrating technical and non-technical skills coaching in an acute trauma surgery team training: Is it too much? The American Journal of Surgery. 2017. In press

[23] Alken A et al. Feedback activities of instructors during a trauma surgery course. The American Journal of Surgery. 2013;**206**(4):599-604

[24] DaRosa DA et al. A theory-based model for teaching and assessing residents in the operating room. Journal of Surgical Education. 2013;**70**(1):24-30

[25] Roberts NK et al. The briefing, intraoperative teaching, debriefing model for teaching in the operating room. Journal of the American College of Surgeons. 2009;**208**(2):299-303

[26] Meyerson SL et al. Defining the autonomy gap: When expectations do not meet reality in the operating room. Journal of Surgical Education. **71**(6):e64-e72

[27] Van Merriënboer JJ, Kirschner PA, Kester L. Taking the load off a learner's mind: Instructional design for complex learning. Educational Psychologist. 2003;**38**(1):5-13

[28] Janssen-Noordman AM et al. Design of integrated practice for learning professional competences. Medical Teacher. 2006;**28**(5):447-452